Impact of using Geogebra on Students' Conceptual and Procedural Knowledge of Limit Function

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Abstract

The purpose of the study was to identify the effect of using GeoGebra on conceptual and procedural knowledge of limit function according to group and ability. The study involved students from a high school in Riau, Indonesia. A total of 138 students were in the treatment group and 146 students were in the control group. Data were collected using the conceptual and procedural test of limit function. T-test and two-way ANOVA were employed with the Statistical Package for the Social Sciences (SPSS) 19.0. The findings of the study showed significant differences in students' conceptual and procedural knowledge based on student groups and ability. The findings present implications in the field of education that promote the use of GeoGebra as a means of improving students' knowledge in mathematics.

Keywords: *Conceptual knowledge, procedural knowledge, limit function, GeoGebra*

1. Introduction

The use of technology in teaching and learning elicits many possibilities. One possibility is that the uses of technology enable students to understand mathematical concept. The use of technology could also produce symbols, formulas, tables, graphs, numbers, equations, and manipulative materials to connect different ideas, which are parts of conceptual and procedural knowledge (Post, 1998). Teachers should be ready to accept current changes and endeavors to make the latest technology a reality in the classroom. Educators, who have been entrusted to educate the nations, should give the use of technology in the teaching and learning of mathematics serious attention. Furner and Marinas (2007) stated that it is an educator's responsibility to provide students with a bright future to face today's world, which relies heavily on mathematics, science, and technology. Learning by technology could present positive outcomes for students in the future. By providing them with the chance to learn and understand mathematics through technology, students could be equipped with the knowledge to compete and function in this high-tech world. Practice and familiarity with the features of a software application and knowledge of accessing and using such software is necessary to motivate teachers to appreciate the advantages that can be achieved in the teaching and learning of mathematics (Crisan, 2005). The knowledge gained could be linked to teachers' mathematical tasks and could be useful in developing creative thinking related to the use of software in the classroom. To aid educators in integrating technology in the teaching and learning of mathematics, the proposed research included the use of GeoGebra in the teaching of mathematics. This software plays a role in helping teachers conduct the teaching and learning process of mathematics.

The use of GeoGebra software is deemed to be alternative software for teachers to integrate technology in the teaching and learning of mathematics. Based on a needs analysis, identified topics to be integrated with technology include geometry, algebra, and functions (Haclomeroglu, 2009; Rincon, 2009). Mathematical representations (e.g., symbols, graphs) generated by GeoGebra software could help teachers explain mathematical concepts and procedures. Hiebert and Lefevre (1986) categorized conceptual knowledge as knowledge that is rich with relationships or connections among information that allows information to be accessed and used flexibly. Conceptual knowledge allows students to identify, provide symbols, and produce examples from a given question. Instances of such concepts include correlating, manipulating, and differentiating; identifying and applying theories of mathematics; knowing and applying facts and definitions; comparing, differentiating and integrating concepts and rules; interpreting and applying notations, symbols, and terminologies used to represent concepts; and interpreting assumptions and relationships that involve mathematical concepts (Baker, 2002).

2. Statement of the Problem

A number of teachers do not perceive technology as beneficial in the process of effective teaching and learning, especially in increasing students' conceptual and procedural knowledge in mathematics. Teachers exhibit preference for traditional (conventional) methods in explaining the definitions of concepts and performing procedures from learned concepts (Rahmawati, 2002). Suratman (2011) conducted research in Indonesia and found that the level of conceptual and procedural knowledge of mathematics among high school students was low. Additionally, special reference was given to the topic of limit functions (Budiarjo, 2012). Apart from problem related to teaching methods, this topic is deemed difficult for students. Selden and Selden (1992) stated that the topic of functions incorporates various modern mathematical branches and plays a significant role in this field. As a means of elevating the level of mathematics, it is essential that students to have a deep and flexible mental concept of functions. Calculus is a starting point of a higher mathematical thinking, and functions are key concepts in calculus (Vinner, 1992).

Students' problem with the topic of functions is further extended to the topic of limit functions. Low levels of student knowledge in the topic of functions affect the topic of limit functions. Williams (1991) pointed out that conceptual difficulties in calculus among students extend to the concept of function, which is the foundation of all standard modern analysis. It is also the foundation of traditional pedagogy in the introduction of calculus. As Tall and Ramos (2004) explained, calculus is the culmination of several areas of mathematical development. The reason that may lead to teachers' difficulties in teaching the concept of function is that mathematical and cognitive approaches to limit functions are slightly different.

Research related to conceptual and procedural knowledge based on high school students in Indonesia is scarce. A similar research on students' conceptual knowledge conducted by Oktiana et al. (2010) ascertained significant differences in high school students' mathematical concepts based on ability level. Research findings have revealed that significant differences between students' of high, medium, and low-level of competence do exist. However, no significant difference has been found between students of medium and low ability levels. Problems set forth as discussed illustrate the urgent need for teachers to perform apt endeavors as to appropriate teaching strategies that could contribute to the success of the teaching process. Effective and efficient learning processes are possible when accurate learning strategies are employed. Slameto (2003) justified that appropriate learning strategies would maximize the outcome of a lesson. Thus, the researcher intended to explore students' ease of understanding the teaching materials through GeoGebra, which will, hopefully, enable students to understand the concepts presented in the material as well as their relations to other materials.

3. Aim of the Study

This study aimed to determine the effectiveness of using GeoGebra on students' conceptual and procedural knowledge of limit function.

4. Research Methodology

This research employed a nonequivalent pretest and posttest control group design. Quasi-experimental design was chosen because the present study used intact groups as subjects (Wiersma, 2000). In other words, research subjects are not chosen randomly (Johnson & Christensen, 2000). Internal validity was considered in this research by referring to Frankfort and Nachmias (2000). This study was conducted with 284 Year 2 students from senior high schools in Rokan Hulu Riau, Indonesia. Students were divided into either the control or experimental group; 138 of these students were assigned to the experimental group, and 146 were placed in the control group. The reliability index for the conceptual and procedural knowledge test of limit functions was 0.83. The value indicates that the reliability of the test items was at an excellent level (Lim 2007).

5. Findings

5.1 Analysis for Pretest of Conceptual and Procedural Knowledge Test of Limit Function

Kolmogorov Smirnov analysis was conducted for the conceptual knowledge pretest on limit function for student demographic profiles, group, and ability (see Table 1).

Table 1. Kolmogorov Smirnov Analysis for the Conceptual Knowledge Test Pretest on Limit Function

Knowledge	Profile	Kolmogorov-Smirnov			
		Demographic	Statistics	Df	Sig
Conceptual	Group	Experimental	0.072	138	0.074
		Control	0.073	146	0.052
	Ability	High	0.078	76	0.200
		Medium	0.073	132	0.085
		Low	0.088	76	0.200
Procedural	Group	Experimental	0.074	138	0.064
		Control	0.073	146	0.058
	Ability	High	0.087	76	0.200*
		Medium	0.077	132	0.056
		Low	0.080	76	0.200*

The findings revealed a significance value on the conceptual knowledge pretest for the experimental group of $p = 0.074$ and the control group of $p = 0.052$. The values for the conceptual knowledge pretest on limit function for both the groups were $p > 0.05$. These findings show that both the experimental and control groups are homogenous, and treatment could be applied to these groups as a mean of identifying differences caused by the treatment. Subsequently, based on student ability, those with a high-level of competence yielded a significance value of $p = 0.200$, medium-level of competence yielded $p = 0.085$ and low-level of competence yielded $p = 0.200$. Because all significance values were $p > 0.05$, the distribution of scores for the conceptual knowledge pretest was normal. As a conclusion, treatment could be applied to both groups to determine differences of the effect between the groups.

The significant value for the procedural knowledge pretest on limit function for the experimental group was $p = 0.064$ and the control group was $p = 0.058$. All values for the procedural knowledge retest were $p > 0.05$. These findings show that both groups were homogenous. Subsequently, based on students ability, those with a high-level of competence yielded a significance value of $p = 0.200$, medium-level of competence $p = 0.056$, and low-level of competence $p = 0.200$. Because all significance values were $p > 0.05$, the distribution of score for the procedural knowledge pretest was normal. As a result, treatment could be applied on both groups to determine differences of the effect between the groups.

5.2 Analysis for Posttest of Conceptual Knowledge Test of Limit Function

A two-way ANOVA was conducted to determine differences in conceptual knowledge of limit function between the experimental and control groups based on ability. Before the analysis was performed, a Levene's test was conducted to test similarities that existed among variables (see Table 2).

Table 2. Levene's Test for Conceptual Knowledge of Limit Function between Groups based on Ability

F	df1	df2	*p*
0.728	5	278	0.603

The findings revealed no significant variance-covariance differences among the dependent variables for all levels of the independent variables, $F = 0.603$, $p > 0.05$. This finding could be interpreted as variance-covariance for the dependent variables is homogeneous across the independent variables. Therefore, the two-way ANOVA was performed to determine differences that existed between the group in terms of conceptual knowledge based on ability (Pallant, 2007; see Table 3).

Table 3. Mean and Standard Deviation of Conceptual Knowledge of Limit Function between Groups based on Ability

Group	Ability	N	Mean	Standard Deviation
Experimental	High	37	78.78	8.929
	Medium	64	73.83	9.459
	Low	37	71.89	8.925
	Total	138	74.64	9.488
Control	High	39	70.90	8.950
	Medium	68	70.29	11.126
	Low	39	61.41	10.256
	Total	146	68.08	11.052

The findings revealed that in the experimental group, students of high-level of competence (M = 78.78; SD = 8.929) had higher levels of mathematical conceptual knowledge of limit function compared to students of medium competence (M = 73.83; SD = 9.459) and students of low competence (M = 71.89; SD = 8.925). The same trend was found in the control group where students of high competence has higher levels of mathematical conceptual knowledge (M = 70.90; SD = 9.950) than did students of medium competence (M = 70.29; SD = 11.126) and students of low competence (M = 61.41; SD = 10.256). To ensure that these differences were statistically significant, a two-way ANOVA test was performed (see Table 4).

Table 4. Two-Way ANOVA Differences in Conceptual Knowledge of Limit Function between Groups based on Ability

Independent Variable	Type III Sum of Squares	Df	Mean Square	F	*P*
Group	3535.84	1	3535.843	36.801	0.000
Ability	2668.96	2	1334.478	13.889	0.000
Group*Ability	627.30	2	313.648	3.264	0.040
Std Error	26710.09	278	96.079		
Total	1475550.00	284			

The findings revealed significant differences in conceptual knowledge of limit function between the experimental and control groups, F = 36.801 and p = 0.000. n addition, significant differences existed in conceptual knowledge of limit function based on ability, F = 13.880 and p = 0.000. To examine these differences further, a Pos Hoc Scheffe analysis was performed (see Table 5).

Table 5. Pos Hoc Scheffe Differences in Conceptual Knowledge of Limit Function based on Ability

(I) Level	(J) Level	Mean Difference (I-J)	Std Error	*P*
High	Medium	2.7293	1.41141	0.156
	Low	8.2237*	1.59010	0.000
Medium	High	-2.7293	1.41141	0.156
	Low	5.4944*	1.41141	0.001
Low	High	-8.2237*	1.59010	0.000
	Medium	-5.4944*	1.41141	0.001

The results yielded significant differences in conceptual knowledge of limit function between students of high and low competence, p =0.000. In terms of mean, students with high competence had higher levels of conceptual knowledge compared to students of medium competence with a mean difference of 8.2237. Significant differences existed in conceptual knowledge between students of medium and low competence, p = 0.000. The mean of the analysis demonstrated that students of medium competence had higher conceptual knowledge compared to students of low competence with a mean difference of .4944. As for students of high and medium competence, no significant difference was found, p = 0.156.

Significant differences existed in conceptual knowledge between the experimental and control groups, $F = 3.264$; $p = 0.040$. Owing to these significant differences, it could be assumed that an interaction between group and level of competence in conceptual knowledge of limit function exists (see Figure 1).

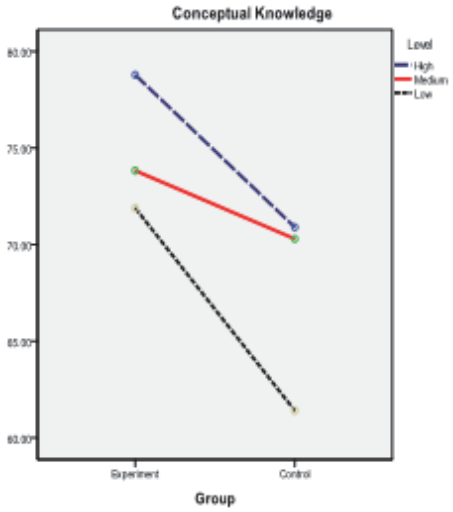


Figure 1. Interaction Between Group and Level of Competence Toward Conceptual Knowledge of Limit Function.

As seen in Figure 1, students from the control group had the lowest level of conceptual knowledge of limit function. A similar result was found in the experimental group, as students of low competence had the lowest level of conceptual knowledge of limit function. On the other hand, students with high competence from both groups had the highest conceptual knowledge of limit function. Students of medium and low competence from the experimental group, they had similar means of conceptual knowledge. Students of high and medium competence from the control group also exhibited similar means of conceptual knowledge. As a whole, it could be concluded that a significant interaction existed between group and level of competence of conceptual knowledge of limit function

5.3 Analysis for Posttest of Procedural Knowledge Test of Limit Function

A two-way ANOVA was conducted to determine the difference in procedural knowledge of limit function between experimental and control group based on ability. Before the analysis was performed, Levene's test was conducted in order to test the similarities that exist among variables. The data obtained from Levene's test are tabulated in Table 6:

Table 6. Levene's Test for Procedural Knowledge of Limit Function between Groups based on Ability

F	df1	df2	*P*
0.916	5	278	0.471

The findings revealed that no significant variance-covariance differences existed among the dependent variables for all levels of the independent variables, F = 0.471, p > 0.05. This finding means that variance-covariance for the dependent variables was homogeneous across the independent variables. Therefore, a two-way ANOVA could be performed to determine the differences that existed between the experimental and control groups in terms of their conceptual knowledge based on ability (Pallant, 2007).

Table 7 illustrates in experimental group. Students of high competence (M = 79.46; SD = 9.036) had higher levels of mathematical conceptual knowledge of limit function compared to students of medium competence (M = 77.11; SD = 8.674) and students of low competence (M =71.49; SD = 8.238). Students in the control group with high competence had higher levels of mathematical conceptual knowledge (M = 77.43; SD = 10.568) than did students of medium competence (M = 71.03; SD = 8.576) and students of low competence (M = 71.67; SD = 7.009).

Table 7. Mean and Standard Deviation of Procedural Knowledge of Limit Function between Groups based on Ability

Group	Ability	N	Mean	Standard Deviation
Experimental	High	37	79.46	9.036
	Medium	64	77.11	8.674
	Low	37	71.49	8.238
	Total	138	76.23	9.118
Control	High	39	77.43	10.568
	Medium	68	71.03	8.576
	Low	39	71.67	7.009
	Total	146	72.91	9.149

To ensure that these differences were statistically significant, a two-way ANOVA test was performed (see Table 8).

Table 8. Two-Way ANOVA Differences in Procedural Knowledge of Limit Function between Groups based on Ability

Independent Variable	Type III Sum of Squares	Df	Mean Square	F	*P*
Group	462.746	1	462.746	6.079	0.014
Ability	1855.552	2	927.776	12.189	0.000
Group*Ability	515.668	2	257.834	3.387	0.035
Std Error	21160.864	278	76.118		
Total	1601625.000	284			

The findings show significant differences in procedural knowledge of limit function between the experimental and control groups, $F = 6.079$, $p = 0.014$. In addition, significant differences existed in procedural knowledge of limit function based on ability, $F = 12.189$, $p = 0.000$. To examine these differences further, Pos Hoc Scheffe (see Table 9).

Table 9. Pos Hoc Scheffe Differences in Procedural Knowledge of Limit Function based on Ability

(I) Level	(J) Level	Mean Difference (I-J)	Std Error	*P*
High	Medium	4.4438*	1.25627	0.002
	Low	6.8421*	1.41531	0.000
Medium	High	-4.4438*	1.25627	0.002
	Low	2.3983	1.25627	0.164
Low	High	-6.8421*	1.41531	0.000
	Medium	-2.3983	1.25627	0.164

Significant differences existed in procedural knowledge of limit function between students of high and medium competence with a mean difference of 4.4438 ($p = 0.002$). Students of high competence had higher levels of procedural knowledge compared to students of medium competence. Significant differences existed in procedural knowledge of limit function between students of high and low competence with a mean difference of 6.8421 ($p = 0.000$). The mean of the analysis showed that students of high competence had higher levels of procedural knowledge compared to students of low competence. Students of medium and low competence did not significantly differ ($p > 0.05$).

Significant differences existed in procedural knowledge of limit function between the experimental and control groups based on ability, $F = 3.387$, $p = 0.035$. Because of these significant differences, it could be assumed that an interaction between group and level of competence in procedural knowledge of limit function exists (see Figure 2).

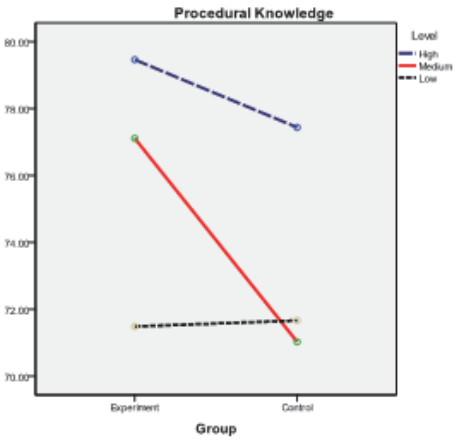


Figure 2. Interaction between group and level of competence toward procedural knowledge of limit function

As illustrated in Figure 2, students of high competence from the experimental group had the highest level of procedural knowledge of limit function. On the other hand, students of medium competence from the control group had the lowest level of procedural knowledge of limit function.

6. Discussion

The analysis of two-way ANOVA indicated significant differences in mathematical conceptual and procedural knowledge of limit function between students of different levels of competence. Conceptual knowledge of limit function shows that students with high and low levels of competence exhibited more improvement in conceptual knowledge compared to those of medium competence. This improvement could be attributed to the effectiveness of teaching and learning method employed. Students of high and low competence adapted better to the new method. Furthermore, differences in improvement could be due to the disparity of students' computer-related skills. This statement is in support of research conducted by Kosnin and Lin (2010), who claimed that disparity in computer-related knowledge and skills could render an obstacle for teachers to conduct a research that uses technology for teaching and learning as its apparent effect is only visible in students who possess high levels of technology-related skills. According to the findings obtained from this research, students who have higher levels of technology-related skills could master taught topics faster compared to those who are weaker in these skills.

Although the GeoGebra software affects students of medium competence, the level of increase was less than that among students of high and low competence. Generally, the results of this research showed that GeoGebra is suitable for students of all levels of competence. The advantages of GeoGebra include providing clearer information and production of images and graphics that can help greatly in understanding concepts of mathematics. Findings from this research support those explicated in research by Stojanovska and Stojanovski (2009), which assert that the GeoGebra software allows students to explore mathematics from home and school, and allows for interactions between teacher and student. Thus, the use of the GeoGebra software could enhance the conceptual knowledge of students of diverse abilities.

Significant differences in procedural knowledge of limit function existed based on students' levels of competence. Students of high competence had higher levels of procedural knowledge than did students of medium and low competence. Students of high and medium competence showed an increase in procedural knowledge, in which the latter displayed a higher level of improvement. It could be deduced that students of medium competence are more receptive to the teaching and learning method used. GeoGebra teaching modules allow students to accommodate their prior knowledge to newly acquired knowledge through enrichment exercises included in the modules.

Students of low competence did not show any improvement. This finding implies that the use of GeoGebra software on the topic of limit function was not effective in enhancing the procedural knowledge of these students. The reason underlying this failure could be due to the fact that more time was allocated in the presentation of concepts that are unfamiliar to students. This finding is similar to research by Engelbrecht et al. (2005), which claimed that students' procedural knowledge is lower after learning and using a new method that involves a visual method.

A two-way ANOVA test showed a significant interaction between group and level of competence for conceptual and procedural knowledge of limit function. Students who used the GeoGebra software had higher levels of conceptual

knowledge of limit function than did students who used the conventional method. This improvement of conceptual knowledge occurred for students at all level of competence, which suggests that the GeoGebra software affects the increase in conceptual knowledge among students. Additionally, students' knowledge could also be enhanced and solidified using teaching modules of GeoGebra as those abstract concepts presented are readily accepted by students of diverse competencies. As Antohe (2009) stated, students could visualize abstract concepts and make connections among these concept in mathematics using GeoGebra.

7. Conclusion

The use of GeoGebra has succeeded in increasing students' conceptual and procedural knowledge of limit function. Using the GeoGebra software allows teachers to present images on the concepts of function and limit function. Apart from that, procedures involved could also be conveyed in detailed steps using GeoGebra. For instance, with the GeoGebra software, it is possible to produce graphics directly without materials from outside. Advantages of GeoGebra allow teachers to be more creative in constructing more effective lessons that permits two-way teaching and learning process. The use of GeoGebra also encourages students to be more active in learning as they are provided with opportunities to use GeoGebra as a medium to reproduce their knowledge on the topic being taught. In addition, students could share ideas with their counterparts. Production of concepts and procedures are also made possible with steps of learning in GeoGebra. As a result, students could take an active role in learning through their attempts in the search for problem solutions using GeoGebra or on paper. Hence, GeoGebra can be considered an alternative for schools to run their mathematics laboratories and use GeoGebra in the teaching and learning process. The use of GeoGebra gives teachers an opportunity to create different teaching techniques. Nonetheless, it is necessary to provide training for teachers on the advantages of GeoGebra and its operational skills as part of the effort to increase students' conceptual and procedural knowledge in mathematics.

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