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The Effectiveness of the GeoGebra Software: The Intermediary Role of Procedural Knowledge On Students' Conceptual Knowledge and Their Achievement in Mathematics

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ABSTRACT
The aim of this study was to identify the effects of GeoGebra software on students' conceptual and procedural knowledge and the achievement of Form Two students in Mathematics particularly on the topic Function. In addition, this study determined the role of procedural knowledge as a mediator between conceptual knowledge and students' achievement. This study employed a quasi-experiment approach on 345 students divided into two groups. A group with 169 students used the GeoGebra software, while another 176 students used the conventional method to learn Mathematics. The data were collected through conceptual and procedural tests, and from students' achievement in the topic Function of the Mathematic examination. The data were analysed using the SPSS 22.0, AMOS 18.0 and ANATES v4 software. Findings of the study show that students who used GeoGebra to learn Mathematics have higher mathematical conceptual and procedural knowledge compared to those who learnt Mathematics through the conventional methods. Both experiment groups show that procedural knowledge is a significant mediator between conceptual knowledge and students' achievement in Mathematics. In conclution, GeoGebra software is capable of enhancing students' conceptual and procedural knowledge, which at the same time significantly improves students' achievement.
Keywords: conceptual, function, GeoGebra, procedural, quasi-experiment

INTRODUCTION

Technology use in Mathematics teaching helps students to easily acquire basic mathematical skills. Organised and well-planned supports as well as enough practice would greatly help students to improve their skills particularly in exploring their potential in information technology to the maximum. Students need guidance in applying the latest technology to solve various mathematical problems (Oldknow & Taylor, 2000). The computer is now

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State of the literature

- There are past studies that show the effects of GeoGebra on students' performance whether in geometry; algebra and calculus (Arnbain & Shukor, 2015; Botana et al., 2015; Zengin et al., 2012). The advantages of GeoGebra are able to explain concept and have interaction between teacher and students in the teaching and learning process in the attempt to understand the taught topic. Few studies also have identified the benefits of GeoGebra in helping out to understand mathematical concepts and procedures (Caglayan, G. 2015; Supriadi et al. 2014; Rincon, 2009). Most of the conceptual explanations using GeoGebra are in the forms of pictures or visuals in order to relate to the actual situation in daily life. On the other hand, for explaining the procedures, graphics, pictures and symbols are used. Based on these advantages of using GeoGebra, a study will be carried out to identify the effects of using GeoGebra in conceptual and procedural knowledge and students' performance in Mathematics.

Contribution of this paper to the literature

- The study contributes to the library research by contributing to the findings for advantages and priority in using GeoGebra for teaching and learning of Mathematics especially in the effort to improve Mathematical concepts, procedures and performance.

widely used as a teaching aid in Mathematics in order to enhance students' self-motivation and self-confidence (Sivin-Kachala & Bialo, 2000). The use of computer in teaching and learning Mathematics is actually a sophisticated method as opposed to conventional methods to produce a brilliant generation in the aspects of physical, emotional, spiritual and intellectual development (Norazah & Effandi, 2007). Various types of computer software are commonly used to help students be more responsible for their own learning through a more creative and attractive exploration approach. In fact, teaching and learning software are becoming more popular and in demand especially in the Calculus subject (Ahmad Fauzi et al., 2009).

Teachers should embrace the current changes and strive to realise the use of the latest technology in the classroom. Educators should try the hardest in making Mathematics a very interesting subject in order to attract students' interest and at the same time to help them consciously focus on important mathematical concepts. It is the teachers' responsibility to prepare students to focus on the future world which undoubtedly would depend on mathematics, science and technology (Furner & Marinas, 2007). Technology-based learning provides symbols, formula, tables, graphs, numbers, equations and manipulative materials to link them with various real life ideas and those are indeed parts of conceptual and procedural knowledge (Post 1998). Technology application in teaching and learning Mathematics helps students to better understand basic mathematical concepts and to experience intuition in solving certain mathematical problems (Rohani et al., 2009).

Conceptual knowledge

Hibert (1986) in his book *Conceptual and Procedural Knowledge: The Case of Mathematics* has defined conceptual knowledge as a chain of multiple knowledge. Groth and Bergner (2006) considered conceptual knowledge as a web of knowledge, cognitive chains where the relationship among the nodes is equally important with the discrete dics of information nodes. Conceptual knowledge is also referred to as basic knowledge of mathematical arrangement with regard to relationship and interconnection of mathematical ideas which enables one to explain and bring meaning to mathematical procedures. Hiebert and Lefevre (1986) categorised conceptual knowledge as a great knowledge of interrelated information, which enables the information to be easily and flexibly accessed. Students can only acquire this conceptual knowledge when they are able to identify, to provide symbols and to give examples for questions given to them. The examples of concepts are to correlate, to manipulate, to differentiate concepts, to identify and apply the rules, to know and to apply facts, to define, to differentiate and to integrate concepts with rules, to define and apply symbols, and terminologies of concepts or to interpret assumptions and relationship of mathematical concepts (Baker, 2002).

Based on several previous studies, it was found that Function is one of the tough Mathematics topics for students (Bell, 2001; Infante, 2007; Jensen, 2009; Ratliff, 2009; Teachey, 2003). Thus, it will be difficult for students to understand Mathematics without solid conceptual and procedural knowledge or at least they need to acquire one of them. There will be a time when concept and procedure are not interrelated, which will be easy for students to understand Mathematics. However, they might be able to find the answer, but be unable to comprehend the situation; thus this actually does not solve their mathematics problem. According to Dede Suratman (2011) the level of Mathematics conceptual and procedural knowledge among secondary school students is still at the very low level, particularly on the Function topic (Setu Budiarjo, 2012). Hence it can be said that students have the tendency to develop and understand certain concepts and fields of study differently. According to Scheja and Pettersson (2010), this variation happens due to differences in the areas of studies, especially in the lesson structures, the depth and broad contents of the subjects.

The teaching method applied is another factor that creates difficulty for students in understanding the Function and Function Limit topics. Selden and Selden (1992) described the functional concept as an interlink of several different sub-topics of new Mathematics and functional concept indeed needs to be focused on. The efforts of helping students to get higher achievement involves flexible and in-depth mental conception of the function. In other words, students need to have a solid and strong knowledge about the function. Calculus is the starting point of a higher mathematical thinking and function is the main concept of calculus (Vinner, 1992). According to Williams (1991) students would always face difficulty in understanding the concepts of calculus and limit; however, these two are the foundation for all standards of modern analysis, and also the basic conventional pedagogy in the introduction of Calculus.

Procedural Knowledge

Hiebert and Lefevre (1986) in their book *Conceptual and Procedural Knowledge: The Case of Mathematics* have categorised procedural knowledge in two parts, (a) knowledge of mathematical symbols and (b) knowledge of algorithm or rules to be used in solving mathematical problems. Apart from that, knowing the procedures is actually being aware of the approach to be used in the process of manipulating mathematical symbols. According to Sáenz (2009), procedural knowledge focusses on the skills needed in problem solving. Procedure is actually a knowledge which shows the order or sequence of actions and it is a comprehensive learning of all the components or steps which are actually considered as a complex procedure. Procedural knowledge is actually a basic skill but important to be mastered by all students (Effandi et al., 2007). A student who has acquired procedural knowledge would have the ability and skills to efficiently apply certain procedures to solve a problem by using a precise symbolic system or mathematical rule effectively.

Hiebert and Lefevre (1986) have stated that mathematic procedural knowledge involves two types of information. The first information is the knowledge about integration of individual symbols and the other information involves syntactic convention of symbols received. Regardless of the types of information, both involve information on rules or procedures in order to solve any mathematical problem. Several procedures require students to have ability to use interrelated ingredients to manipulate symbols. However, procedural knowledge includes the strategies to solve a problem which in its operation does not directly involve certain symbols. The difference between procedural and conceptual knowledge is more about their main relationship, as the main interaction of procedural knowledge is "after" the use of sub-sequence of a procedure and in the procedure linear. Whereas, conceptual knowledge integrates or absorbs a variety of relationships (Hiebert & Lefevre, 1986). Procedural knowledge in this study refers to the impacts of teaching and learning methods used by mathematics teachers on students' ability to use a particular procedure to solve mathematical problems by using symbols, correct problem solving steps/sequences, plotting graphs and tables, as well as by developing calculus in teaching and learning mathematics.

The ability to relate conceptual and procedural knowledge would benefit the students tremendously, especially in their ability to acquire and apply procedural knowledge (Hiebert & Lafevre, 1986). Developing the ability to relate conceptual knowledge of formal Mathematics symbols involves a process of providing meanings to the symbols. Developing a relationship between conceptual knowledge and mathematics procedures contributes significantly to memory acquisition and storage and effective use of memory. According to Carpenter (1986), it is not easy to build a strong relationship or to relate conceptual knowledge with procedural knowledge. This is due to continuous problems in gaining conceptual knowledge; hence it would be difficult to measure it directly as it needs detailed observation on certain procedures. Procedural knowledge is very much related to anything done by the students. Hence it is easily observed compared to conceptual knowledge, which is basically acquired by students from the steps of procedures that they conducted.

Some researchers have given a more concrete psychological definition on certain academic domains to determine the criteria of different levels of knowledge (Nezhnov, Kardanova, & Ryabinina, 2013). This study focusses on three academic domains namely academic achievement, conceptual knowledge and procedural knowledge. The main concern of this study is on inability of students to relate their procedural and conceptual knowledge of Mathematics subject which resulted with poor academic achievement (Scheja & Pettersson, 2010). There have been many efforts to enhance students' conceptual and procedural knowledge (Castro, 2011, Cowan, 2011, Duru, 2011). Other previous studies including quasi-experimental methods are conducted on the effects of using technology in teaching and learning Mathematics (Harper, 2007; Deslauriers, 2007; Pitsolantis, 2007). Those studies encourage teachers to exploit technology in Mathematics teaching and learning, particularly with the objective to enhance conceptual and procedural knowledge which then will have a significant effect on students' achievement.

Academic Achievement

Academic achievement is commonly shown by students' performance in school. Higher academic achievement depicts that students are leaning toward excellence (Robiah, 1994). Academic achievement can also refer to students' learning ability and skills and the marks they get on the subjects studied in school. In other words, achievement in this study is referred to students' success in school examinations. The achievement data were collected from the Mathematics teachers of the schools. Holgado et al. (2013) has found a significant and positive relationship between students' involvement and their academic achievement. Various teaching and learning aids are used to encourage students' involvement in class. According to Kiuru et al. (2014), students' achievement can be improved by teachers who wholeheartedly support their students by providing interesting teaching methods to attract students' interest.

GeoGebra Software

GeoGebra is a dynamic Mathematics software on Geometry, Algebra and Calculus (Hohenwarter et al., 2008; Rincon, 2009). The GeoGebra software is used as an alternative software to integrate technology in teaching and learning Mathematics. A needs analysis was conducted which found that Geometry, Algebra and Function were the three focus topics to be integrated with technology (Rincon, 2009). Mathematics representatives (symbols, and graphs) are created by the GeoGebra software to help teachers in describing mathematical concepts and procedures. In addition, Haciomeroglu et al. (2009) have proven that the GeoGebra Software facilitates the process of teaching Geometry, Algebra and Calculus. Thus, it is essential to integrate software with the conventional classroom learning methods to teach Geometry, Algebra and Calculus. The free software enables students to easily download learning materials; thus it can be used as a computer-based homework. The software teaching and learning materials are easily accessible and extensive to assist students in their learning and to help teachers in their teaching.

GeoGebra can be applied in Mathematics especially in teaching and learning Geometry, Algebra and Calculus (Antohe, 2009; Haciomeroglu, 2009; Hutkemri & Effandi, 2010; Rincon, 2009). The use of GeoGebra in teaching and learning Mathematics is one of the approaches in the efforts to create a meaningful learning environment. It is widely recommended to be applied in various activities which are based on mathematical concepts. In addition, the software is very helpful in explaining concepts and procedures through created graphics, images, and symbols. The application of GeoGebra software would create a conducive learning environment as it is a very dynamic educational technology with the potential to aid students in their mathematical exploration, for instance through problem solving, calculation, development, modelling and reflection (Bu et al., 2011).

The GeoGebra software used by the researcher can be used in schools, classrooms and any educational environment, with the main purpose being to help enhance students' knowledge of mathematical concepts and procedures. In this study, the GeoGebra software was used to improve students' conceptual and procedural knowledge based on the need to integrate technology in teaching and learning Mathematics. The software uses symbols, formulas, tables, graphs, numbers and equation which were intelligently designed to strengthen students' conceptual and procedural knowledge in Mathematics (Haciomeroglu et al., 2009; Rincon, 2009). The GeogGebra software was chosen by the researcher as one of the teaching methods. Hence, it is hoped to benefit students, teachers and the Education Ministry, as an effort to improve students' conceptual and procedural knowledge.

Conventional Learning

Conventional teaching normally focuses on mathematics procedures, as students are taught and given practice on procedural type of questions in preparing for the national examination. Hence, students would have the tendency to solely depend on the learning process that they have experienced in school. Consequently, students' mathematical knowledge is shallow and not well developed. Normally, teachers who resort to conventional teaching would rarely apply conceptual-based teaching strategies. It is indeed convenient to use conventional teaching as all of the learning materials are readily available in the textbooks (Maryunis, 1989). Textbooks do not really require teachers to change their traditional teaching style. Years of teaching experiences would strengthen a kind of routine and teaching habit especially in the ways of delivering the teaching and learning contents and mathematical tasks. On the other hand, students are also comfortable with the traditional learning style, as they do not really face difficulty in adjusting themselves to their teacher's teaching style.

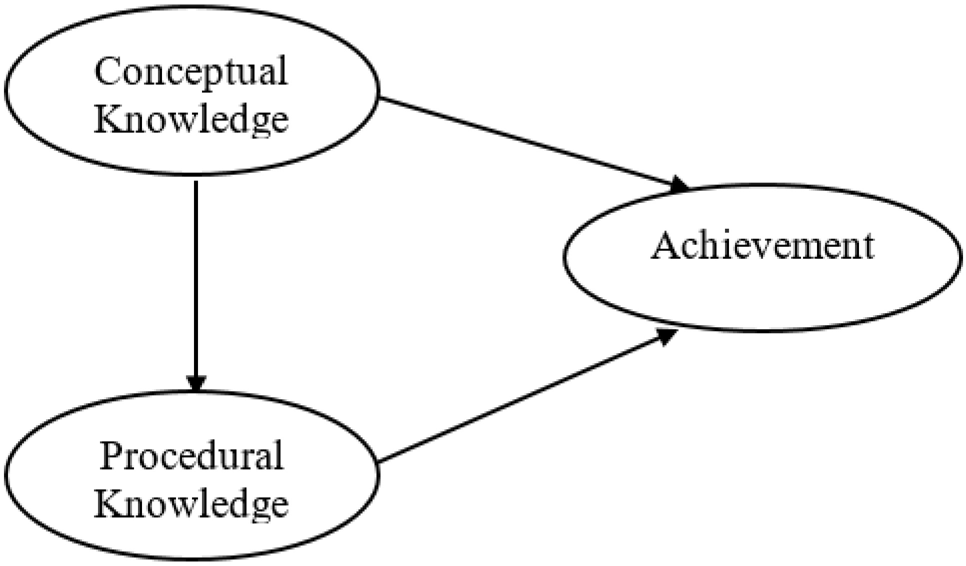

Figure 1. Hypothesized contribution model with conceptual and procedural knowledge and achievement

Figure 1 shows the hypothesised path model. The hypothesised structural model was fitted to the data to estimate the parameters, in order to address the following specific research questions:

1. Is there any significant difference in the level of conceptual and procedural knowledge between students who used the GeoGebra software with students who used the conventional method, based on learning ability?
2. What are the impacts of procedural knowledge as a mediator between conceptual knowledge and academic achievement on students who used the GeoGebra software and conventional method?

METHODOLOGY

Participants

The data were collected from 345 Form Two students of secondary schools in Riau, Indonesia. Students were divided into two groups; one group used the GeoGebra software (n = 169) and another group used the conventional method (n = 176). The participants were Form Two students from two secondary schools who were randomly selected based on similar characteristics of the schools and students. The schools were Grade A schools and selected due to the availability of the technology facility in the school

Procedure

The experimental method is a research plan conducted to determine the influence or impacts of a manipulation. The researcher purposely and systematically manipulated a natural phenomenon to observe a series of changes experienced by the phenomenon (Sekaran, 1992). Quasi-experiment with pre- and post-tests (Non-equivalent pretest and posttest control group design) was designed to observe the real impact or the influence on a real or natural situation. Quasi-experiment was the best approach due to the availability of the original classes of students (Wiersma, 2000). 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 treated by teaching and learning Mathematics using the GeoGebra software. However, students in the control group went through the normal conventional learning in their tutorial classes.

Both groups experienced the teaching and learning process in their normal classrooms, and they were taught the same Functional topic. Students in the control group used the common stationery such as papers, pen and ruler, however students of both groups (treatment and control groups) have similar experience and they are not really familiar on the use of technology in teaching and learning. Students of both groups have the same academic background, where each group consisted of high achievers, low achievers and average students. Students of both groups also experienced the same activities and had the same learning objectives. The only difference is on the teaching methods on which students in the treatments group used the GeoGebra software while students in the other group used pen, papers and ruler. The lessons were carried out for 8 hours in three contact hours per week and students were given their tasks conventionally. Two teachers were purposely selected and trained to teach both groups on the Function topic respectively. Both groups were observed for the duration of eight weeks. Students from both groups were given a pre-test and a post-test on the Function topic and Function Limit. The same questions were designed for both tests, in order to determine the treatment impacts and effects.

Internal validity and external validity were considered in this study. According to Gall et al. (2003), internal validity refers to how the extraneous variable can be controlled to ensure a precise effect from a treatment variable. The researcher tried to reduce this threat by taking the characteristics of the threat into consideration. According to Sekaran (1992), in contrast, external validity is about how an inference can be concluded of the population based on results of an experiment. With regard to this study, findings of this research cannot be generalised to all students in other schools, but only to students of schools having the same or similar characteristics with the students involved in this study.

Measure

Conceptual knowledge*:* There are 5 questions in the instrument to measure students' conceptual knowledge of the Function topic in their Mathematics subject. The questions were adapted from previous studies by Teachey (2003) and Jensen (2009). Among the questions to test the knowledge are "to describe the rules of Function, derivative function and inverse function as well as to explain patterns of the function". Each question has a minimum of 0 score (wrong) and a maximum of 4 (Excellent). The ideal score is 20. The marks were then converted to a scale of 100 for analysis purposes. Some of the questions to test students' conceptual knowledge are including to provide examples of functions in daily life. The objective of the questions is to determine students' knowledge on the concepts of Functions based on their daily or real life experiences.

Procedural knowledge: There are five questions to determine respondents' procedural knowledge. Among the items are to solve equation of composite function, inverse function and to solve inverse function from composite function. The questions were adapted from previous studies by Bell (2001), Teachey (2003) and Jensen (2009). Each question has a minimum of 0 score (wrong) and a maximum of 4 (Excellent). The ideal score is 20. The marks were then converted to a scale of 100 for analysis purposes. The examples of questions to test procedural knowledge are asking students to solve the function equation of $f(x) = x^2 + 1$; to determine the formula of $f^{-1}(x)$ and to graph the functions. The objective of these questions is to know students' procedural knowledge from the calculation process and graphic drawings for the functions equation.

Achievement: students' achievement marks were gathered from the Form Two mathematics teachers. Questions of the school achievement test were designed by the respective teachers and were validated by the school's administration. The data used were from the overall achievement marks received by students on the Function topic, and the marks were in the range from 0 to 100. Students were divided into categories by referring to Sudjana (2005) who divided students into 27% of high achievers, 27% low achievers and the balance was a category of average students.

The instrument focused on its content validity to measure conceptual and procedural knowledge. The instrument was designed as a test to determine conceptual and procedural knowledge of the Mathematics subject. Content validity was an important aspect and was designed by adapting with the instruments provided by Best and Kahn (2003) and Creswell (2005). The conceptual and procedural knowledge instrument was validated by experienced calculus teachers. The content validity was assessed by the experts who certified that the designed instrument was fit to be used in the real study. After the instrument was validated, a pilot study was conducted to test the instrument reliability. The reliability of the questions for conceptual and procedural knowledge based on the Function topic was determined by discriminant index, difficulty index and Cronbach's alpha. The discriminant index shows whether the designed questions are able to differentiate between high-achieving students and low-achieving students (Erman Suherman & Yahya Sukjaya, 1990). The difficulty index is the average correct items answered by members of the group being tested (Bhasah, 2007). However, according to Erman Suherman and Yahya Sukjaya (1990), difficulty index shows the difficulty level of the questions.

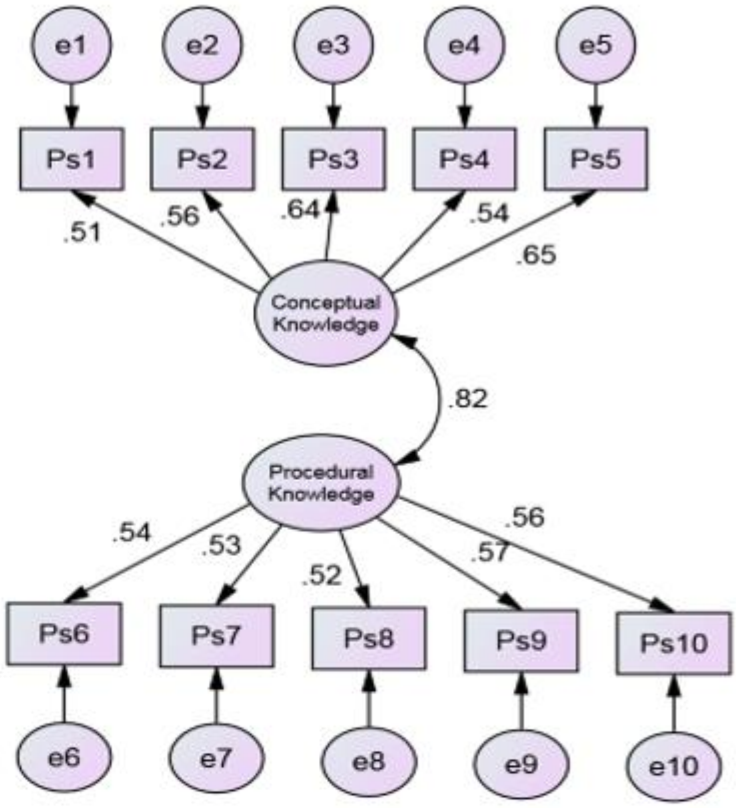

Figure 2. Loading Factor of the test for conceptual and procedural knowledge

A pilot study was carried out on 60 students. The ANATES4 software was use to analyse and determine the discriminant index and difficulty index. The analysis showed the difficulty index of the questions to measure conceptual knowledge (31.25% - 40.53%) and procedural knowledge (48.44%-69.53%) was at the moderate level (Karno to 1996). The value of discriminant index for each item of the test questions for conceptual knowledge (31.25% to 40.63%) and procedural knowledge (32.81% to 60.94%) showed that it was at a good level and the reliability value of the test questions for conceptual knowledge (.82) and procedural knowledge (.83) was at a good level (Lim, 2007). Therefore, each item to test students' conceptual and procedural knowledge of the functions topics were retained in the actual study. Confirmatory factor analysis (CFA) was conducted using the AMOS software in order to get a good model of the relationship and contribution of students' conceptual and procedural knowledge towards their achievement. The CFA analysis was conducted on the real research data of the conceptual and procedural knowledge, which involved 345 students. **Figure 2** shows the values of the confirmation factor.

Loading Factor of the Conceptual and Procedural Knowledge

Confirmatory factor analysis is important to confirm the validity and reliability of any measurement used in most of studies on social science (Harrington, 2009). The Acceptance criteria of conventional chi-square are shown by the significant results. The chi-square relative (CMINDF) should be between 1 and 5 in order to get a suitable model. TLI, CFI, and GFI values should be in the range of 0 to 1. However, RMSEA should be below 0.08 to show an acceptable value for the data (Schumacker & Lomax, 2004). According to Awang (2012), the RMSEA value of 0 to 1 is still acceptable.

Data Analysis

Figure 2 shows the measurement model of conceptual and procedural knowledge to determine the relationship between the variables and indicators of latent variables. Each indicator variable and latent variable is represented by a rectangle and a circle respectively. All item burdens on each conceptual knowledge item were greater than 0.5 and they were significant. The items with value < 0.5 would be removed (Awang, 2012). However, according to Hashim and Sani (2008), 0.4 value of item burden is acceptable to be used in a study. Each item in the instrument to measure students' conceptual and procedural knowledge was retained to be used in the real study. The goodness of fit index and chi-square show the chi-square significant level of the model was at a good level and deemed to be significant (χ^2 = 92.342, df = 34, $p<0.05$) (Kline, 2005). Chi square/df (92.342/34 = 2.716), CFI = 0.91, GFI = 0.95, TLI = 0.90 and RMSEA = 0.07. This shows that a good model has been designed.

The SPSS 22.0 software was used in this study to determine any enhancement in students' conceptual and procedural knowledge. The MANOVA factorial analysis was used to measure the enhancement or the difference in students' knowledge. The AMOS 18.0 software was used to determine the contribution of conceptual and procedural knowledge toward students' achievement and also to identify the relationship of the two types of knowledge. In this study, we dealt with the missing data through full-information maximum likelihood estimation, allowing us to include all available data. Decisions concerning model fit of these data were based on four fit indices: the chi-square fit index, Bentler comparative fit index (CFI), Tucker-Lewis fit index (TLI), and root mean square error estimate (RMSEA). Following Kline (2005), model fit is excellent when the coefficient for CFI and TLI is greater than 0.95; and model fit for both is deemed adequate if the coefficient is greater than 0.90 (Byrne 2010). For the RMSEA, a coefficient less than 0.05 indicates an excellent fit, and a coefficient under 0.08 indicates an acceptable fit.

Table 1. CFA of students' conceptual and procedural knowledge

Parameter	Coefficient
CFI	0.91
GFI	0.95
TLI	0.90
RMSEA	0.07
Df	34
χ^2	92.342
χ^2/df	2.716

Note. CFI: Comparative Fit Index; GFI: Adjusted Goodness of Fit Index; TLI: Tucker-Lewis fit index (TLI); RMSEA: Root Mean Square Error; df: Degrees of Freedom; χ^2: Chi-square goodness of fit.

RESULTS

The difference of conceptual knowledge based on groups and students' ability

Two-way ANOVA analysis was conducted to determine the difference in students' conceptual knowledge on the Function topic, which was between students who studied the mathematics topic using the GeoGebra software and students who studied using the conventional method. The variance homogeneity test was first carried out before the two-way ANOVA test using Levene's test. Levene's test showed that the variances of the variables scattered equally with the F value = 1.606 and sig = 0.158 (p >0.05). This showed that two-way ANOVA could be conducted to determine the difference in students' conceptual knowledge on the Function topic. **Table 2** shows the mean of students' conceptual knowledge after the learning methods were carried out.

Students who used the GeoGebra software showed higher ability in conceptual knowledge compared to students who learnt using the conventional method. Results of students in the treatment group (using the GeoGebra software) showed that high-achieving students have the highest conceptual knowledge (mean = 80.65 and sd = 13.23). This is followed by low-achieving students (mean = 73.33 and sd = 11.430) and moderate students

Table 2. Mean and standard deviation of students' conceptual knowledge of the Function topic

Knowledge	Groups	Ability	N	Mean	Std. Deviation
Conceptual	Treatment	High	46	80.65	13.23
		Moderate	78	71.47	12.41
		Low	45	73.33	11.43
		Total	169	74.47	12.91
	Control	High	51	74.90	10.02
		Moderate	80	68.31	11.69
		Low	45	58.89	10.33
		Total	176	67.81	12.35
	Total	High	97	77.63	11.95
		Moderate	158	69.87	12.12
		Low	90	66.11	13.04
		Total	345	71.07	13.04

Table 3. Two-way ANOVA on the difference of students' conceptual knowledge of the Function topic

Source	Type III Sum of Squares	df	Mean Square	*F*	Sig.
Corrected Model	12501.163[a]	5	2500.233	18.425	0.000
Group	4909.706	1	4909.706	36.181	0.000
Ability	6782.958	2	3391.479	24.993	0.000
Group * Ability	1864.140	2	932.070	6.869	0.001
Error	46002.025	339	135.699		
Total	1801200.000	345			

(mean = 71.47 and sd = 12.41). Students in the control group were taught using the conventional method and the results showed that high-achieving students have the highest conceptual knowledge (mean = 74.90 and sd = 10.02). This is followed by moderate students (mean = 68.31 and sd = 11.69) and low-achieving students (mean = 58.89 and sd = 10.33). It was found that students regardless of their level of ability, high, moderate and low achievers who learnt the Function topic with the help of the GeoGebra software have indeed higher conceptual knowledge than students taught using the conventional method. Overall, it can be concluded that students who used the GeoGebra software would have higher conceptual knowledge than those who did not. The finding is statistically shown in **Table 3**.

Overall, there is a significant difference in students' conceptual knowledge of the

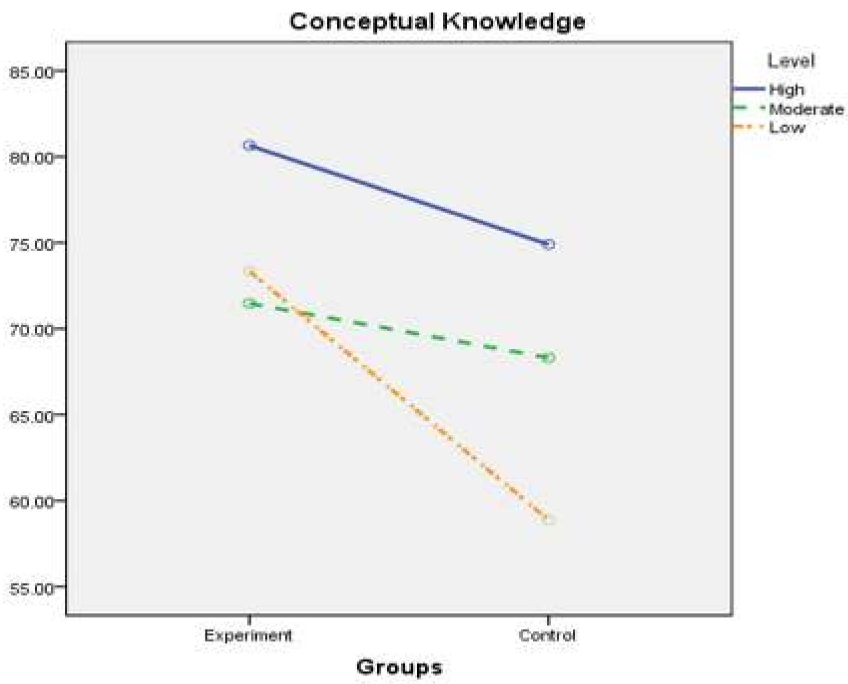

Figure 3. Interaction among groups, students' ability and their Mathematics conceptual knowledge

Table 4. Post Hoc Scheffe test results on the difference of conceptual knowledge based on students' ability

(I) ability	(J) ability	Mean Difference (I-J)	Std. Error	Sig.
High	Moderate	7.75*	1.50	0.000
	Low	11.52*	1.70	0.000
Moderate	High	-7.75*	1.50	0.000
	Low	3.76	1.54	0.052
Low	High	-11.52*	1.70	0.000
	Moderate	-3.76	1.54	0.052

function topic after both teaching methods were carried out with the *F* value = 36.181 and sig = 0.000 ($p< 0.05$). In the aspect of students' ability, there is a significant difference in students' conceptual knowledge based on ability, with the *F* value = 24.993 and sig = 0.000 ($p>0.05$). Results of the two-way ANOVA analysis show a significant interaction between students of different ability with their procedural knowledge on the Function topic in Mathematics with the *F* value = 6.869 and sig = 0.001 ($p<0.05$). The patterns of interaction between students of different ability and their conceptual knowledge are shown in **Figure 3**.

Figure 3 shows that low-achieving students who learnt Mathematics using the GeoGebra software have higher conceptual knowledge than moderate students but the difference is not statistically significant. In addition, **Figure 3** shows that students who used the Geogebra software have higher conceptual knowledge than students who were taught conventionally. The Post Hoc Scheffe test was also conducted to identify the difference in students' conceptual knowledge. The analysis was done to investigate the difference in conceptual knowledge among students of different ability; the high achievers, moderate achievers and low achievers. Results of the Post Hoc Scheffe test are shown in **Table 4**.

Table 4 shows that a significant difference in the level of conceptual knowledge on the Function topic, between high achievers and moderate students, with the mean difference of = 7.75 and sig = 0.000 ($p<0.05$). The mean score shows that high-achieving students have

Table 5. Mean and standard deviation of students' procedural knowledge of the Function topic

Knowledge	Groups	Ability	N	Mean	Std. Deviation
Procedural	Experiment	High	46	78.91	13.12
		Moderate	78	76.15	12.11
		Low	45	68.22	14.93
		Total	169	74.79	13.74
	Control	High	51	76.08	8.79
		Moderate	80	69.75	13.68
		Low	45	67.89	9.62
		Total	176	71.11	11.86
	Total	High	97	77.42	11.09
		Moderate	158	72.91	13.29
		Low	90	68.06	12.49
		Total	345	72.91	12.93

higher conceptual knowledge than moderate students. In addition, there is also a significant difference in conceptual knowledge of the mathematics Function topic among high-achieving students and the low achievers with mean difference of 11.52 and sig = 0.000 (p <0.05). High-achieving students have higher conceptual knowledge than the low achievers. Results of the study also show that there is no significant difference in conceptual knowledge between moderate students and the low achievers, as the mean difference = 3.76 and sig = 0.052 (p>0.05). Moderate students have the same level of conceptual knowledge as the low achievers.

The difference in procedural knowledge based on groups and students' ability

Two-way ANOVA analysis was conducted to determine the difference in students' procedural knowledge on the Function topic, between students who studied the mathematics topic using the GeoGebra software and students who studied using the conventional method. Levene's test showed that the variances of the variables scattered equally with the F value = 1.606 and sig = 0.120 (p>0.05). The variances were scattered homogenously. This shows that the two-way ANOVA could be conducted to determine the difference in students' procedural knowledge on the Function topic. **Table 5** shows the mean of students' procedural knowledge after the learning methods were carried out.

Students who used the GeoGebra software showed a higher procedural knowledge compared to students who learnt using the conventional method. Results of students in the treatment group (using the GeoGebra software) showed that high-achieving students have higher procedural knowledge (mean = 78.91 and sig = 13.12) than moderate students (mean = 76.15 and sd = 12.11) and low achieving students (mean = 68.22 and sd = 14.93). Results for the control group students who were taught using the conventional method also show that high-achieving students have higher procedural knowledge (mean = 76.08 and sd = 8.79) than moderate achieving students (mean = 69.75 and sd = 13.68) and low-achieving students (mean = 67.89 and sd = 9.62). It was found that students who learnt the Function topic with the help of GeoGebra software have higher procedural knowledge than students taught using the conventional method. The difference is statistically shown in **Table 6**.

Overall, there is a significant difference in students' procedural knowledge of the function topic after both teaching methods were carried out with the F value = *5.419* and sig

Table 6. Two-way ANOVA the difference of students' procedural knowledge on the Function topic

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5912.677[a]	5	1182.535	7.771	0.000
Group	824.567	1	824.567	5.419	0.021
Ability	4155.059	2	2077.529	13.653	0.000
Group * Ability	560.682	2	280.341	1.842	0.160
Error	51584.715	339	152.167		
Total	1891625.000	345			

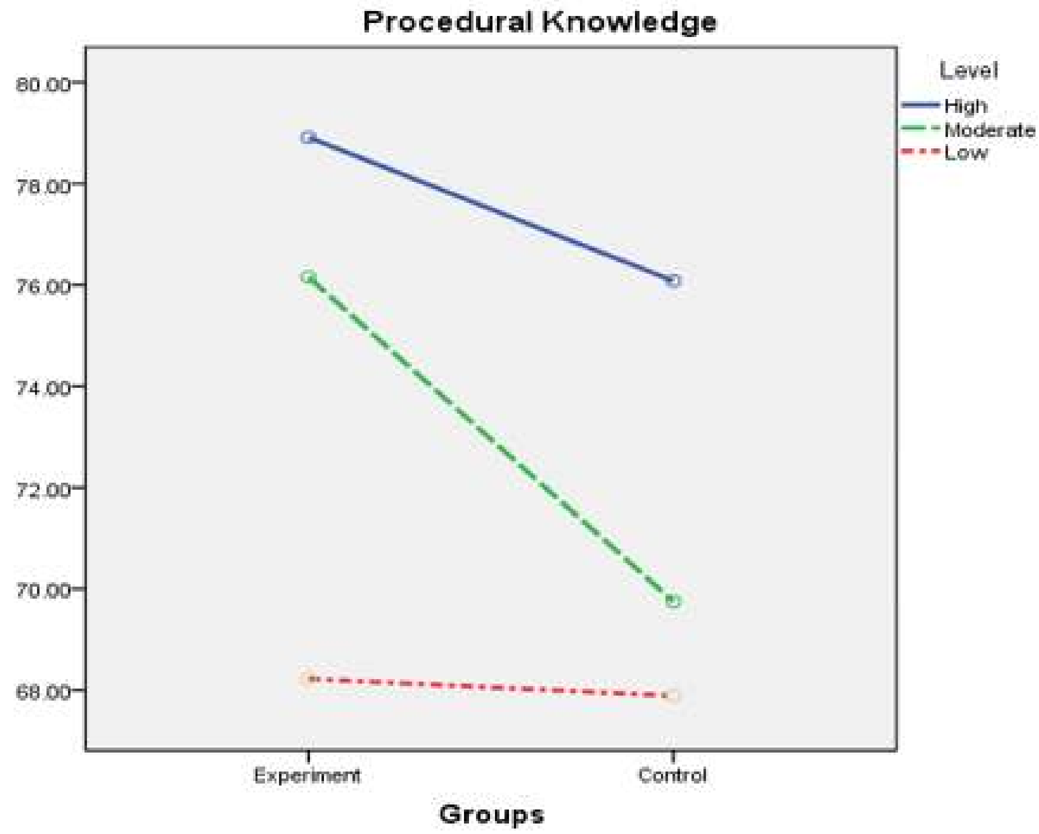

Figure 4. Interaction among groups, students' ability and their Mathematics procedural knowledge

= 0.021 ($p < .05$). In the aspect of students' ability, there is a significant difference in students' procedural knowledge based on students' ability, with the F value = 13.653 and sig = .000 ($p > .05$). Results of the two-way ANOVA analysis show no significant interaction between students of different ability with their procedural knowledge on the Function topic in Mathematics with the F value =1.842 and sig = 0.160($p > .05$). The patterns of interaction between students of different ability and their procedural knowledge are shown in **Figure 4**.

Figure 4 shows that high-achieving students who learnt Mathematics using the GeoGebra software and conventional method have higher procedural knowledge than moderate and low-achieving students. **Figure 4** also shows that students who used the Geogebra software have higher procedural knowledge than students who were taught conventionally. The Post Hoc Scheffe test was also conducted to determine the difference in students' procedural knowledge. Results of the Post Hoc Scheffe test are shown in **Table 7**.

Table 7 shows that there is a significant difference in the level of procedural knowledge on the Function topic, between high achievers and moderate students, with the mean difference of = 4.51 and sig = 0.019 (p<0.05). The mean score shows that high-achieving students have higher procedural knowledge than moderate achieving students. In addition, there is also a significant difference in procedural knowledge for the mathematics Function topic between high-achieving students and the low achievers with mean difference of = 9.37 and sig = 0.000 (p< 0.05). High-achieving students have higher procedural knowledge than the low achievers. Results of the study also show that there is a significant difference in procedural knowledge between moderate achieving students and the low achievers, as the mean difference is = 4.86 and sig = 0.012 (p>0.05). Moderate achievers have a higher level of procedural knowledge than the low achievers.

The role of procedural knowledge and its effects as the mediator between conceptual knowledge and the achievement of students who used the GeoGebra software

An analysis on relationship and contribution was done using the SEM to determine the role of procedural knowledge and its effects as the mediator in the relationship between conceptual knowledge and students' achievement. Results of the analysis show the measurement of the Chi Square/df = 2.060, *Root Mean Square Error Approximation* (*RMSEA)* = 0.079, *Goodness of Fit Index (GFI)* = 0.92, Tucker-Lewis fit index (TLI) = 0.93 and *Comparative Fit Index* (CFI) = 0.94. All types of evaluations have shown that the data used in this study were fit and compatible with the suggested model (Byrne, 2010). Results of the structural equation model (SEM) show that the suggested regression model was fit, since the conceptual knowledge (β = 0.44, p<0.05) and procedural (β = 0.63, p<0.05) are significant predictor variables on students' achievement in the Mathematics subject. Apart from that the SEM analysis show a strong relationship between students' conceptual and procedural knowledge (r = 0.88, p<0.05).

Table 7. Post Hoc Scheffe test results on the difference of procedural knowledge based on students' ability

(I) ability	(J) ability	Mean Difference (I-J)	Std. Error	Sig.
High	Moderate	4.51*	1.59	0.019
	Low	9.37*	1.80	0.000
Moderate	High	-4.51*	1.59	0.019
	Low	4.86*	1.63	0.012
Low	High	-9.37*	1.80	0.000
	Moderate	-4.86*	1.63	0.012

Table 8. Sobel's test on the effect of procedural knowledge as a mediator between conceptual knowledge and students' achievement

Mediator	z	p
Conceptual knowledge → procedural knowledge → achievement	9.78	0.000

The Sobel test analysis was conducted to identify the role of students' procedural knowledge as a significant mediator between students' conceptual knowledge and their achievement. **Table 8** shows that students' procedural knowledge is a significant partial mediator for conceptual knowledge (z = 9.78, $p < .05$) on academic achievement. Hence, there is a direct significant effect of conceptual knowledge on students' academic achievement (Ed = 0.44, p<0.05). Indirectly it can be concluded that the effect of conceptual knowledge on academic achievement is influenced by the role of students' procedural knowledge as a significant partial mediator (Ei = 0.55, p<0.05).

The role of procedural knowledge and its effects as the mediator in the relationship between conceptual knowledge and the achievement of students who use the conventional method

Results of the structural equation model SEM analysis show the measurement of the Chi Square/ df = 1.801, *Root Mean Square Error Approximation* (*RMSEA)* = 0.079, *Goodness of Fit Index (GFI)* = 0.93, Tucker-Lewis fit index (TLI) = 0.92 and *Comparative Fit Index* (CFI) = 0.94. All types of measurements have shown that the data used in this study were fit and compatible with the suggested model (Byrne, 2010). Results of the structural equation model (SEM) show that the suggested regression model was fit to be used, as the conceptual knowledge (β = 0.44, $p < .05$) and procedural knowledge (β = 0.68, p<0.05) are significant predictor variables for students' achievement in the Mathematics subject. In addition, the SEM analysis shows a strong relationship between students' conceptual and procedural knowledge (r = 0.71, p<0.05).

The Sobel test analysis was conducted to determine the role of students' procedural knowledge as a significant mediator between their conceptual knowledge and their achievement. **Table 9** shows that students' procedural knowledge is a significant partial mediator for procedural knowledge (z = 9.78, p <0.05) towards academic achievement. Hence, there is a direct significant effect of conceptual knowledge on students' academic achievement (Ed = 0.44, p<0.05). Indirectly, it can be concluded that the effect of conceptual knowledge on academic achievement is influenced by the role of students' procedural knowledge as a significant partial mediator (Ei = 0.48, p <0.05).

Table 9. Sobel's test on the effect of procedural knowledge as a mediator between conceptual knowledge and students' achievement

Mediator	z	p
Conceptual knowledge → procedural knowledge → achievement	6.62	0.000

DISCUSSION

Findings of this study show a significant difference in procedural and conceptual knowledge of mathematics Function topic between students who used the GeoGebra software and those taught using the conventional method. This has proven that teaching and learning process using the GeoGebra software would significantly enhance and strengthen students' conceptual knowledge on the Function topic in Mathematics. This is because the GeoGebra software helps students to see the concepts of the Function topic and to directly relate the concepts with their daily life. Thus, it will be easier for students to apply the concepts in other fields. Findings of this study are in favor of the statement by Antohe (2009) that the GeoGebra software helps students to clearly see the abstract concept, hence this helps students to relate the concept with other mathematical knowledge.

Conceptual knowledge is really important in the Mathematics learning process. Teaching and learning mathematical concepts through the GeoGebra software help students to prioritise mathematical concepts which are interconnected with students' learning in the classroom and outside it. Teachers should be aware that knowledge is not easily transmitted or transferred from one person to others. In fact, knowledge is developed by the students themselves through their interaction process with the learning environment (Azizi & Elanggovan, 2010). Thus, students' environment could be used as a real example and taken as a visible link to relate the mathematical ideas with daily life experience. It also provides a new meaning to the learning concept, which consequently would strengthen students' understanding on the concepts and to help them improve their own procedural knowledge.

All students regardless of their ability have shown an increase in their conceptual knowledge of the Function topic. This shows that the GeoGebra software has positive effects and it does help to enhance students' conceptual and procedural knowledge on Mathematics. High achievers, moderate achievers and low achievers who learnt the Function topic using the GeoGebra software all experienced an improvement and their knowledge is also strengthened. The software was designed for users regardless of their ability, to easily understand abstract mathematical concepts. It also assists students in applying the concepts. This confirms the opinion by Antohe (2009) that the use of GeoGebra software helps students to clearly see the abstract concepts, thus helping them to make a connection and to have a better understanding of Mathematics.

Low-achieving students experienced a slight enhancement of their procedural knowledge. This shows that the GeoGebra software cannot do wonders on low achievers' procedural knowledge even though they did use the software in learning the function topic. Conclusion can be made that this might be due to the students' interest. Low-achieving students were more interested with the abstract patterns of the software but faced difficulty in applying the abstract patterns. This is because the contents of the GeoGebra software mostly concentrate on teaching the concepts, and due to time constraint, it was difficult for low-achieving students to quickly develop their own understanding. However, this supports the findings of research conducted by Engelbrecht et al. (2005), which found that students' procedural knowledge would be reduced when they were orally introduced to a new method using numbers, algebra and visuals. This is more likely due to time constraint as they were exposed to the new method only for a short period. In fact, low-achieving students are basically having difficulty solving mathematics problems. However, the GeoGebra module is time effective and it helps students to solve mathematical problems faster, and this would advantage good and moderate students, as they could acquire the concept faster than poor students.

Time constraint is another reason why it is difficult for students to learn mathematical procedures. According to Harper (2007), the use of technology reduces students' procedural ability. This is because the GeoGebra software focusses on assisting students to master mathematical concepts. Hence, it is the opposite of traditional teaching which focusses on solving procedure problems. This causes low achievers in the traditional group to have longer time to master procedures in the Functions topic.

The use of GeoGebra software benefits students, as it provides clear information through the use of attractive pictures, images and graphics, which are actually good for students' conceptual knowledge. According to Rincon (2009), the GeoGebra software aids students to clearly see the abstract concepts and then to relate the concepts with Mathematics. Hence, good conceptual knowledge helps students to solve procedural problems. The use of GeoGebra software in teaching and learning helps students to explore the learning topics and to relate the topics with a more complex environment. Apart from that, it enables students to solve mathematics problems easily and they are able to explain the questions. According to Bu, Mumba, and Alghazo (2011), the use of GeoGebra software in the teaching and learning process provides the opportunity for students to personally involve in mathematics modeling, exploration of problems and exposure to open-ended questions. Thus, students can diagnose their own process of solving the mathematic problems.

Besides enhancing students' conceptual and procedural knowledge of mathematics, the software also provides the chance for students and teacher to interact with each other accordingly. The software enables teachers to widen their teaching scope by exploring various approaches to content delivery. Consequently, this improves the teaching and learning environment. On the other hand, students are becoming more active and responsible for their own learning process as they are personally involved in the GeoGebra module which allows a self-learning process. According to Bu et al. (2011), the GeoGebra software improves the learning environment through its presentation of entities, calculation utilities, documentation tools and user-friendly web characteristics. Those characteristics expose students and teachers to a broader teaching and learning scope inside and outside the classroom. An effective learning should be able to enhance students' conceptual and procedural knowledge on the Function topic. The GeoGebra software increased the student-teacher interaction and made students more active in their learning process as they experience individual learning in order to master the topic.

The SEM analysis shows a significant influence of conceptual knowledge on procedural knowledge at least on the Function topic in Mathematics subject. The same result was found by Rittle-Johnson and Star (2007), who found a significant contribution of conceptual knowledge on procedural knowledge. A study by Jensen (2009), had also shown the influence of conceptual knowledge on procedural function. This depicts how having previous knowledge on mathematical concepts would greatly help students to enhance their procedural knowledge. This piece of information is a very important indicator for educators in their efforts to enhance students' conceptual and procedural knowledge particularly for the Mathematics subject. Hence, the best initial effort would be to strengthen students' foundation or basic concepts, in order to improve their ability to solve mathematic problems especially in symbol-based calculation and any solution of mathematics problem involving procedures.

A model of equation regression was developed as a residue effect of the study. It is actually due to the role of procedural knowledge as a mediator between conceptual knowledge and students' achievement. The effect is actually almost similar or equal for students who learnt the function topic using the GeoGebra software and those who learnt the topic using the conventional method. Procedural knowledge is a significant mediator between conceptual knowledge and achievement. This finding supports results of a study conducted by Eisenhart et al. (1993), who found conceptual knowledge is about knowing mathematical structures which involves linkage of ideas to explain and provide meanings to mathematical procedures. In other words, both conceptual and procedural knowledge are important aspects in knowing Mathematics; hence, to be able to know the procedures, one needs to master the concepts first.

The experiment has successfully enhanced students' conceptual and procedural knowledge on the Function topic in Mathematic subject. Results of this study support the statement from Hohenwarter et al. (2008) on how the GeoGebra software can be utilized in explaining the concepts of the Functions topic. This is because the use of GeoGebra software enables teachers to deliver mathematical concepts through animation-based activities as designed in the software, whereas the software was designed to provide procedures or detailed steps to solve mathematics problems. Graphics are also directly presented in the software. Using the GeoGebra software in the classroom offers several benefits, as it allows teachers to be more creative in their own teaching, making it more effective particularly through the two-way teaching and learning process.

In addition, students are given the opportunity to use their own ideas and to present their own works. This is somehow very different than the conventional learning where students are passively waiting for the teacher to deliver information as they do not have the chance to present their own ideas. Learning Mathematics with GeoGebra software provides possible active interaction between teachers and students, which is very rare in conventional learning. Thus, it is essential for the school administrators to organise a course of training for detailed explanation on the benefits and to train teachers on using the software. A proper explanation would greatly help teachers in their efforts to enhance students' conceptual and procedural knowledge in mathematics. In addition, school administrators should actively take action in eliminating teachers' negative attitude towards technology use in teaching and learning.

CLOSING

This study has successfully improved and enhanced students' conceptual and procedural knowledge. The main advantage of using GeoGebra software is that it provides easy ways to increase the procedural and conceptual knowledge of Form Two students on the Function topic in Mathematic. The secondary school students who learnt the Function topic from the GeoGebra software have higher conceptual and procedural knowledge than students who learnt the topic using conventional methods. Procedural knowledge is very important for students especially in learning mathematics. Procedural knowledge was found as a significant mediator between conceptual knowledge and students' achievement. It is important for students to be able to tap their conceptual knowledge in order to give meaningful association of mathematical symbols with the other entities. The ability to connect conceptual knowledge with sequences, algorithm or procedures would reduce the large process or procedures to be learnt in mathematics and at the same time it allows students to choose the best procedures to be memorised and re-used effectively when needed.

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