DEVELOPING STUDENTS' CRITICAL THINKING, MATHEMATICS ACHIEVEMENT, AND INTEREST TOWARDS MATHEMATICS THROUGH THE INTEGRATION OF CLASSWIZ SCIENTIFIC CALCULATOR INTO MATHEMATICS LEARNING

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CHAPTER 1. INTRODUCTION

1.1. Background

A number of studies reported that modern society or also often called as the 21st century requires more than content knowledge (Ananiadou & Claro, 2009; OECD, 2013c; Partnership for 21st Century Skills, 2002) and reduces the need for performing routine tasks and procedural works (Autor, Levy, & Murnane, 2003; Levy & Murnane, 2004). Instead, the modern era demands more non-routine tasks involving critical thinking, complex communication, and collaborative works. In order to cope with the demands of 21st century, the Partnership for 21st Century Skills (2002) points out the importance of the ability to think critically, to apply knowledge to new situations, to analyze information, to comprehend new ideas, to make decisions, and to communicate and collaborate. Equivalently, the National Research Council (2011) also highlights that the skills required for the 21st century include the ability to solve complex problems, to think critically, to communicate effectively, to work in collaboration, to adapt to changing conditions, and to acquire information. These skills are often called as 'the 21st century skills' and simplified into four Cs: creativity and innovation, critical thinking, communication, and collaboration. According to the Partnership for 21st Century Skills, these skills can be developed through core subject matter, such as mathematics, science, and language. Among these four skills, critical thinking is directly relevant to mathematics.

A clear link between mathematics and critical thinking can be seen in the Programme for International Student Assessment (PISA). PISA is an international assessment program that assesses 15 years old students' mathematical literacy. This literacy involves a wide array of competencies including critical, reasoning, problem solving, and generalizing (OECD, 2003, 2009, 2013a). Critical thinking is also considered in the Trends in International Mathematics and Science Studies (TIMSS) test. One of the cognitive domains assessed in TIMSS test is *reasoning* that involves the capacity for logical, critical, and systematic thinking, such as making conjectures, making logical deductions, and justifying results (Garden et al., 2006). Indonesia's regular participation in PISA and TIMSS indicates that the Indonesian government also pays attention to higher order thinking skills including critical thinking. Nevertheless, the results of PISA and TIMSS show unsatisfactory critical thinking of Indonesian students from elementary school level (Mullis, Martin, Foy, & Hooper, 2016) to junior and senior high school level (Mullis,

Martin, Foy, & Arora, 2012; OECD, 2013b, 2016). This situation indicates an urgent need to develop students' critical thinking.

According to Brewer and Stasz (1996), what students learn in the classroom is influenced by three overlapping dimensions, i.e. curriculum content, instructional strategies, and instructional resources. In agreement with Brewer and Stasz, several studies (Grouws & Cebulla, 2000; Hiebert & Grouws, 2009) also revealed that teachers' teaching practices have a large impact on students' mathematics performance. These studies showed that the strategies used by teachers to teach mathematics, the types of mathematics tasks they gave to students, and the nature of classroom discussions are important factors influencing students' opportunity to learn mathematics. This fact indicates that developing students' critical thinking and mathematics achievement can be done through innovation in teaching strategies. In this respect, we can consider the integration of technology into mathematics learning. One of technologies that can be used for mathematics learning is calculator. In comparison to computer, calculator has several benefits such as its portability and inexpensiveness so that more students could afford it (Demana & Waits, 1992). Although in general the features and programs calculator is underperformed those of computer, but it is not a big trouble for mathematics learning in high schools because the main features of a scientific calculator is already sufficient. A number of researchers have conducted research on the use of calculator in mathematics learning. Kastberg and Leatham (2005) found that students' achievement is positively affected by the use of curricula that integrate graphing calculators. These students had an improvement not only in their calculator expertise, but also in their mathematical understanding. The findings of Kastberg and Leatham confirmed a meta-analysis study conducted by Ellington (2003). In her study, Ellington performed a meta-analysis of the effects of calculators on students' mathematics achievement and attitude. She analyzed 54 research studies and found that the use of calculators for both classroom instruction and assessment improved students' operational skills and problem solving skills. Furthermore, students who used calculators for learning mathematics showed better attitudes towards mathematics than students who did not use calculators.

Considering the abovementioned studies, the present study is aimed to investigate the effect of the integration of Classwiz scientific calculator into mathematics learning on students' critical thinking skills. In addition to critical thinking skills, the present study also considers students' mathematics achievement and interest towards mathematics. Students' mathematics achievement is considered in the present study because this aspect is the main goal of mathematics learning. The inclusion of interest towards mathematics in the present study is due

to its potential influence on students' achievement. As reported by Singh, Granville, and Dika (2002), interest and motivation have positive effects on students' mathematics and science achievement.

1.2. Statement of the Problem

Classroom teaching practice is an important factor influencing students' achievement, including in mathematics (Brewer & Stasz, 1996; Grouws & Cebulla, 2000; Hiebert & Grouws, 2007; Wijaya, van den Heuvel-Panhuizen, & Doorman, 2015). Classroom teaching practices do not only include instructional strategies, but also instructional media and textbooks. Considering the potential benefits of calculators (Ellington, 2003; Kastberg & Leatham, 2005), it is important to integrate the use of calculators for mathematics learning. According to Kissane and Kemp (2012), scientific calculators are programmable so that they could provide students with ample opportunity to explore various aspects of mathematics in new ways. Such exploratory characteristic indicates that calculators can be used to develop higher order thinking skills such as critical thinking skill because this skill corresponds to investigation and generalization. Despite these potential benefits of calculators, a TIMSS study (Mullis, Martin, & Foy, 2009) reported that the use of calculators for exploring concepts is still low. Furthermore, TIMSS studies only focus on grade four ad grade eight which means attention to the use of calculators in senior high school is still lacking.

The abovementioned situation could raise questions concerning the effects of scientific calculators on the critical thinking skills and mathematics achievement of senior high school students. The dichotomy of general senior high school (SMA) and vocational high school (SMK) in Indonesia leads into a more specific investigation into the effects of scientific calculators in each school type. Another interesting investigation is whether the students' interest towards mathematics improves after they use scientific calculators to learn mathematics. Lastly, investigating the relationships among critical thinking skills, mathematics achievement, interest towards mathematics, and the use of Classwiz scientific calculator.

1.3. Objective of the Study

The proposed research aims to investigate the effectiveness of the Classwiz scientific calculator on the improvement of students' critical thinking skills, mathematics achievement, and interest towards mathematics. In particular, this research project seeks to:

a. develop or modify instructional resources that integrates Classwiz scientific calculator

b. develop classroom activities that utilize Classwiz scientific calculator;
c. investigate the effectiveness of the integration of Claswiz scientific calculator into mathematics learning from the perspectives of students' critical thinking skills, mathematics achievement, and interest towards mathematics;
d. investigate the effectiveness of the integration of Claswiz scientific calculator into mathematics learning from the perspectives of students' critical thinking skills, mathematics achievement, and interest towards mathematics by school type (SMA or SMK) and gender.
e. investigate the relationships among critical thinking skills, mathematics achievement, interest towards mathematics, and the use of Classwiz scientific calculator.

1.4. Research Questions

The proposed research will seek to find answers to the following questions:

a. Is there any significant effect of the use of Classwiz scientific calculator on students' critical thinking skills?
b. Is there any significant effect of the use of Classwiz scientific calculator on students' mathematics achievement?
c. Is there any significant effect of the use of Classwiz scientific calculator on students' interest towards mathematics?
d. Is there any significant difference in the critical thinking skills of the students who used the Classwiz scientific calculator by school type (SMA or SMK)?
e. Is there any significant difference in the critical thinking skills of the students who used the Classwiz scientific calculator by gender?
f. Is there any significant difference in the mathematics achievement of the students who used the Classwiz scientific calculator by school type (SMA or SMK)?
g. Is there any significant difference in the mathematics achievement of the students who used the Classwiz scientific calculator by gender?
h. Is there any significant difference in the interest towards mathematics of the students who used the Classwiz scientific calculator by school type (SMA or SMK)?
i. Is there any significant difference in the interest towards mathematics of the students who used the Classwiz scientific calculator by gender?
j. What are the relationships among critical thinking skills, mathematics achievement, interest towards mathematics, and the use of Classwiz scientific calculator?

1.5. Significance of the Study

The results of the present study shall give contribution to the improvement of mathematics education in general. In particular the results of the present study are useful for the following stakeholders:

a. At school level the results of this study could provide an alternative instructional strategy for supporting students' learning in mathematics;
b. At the level of policymakers – e.g. the Ministry of Education and Culture – the present study could provide valuable information for considering the integration scientific calculator into mathematics curriculum for senior high schools;
c. At the level of teacher training – i.e. Teacher Training Institutes (LPTK), the Center for the Development and Empowerment of Mathematics Teachers and Education Personnel (PPPPTK Matematika), and the Institution for Quality Assurance in Education (LPMP) –the results of present study can be used to improve teacher quality; for example by increasing the attention to develop teachers' technological pedagogical content knowledge (TPACK).
d. For the public in general, the results of this study provide useful evidence that could convince the public about the positive impact of integrating scientific calculator into mathematics learning.

CHAPTER 5. CONCLUSION

5.1. The effect of calculator on students' mathematics achievement, critical thinking, and interest towards mathematics

The present study is triggered by a growing concern about the use of calculator for learning mathematics. In her meta-analysis study, Ellington (2003) revealed mixed empirical research findings regarding the effect of calculators on students' performance. Ellington reported positive benefits of calculators as indicated by the improvement of students' operational skills and problem solving skills when calculators were integrated in instruction and assessment. Nevertheless, inconsistent result was found when calculators were only utilized in instructional activities and were not used in assessment. Indonesia calculator is strictly prohibited in assessment although some schools allow the use of calculators during mathematics instruction. Therefore, it is important to investigate the effect of calculators on Indonesian students' performance which in the present study. The main concerns of the present study are students' mathematics achievement, critical thinking skills, and interest towards mathematics. Moreover, this focus is narrowed down from the perspective of school type (SMA or SMK), gender, and school location (western, central, and eastern Indonesia).

The data analysis revealed a significant effect of calculator on students' mathematics achievement and critical thinking. Students who used Classwiz scientific calculator for learning mathematics gained better scores on mathematics achievement and critical thinking than their counterparts in regular classes. A possible reason for this finding is what Kutzler (2000) called as a *concentration* purpose of calculator. In this respect, calculator handled the calculation and, therefore, students could focus on the mathematics concept. This argument is in agreement with Kastberg and Leatham (2005), Ochanda and Indoshi (2011), and Chen and Lai (2015) who found that the use of calculator for learning mathematics could reduce the time to do calculation and to solve problems. A clear example of the *concentration* purpose of calculator is when constructing graphs of functions. In this activity students did not have to do a lot of calculation to obtain pairs of x and $f(x)$ values to be plotted on the Cartesian coordinate because the pairs were generated by calculator. With this strategy, students could give more attention to observe the characteristics of the graphs. Furthermore, once students already master the basic principle of constructing graphs, the students could utilize QR code feature, so they could have even more opportunity to observe the graphs. In addition to the *concentration* purpose of calculator, it

seems that the *experimentation* or *exploration* purpose of calculator (Kissane & Kemp, 2016; Kutzler, 2000) also contributes to the improvement of students' performance; in particular students' critical thinking. Some important aspects in an experimentation or exploration are pattern recognition and generalization. In the present study, students were provided with pairs of x and $f(x)$ values that were generated by Casio scientific calculator. The students were asked to determine the equation formula that fitted the given data. In this situation, students need to formulate an induction and make decision based on the given data. According to Ennis (1985), formulating induction and decision are aspects of drawing inference and, therefore, parts of critical thinking. Similar principles of exploration also occurred when students investigated the characteristics of graphs of functions. As highlighted by Karadeniz (2015), the use of calculators could support students' exploration through graphical and numerical visualization. The third purpose of calculator that might contribute to students' achievement is what Kissane and Kemp called as *affirmation*. After investigating pattern and making generalization or prediction, students were asked to check their prediction by using Classwiz scientific calculator. Such activity can be categorized as 'basis for the decision'; i.e. an indicator of critical thinking Ennis (1985).

To conclude, the finding of the present study suggests that the use calculators in the learning of mathematics could improve students' mathematics achievement and critical thinking. This finding is in line with Salani (2013) and Ochanda and Indoshi (2011) who argued that calculators can support students' concept formation and conjecture generation. According to Ochanda and Indoshi (2011), calculators help students in exploring numbers and generalizing concepts.

With regard to students' interest towards mathematics, the present study did not find any significant effect or contribution of Classwiz scientific calculator. Familiarity with the calculator might be a crucial issue in this situation. Wagner and Gabrieli (1998) revealed a relationship between familiarity and fluency with individual's conceptual recognition memory. However, a lack of familiarity and fluency might hinder students' learning and, consequently, affect students' interest. In the present study, the students were new to Classwiz scientific calculator. They only had less than one week to get familiarized with the calculator before the experiment. Even in one participating school, the students just received the calculator on the first day of experiment. Although the teacher in this school already introduced Classwiz scientific calculator through emulator, but it was not enough because the students could only watch the emulator on the projected screen. These students did not get opportunity to directly use the calculator. In such situation, it is understandable that students' lack of familiarity did not contribute to students'

interest because during the classroom activities the students still struggled with training themselves in using the calculator.

The second focus of the present study is to investigate whether the performance of SMA students and SMK students differs. The data analysis shows that SMA students have a better improvement in their critical thinking ability and interest towards mathematics than SMK students. This finding might correspond to the learning approach in SMA that pays more attention to analytical thinking, whereas in SMK a greater attention is given to practical approach such as concept application. A possible explanation for this finding is SMK students might be already familiar with various kinds of technology; therefore calculators do not really improve their interest. Unlike critical thinking and interest towards mathematics, with respect to mathematics achievement there is no difference between SMA students and SMK students. It is not yet why there is no difference between SMA and SMK. A further study is required to clarify this finding. The third concern of the present study deals with gender. It was found that boys and girls have different gain on critical thinking skills. Significant differences between boys and girls were found with respect to critical thinking skills and interest towards mathematics. The girls have better critical thinking skills and greater interest towards mathematics than the boys. Meanwhile, girls and boys performed equally in term of mathematics performances.

Lastly, we modelled the relationship of mathematical thinking, interest toward mathematics and mathematics achievement. Our model shows that mathematical thinking and interest toward mathematics contribute to the mathematics achievement.

5.2. Limitation of the study and recommendation for further steps

The present study provides several positive results regarding the use of calculators for learning mathematics. However, there are some limitations to be considered. The first limitation deals with the selection of the participating teachers. Teachers who participated in this research were assigned by the ministry of education; Directorate of High School and Directorate of Vocational High School. It can be said that the teachers initially had extrinsic motivation as it is mandated by other people, in this case the high stake holders. Extrinsic motivation is prompted and regulated by external forces (Vansteenkiste, Lens, & Deci, 2006). Having extrinsic motivation could result in positive and negative effects. In education contexts, students cheated due to the external motivation such as emphasis on performance abilities or earning good grades (Anderman, Griesinger, & Westerfield, 1997). External motivation also leads to self-handicapping such as pain, fatigue, lack or practices and efforts to become excuses to poor

performances (Midgley & Urdan, 1995). A study showed that male students decreased the self-efficacy due to extrinsic motivation (Patrick, Ryan, & Pintrich, 1999). The second limitation of this study concerns teachers' familiarity and fluency with the use of calculator. Most of the teachers participating on this research were new to Classwiz scientific calculator. They just got familiarized with the calculator through a 4-days training that was conducted about 2 months prior to the experiment. The use of calculator in teaching of mathematics should be supported by the TPACK competencies (see Mishra & Koehler, 2006). Within a short period of training, it is possible that research teachers have limited mastery of using the calculator (technological content knowledge). Having a short training for the use of calculators might also affect the way teachers delivered the lesson plans and worksheets (technological pedagogical knowledge). Most importantly, teachers must know how to use the technology in pedagogically appropriate ways. The limitation of this study do not only correspond to teacher factors. It was observed that the participating students also had challenges during the research. Some schools received Classwiz scientific calculators late due to shipping problems. Thus, students had limited time to get familiarized with the calculators. The number of calculators for each school is 40 and enough for the use of students in one classroom. Computers or similar devices can provide students with a greater possibility for experimentation if they have access to it (Godwin & Beswetherick, 2003). In this research, the students could only access the calculators during the classroom activities. In such a limited time, students could not explore the calculators at home because the schools kept the calculators at schools. Accessibility and familiarity with the calculators and its features are necessary for students. We assume that it would save the time for students and teachers to proceed the activities if students already know what to do with their calculators.

The abovementioned limitations do not hinder the use of calculators for learning mathematics. Instead these limitations open a room for improvement for further studies or actions. As mentioned earlier, most of the participating teachers mainly held external motivation to join the present study. External motivation is categorized based on locus of causality into four namely; external, somewhat external, somewhat internal, and internal (Deci & Ryan, 1985; Ryan & Deci, 2000). Thus, external motivation can shift into internal motivation. Deci and Ryan (1985) argued that the internalization occurs if individual transforms the attitude, believe, or behavior into a personal value, goal and organization. Different motivation result in different engagement occurs, and intrinsic goal framing produces deeper engagement (Vansteenkiste, Lens, & Deci, 2006). Thus, it is important to make sure that the external motivation of the research teachers has shifted or even internalized. In the other words, we need to support

teachers to progress the motives in order to produce better engagement. With respect to the use of technology, it is essential to support teachers' technological pedagogical content knowledge. Guerrero (2005; 2006) argued that pedagogically appropriate ways of using technology means its integration promotes inquiry, reasoning, contextualized learning, and sense making. As mentioned by Drijvers (2012), although technologies can support students' learning mathematics, the success depends on the design of the activities and how it is used by the teachers, and the educational contexts. We believe that the participating teachers still faced challenges to teach mathematics with calculators. Therefore, we need sufficient training to make sure that research teachers have TPACK competencies.

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