UNIVERSITY OF SOUTHAMPTON

FACULTY OF SOCIAL, HUMAN AND MATHEMATICAL SCIENCES

Southampton Education School

Investigating Indonesian Teachers' Knowledge and Use of ICT in Mathematics Teaching

by

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Thesis for the degree of Doctor of Philosophy

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ABSTRACT

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INVESTIGATING INDONESIAN TEACHERS' KNOWLEDGE AND USE OF ICT IN MATHEMATICS TEACHING

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Countries around the globe see Information and Communication Technology (ICT) as a potential tool for enhancing education. Indonesia, like many other countries, is keen to integrate this technology in the classroom. The aims of this study were to investigate Indonesian teachers' knowledge and practices in the use of ICT in secondary mathematics classrooms as well as to examine the relationship between teachers' knowledge and their classroom practices. In addition, this study sought to reveal barriers faced by teachers to using ICT in their classrooms. The study employed a mixed methods approach whereby both quantitative and qualitative approaches for the data collection were undertaken sequentially. It was conducted in one of Indonesia's provinces, Aceh province; 341 secondary mathematics teachers participated in the quantitative phase, and 10 of them participated in the qualitative phase.

The findings showed that Indonesian secondary mathematics teachers had largely inadequate knowledge of both ICT and ICT use in teaching. In total, 67% of the teachers had used ICT at least once in their teaching, and the most common use of hardware was computers/laptops while in terms of software the teachers used general software more frequently than they used mathematical software. In addition, the teachers commonly used the digital tools to do arithmetic, draw graphs, present contents of mathematics and give classroom instructions. Finally, teachers had not yet achieved a high level of ICT use as most of them still used it for an established form of classroom practices.

The findings of the study revealed a significantly positive correlation between teachers' knowledge and their classroom practices in ICT use. Moreover, the correlation between teachers' knowledge of ICT use in teaching and their classroom practices was stronger than the correlation between teachers' knowledge of ICT and their classroom practices. The qualitative findings provided deeper insights showing that the relationship between teachers' knowledge of ICT

and classroom practices appeared at the subject level and the task level while the relationship between teachers' knowledge of ICT use in teaching and classroom practices appeared at the classroom level, the subject level and the task level.

Finally, based on the findings, the study suggested that Indonesian secondary mathematics teachers need to improve knowledge of both ICT and ICT use in teaching. In addition, teachers as well as policymakers should overcome the main barriers to ICT integration, namely teachers' lack of time to prepare ICT-based lessons, teachers' lack of confidence, and the assessment of students not being in line with the integration of ICT, in order to enhance the integration of ICT in Indonesian secondary mathematics classrooms.

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Academic Thesis: Declaration of Authorship

I, Mailizar Mailizar, declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

Investigating Indonesian Teachers' Knowledge and Use of ICT in Mathematics Teaching

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission:

Signed: ....

Date: 09 March 2018

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Definitions and Abbreviations

BECTA	British Educational Communications and Technology Agency
BPS	Badan Pusat Statistik [Indonesian Central Bureau of Statistics]
CAS	Computer Algebra System
DGS	Dynamic Geometry Software
DMS	Dynamic Mathematics Software
HDI	Human Development Index
ICT	Information and Communication Technology
ICMI	International Commission on Mathematical Instruction
KOMINFO	The Ministry Communication and Information Technology
LMS	Learning Management System
MAS	Mathematics Analysis Software
MM	Mixed Methods
MoRA	Ministry of Religious Affairs
MoEC	Ministry of Education and Culture
NTCM	National Council of Teachers of Mathematics Education
OECD	Organization for Economic Co-operation and Development
PISA	Programme for International Student Assessment
PCK	Pedagogical Content Knowledge
POE	Provincial Office of Education
PTK	Pedagogical Technology Knowledge (PTK)
Pustekkom	Centre for Information and Communication Technology for Education
Regency	Administrative region under province
SITES	Second Information Technology on Education Study

TIMSS	the Trends in International Mathematics and Science Study
TPCK/TPACK	Technological Pedagogical Content Knowledge
UNESCO	United Nations Educational, Scientific, and Cultural Organization

Chapter 1 Introduction

In this chapter, the background to the research is presented in the first section. This section explores the Indonesian context of ICT integration as well as highlights research gaps identified in previous studies. In the next section, the research questions are elaborated to address the research aims and it is then followed by a presentation of the significance of the study. Finally, an overview of the whole chapters of the thesis is outlined in the last section of this chapter.

1.1 Background to the Research

Information and Communication Technology (ICT) has been introduced in many education systems around the world since the mid-1980s. Over the last decade, the integration of ICT in the classroom has received rapidly increasing attention not only in developed countries but also in developing countries. Indonesia, among those countries, has a great interest in this technology in order to enhance the students' learning experience.

As noted in a UNESCO report, the Indonesian Ministry of Education has released a policy advocating the use of ICT as an essential part of the curriculum at schools, universities, and training centres (UNESCO, 2004). To support the implementation of this policy, several programmes have been launched to provide ICT infrastructure at schools, such as *OSOL* (One School One Computer Laboratory) and *WANkota* (City-Wide Area Network of Schools) (UNESCO, 2004). Furthermore, in 2007, the Indonesian government also passed the Ministerial Regulation No. 24 on the schools' standard of infrastructures. The regulation stipulates that schools should be equipped with hardware and software associated with the access of ICT to support learning (MoEC, 2007).

Moreover, Indonesian Law *Number 14 of 2005* on *Teachers and Lecturers* states that:

> Pedagogical competence is the ability of a teacher to manage the learning process associated with learners, including the understanding of educational philosophy, the learners, curriculum development, instructional design, ICT integration, and assessment.

This law strongly stipulates that the integration of ICT is a necessary part of Indonesian teachers' pedagogical competence.

Regarding the mathematics curriculum, the current curriculum emphasises the use of ICT in teaching and learning practice. This is clearly stated in the secondary school mathematics' curriculum document.

> Untuk meningkatkan kefektifan pembelajaran, sekolah diharapkan menggunakan technology informasi dan komunikasi seperti computer, alat peraga, atau media lainya" (In order to improve the effectiveness of teaching and learning, schools should promote the use of information and communication technology such as computer, concrete material and other media (p. 397)".

Looking back at the history of mathematics curriculum reform in the country, in 1984, the government implemented a curriculum which signalled the first attempt and policy directive to integrate modern technologies into the mathematics teaching and learning in Indonesian classrooms (Mailizar, Manahel, & Fan, 2014). Although this was only a starting point in this direction, according to Ruseffendi (1988, p. 102), it was one of the important efforts to strengthen mathematics education in the country. This indicates that the integration of modern technology in teaching and learning has been a feature for quite a long time of the Indonesian mathematics curriculum.

In the last few decades, researchers around the world have conducted studies on the integration of technology in education. According to Goos (2014), a significant body of research has examined the effect of ICT use on students' mathematical achievements, attitude and understanding of mathematical concepts. In contrast, less attention has been given to teachers' technology-mediated classroom practices and the role of a teacher in technology integration (Goos, 2014). While earlier research on ICT use in mathematics teaching has mostly focused on the mathematics outcomes from students' perspectives, more recent studies have shifted focus to the process of the teachers' development of their knowledge and classroom practice (Alison Clark-Wilson, Robutti, & Siclair, 2014).

A range of studies have been conducted in many countries to investigate teachers' knowledge of ICT (e.g., Kandasamy & Shah, 2013; Kazoka & William, 2016; Marzal, 2013; Tezci, 2010). Those studies found that more than a half of the teachers were able to use general software such as Ms Word, Ms Excel and Ms Power Point. With regard to mathematics teachers, researchers (e.g., Fuglestad, 2007) have investigated mathematics teachers' knowledge of ICT and found that teachers had some basic knowledge and general software yet they lacked knowledge of mathematical software. However, Fuglestad's study did not distinguish various types of mathematical software such as Dynamic Geometry Software, Computer Algebra System and Statistical Software.

Furthermore, studies on teachers' knowledge of how to use ICT in teaching have been also conducted in many countries, such as Archambault and Crippen (2009) in the United States, Doukakis, Koilias, Adamopoulos, and Giannopoulou (2011) in Greece, and Al Harbi (2014) in Saudi Arabia, Owusu, Lindsey, and Chris (2015) in New Zealand. In mathematics education, researchers have also investigated mathematics teachers' knowledge in studies such as that by Handal, Campbell, Cavanagh, Petocz, and Kelly (2013) in Australia and Agyei and Voogt (2011) in Ghana. Those studies found that mathematics teachers did not have sufficient knowledge of how to use ICT in teaching.

In relation to teachers' use of ICT in mathematics teaching, researchers have conducted studies looking at various aspects such as teaching approaches (e.g., Law, 2009; Pelgrum & Voogt, 2009) and types of software and hardware used (Becker, Ravitz, & Wong, 1999; Bretscher, 2014; Helen J Forgasz, 2002; Kitchen, Finch, & Sinclair, 2007; Loong, Doig, & Grove, 2011). In terms of teaching approaches, those studies found that teacher-centred practices were still dominant amongst teachers and that teachers continued to use the pedagogical approaches that they have long been practised.

Researchers have also investigated the relationship between teachers' knowledge and teachers' use of ICT in the classroom (e.g., Al Harbi, 2014; Buabeng-Andoh, 2012; Kafyulilo, Fisser, & Voogt, 2012; Kandasamy & Shah, 2013; Tezci, 2010). They found that there are strong positive correlations between teachers' knowledge and classroom practices in the use of ICT.

However, the previous studies have several gaps. Firstly, regarding studies on mathematics teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching, most of the studies have been conducted in developed countries. In contrast, only a few studies have investigated this issue in developing countries. To the best of my knowledge, there are a very limited number of publications reporting on this issue for developing countries, let alone Indonesia.

Secondly, most of the studies on teachers' use of ICT rely only on teachers' self-reports of their use of ICT through employing questionnaire surveys. According to Cox and Marshall (2007), it is difficult to acquire reliable evidence using such a survey technique in investigating the use of ICT. Cohen, Manion, and Morrison (2011) asserted that a self-reported study cannot be immediately verified, and teachers' self-reports of pedagogic practices cannot be assumed to correspond exactly with what they actually do in the classroom. This aligns with Hew and Brush (2006) who have suggested that research in the field of ICT integration should examine teachers in actual practices through classroom observations and not rely only on self-reported data alone.

Thirdly, the previous studies on the relationship between teachers' knowledge and their classroom practices in the use of ICT (e.g., Al Harbi, 2014; Buabeng-Andoh, 2012; Kafyulilo et al., 2012; Kandasamy & Shah, 2013; Tezci, 2010) did not make the distinction between teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching. In addition, these studies did not focus on mathematics teachers. Therefore, such studies failed to provide a clear link between mathematics teachers' knowledge and classroom practices in the use of ICT.

In terms of the Indonesian context, along with the limited numbers of publications, the previous studies on teachers' knowledge and classroom practices in the use of ICT in mathematics teaching have several gaps.

Firstly, the previous studies on mathematics teachers' use of ICT did not look at what type of software and hardware Indonesian mathematics teachers' use and how they utilise them in teaching practices (e.g., Mullis, Martin, & Foy, 2008; Mullis, Martin, Foy, & Arora, 2011; Rimilda, 2015). Moreover, Mullis et al.'s (2011) have shown that the use of ICT in Indonesian mathematics classroom was as follows: 5% to explore mathematics principles and concepts; 7% to look up idea and information; 5% to process and analysis data, and 6% to practice skills and procedures. However, this study was failed to show other pedagogical activities related to the integration of ICT in the classroom.

Secondly, the previous studies on teachers' knowledge (e.g., Marzal, 2013; Puspiratini, Sunaryo, & Suryani, 2013; Rimilda, 2015) had several gaps. For instance, Marzal's (2013) study did not investigate teachers' knowledge of using mathematical software (e.g., Dynamic Geometry and Computer Algebra System) while Rimilda's (2015) study involved five participants who were student teachers at placement schools. Consequently, those studies did not fully reveal knowledge of ICT integration amongst Indonesian secondary mathematics teachers.

Thirdly, the previous studies on teachers' knowledge and classroom practices did not look at teachers' demographic characteristics and teachers barriers to implement ICT in their classroom. Hence, when it comes to implication for practices, they were not able to address what characteristics of teachers who need extra attention in terms of professional development and what barriers need be overcomed by the teachers and Indonesian policymakers in order to enhance the integration of ICT in Indonesian secondary mathematics classrooms.

Therefore, this study seeks to investigate Indonesian secondary mathematics teachers' knowledge and classroom practices in the use of ICT. Moreover, by investigating both issues in a single study, it will allow the present study to examine the relationship between them. In addition, to provide comprehensive implication for practices, this study is also set to examine differences in teachers' knowledge and classroom pratices according to their background as well as exploring Indonesian secondary mathematics teachers' barriers to integrate the digital technology in their classroom.

1.2 Research Questions

The aims of this study were to investigate Indonesian teachers' knowledge and classroom practices in the use of ICT in secondary mathematics classrooms as well as to examine the relationship between teachers' knowledge and their classroom practices. In addition, this study sought to reveal barriers faced by teachers to using ICT in their classrooms. Therefore, the study sought to answer the following research questions:

1. What knowledge do Indonesian secondary mathematics teachers have about ICT and its use in teaching?
2. How do Indonesian secondary mathematics teachers use ICT in their teaching practices?
3. What is the relationship between teachers' knowledge and classroom practices in the use of ICT in mathematics teaching?
4. What barriers do Indonesian secondary mathematics teachers face in the use of ICT in the classroom?
5. Are there significant differences in terms of teachers' knowledge and classroom practices according to their backgrounds?

The first three questions were the main questions for this research. The first question addressed teachers' knowledge into two domains: knowledge of ICT and knowledge of ICT use in teaching. Details of both concepts are addressed in the conceptual framework chapter. The second question dealt with teachers' classroom practices focusing on types of hardware and software as well as functional and pedagogical activities used. The third question explored the relationship between teachers' knowledge and their classroom practices in the use of ICT in the mathematics classroom. In addition, this study was also designed to explore barriers faced by teachers in the implementation of ICT in the classroom and examine the differences in teachers' knowledge and classroom practice in the use of ICT according to their teachers' backgrounds (gender, level of education, teachers' certification, years of teaching experience, and type of school).

1.3 Significance of the Study

It is hoped this study has contributed to theoretical and practical aspects in the field of integration of ICT in the classroom. It contributes to the literature on ICT in mathematics education particularly in the area of teachers' knowledge and classroom practices, which have received increasing attention. Moreover, investigating teachers' knowledge and classroom practices in a single study will allow this study to examine the relationship between them. The contributions of this study to theoretical and practical aspects are as follows.

Firstly, this study examined the relationship between teachers' knowledge and their classroom practices in the use of ICT. This provides an understanding of what knowledge mathematics teachers need for the integration of ICT in the classroom. Moreover, as discussed in the conceptual framework chapter, this study adapted the TPACK model (Mishra & Koehler, 2006) to explore teachers' knowledge of ICT use in teaching and the Pedagogical Map of Mathematics Analysis Software (Pierce & Stacey, 2010) to describe teachers' classroom practices in the use of ICT. The present study, therefore, is important since it contributes to knowledge, particularly in examining the link between teachers' knowledge and classroom practices in the use of ICT in secondary mathematics classrooms.

Secondly, the previous studies on mathematics teachers' knowledge and classroom practices in the use of ICT were mostly carried out in developed countries with high access to ICT resources. Therefore, the findings of this study added to the literature, particularly in terms of this issue in developing countries.

Thirdly, one of the aims of the present study was to reveal Indonesian teachers' knowledge of ICT and knowledge of ICT use in teaching as well as to disclose ways in which ICT is integrated into Indonesian secondary mathematics classrooms. In the Indonesian context, findings for this study are becoming more important since the integration of ICT in the classroom is one of the focuses of Indonesian educational reform. This study provides information that can be used to enhance teacher reform required by the Indonesian Law Number 14 of 2005. Therefore, this study has potential value for the Ministry of Education and Culture and Ministry of Religious affairs in enhancing teacher reform, particularly in terms of the integration of ICT.

Fourthly, it is widely believed that research on teachers' knowledge has strategic value for planning professional development programmes (see Fan, 2014; Polly, McGee, & Martin, 2010). Thus, this study provides an insight into the need for Indonesian mathematics teachers' professional development in the use of ICT. In addition, according to Handal, Cavanagh, Wood and Petocz (2011), investigation of teachers' practice in the use of ICT helps to ensure that students are fully exposed to a curriculum. Hence, it is hoped that this research will provide valuable information on the extent to which Indonesian secondary school students are exposed to the current mathematics curriculum that emphasises on the use of ICT in the teaching and learning process.

Finally, the present study provides a solid basis for further research in the field of ICT in mathematics education in Indonesian. In addition, the results of the present study would be important in supporting the future development of ICT integration in Indonesian secondary mathematics classrooms.

1.4 Outline of the Thesis

This thesis consists of nine chapters. It starts with an introduction in Chapter 1, providing the background of the research, research aim and questions, and significance of the research. In order to put this study into the Indonesian context, Indonesia and its education system are presented in Chapter 2; the chapter highlights the Indonesian education system, teacher reform and ICT policy. Chapter 3 presents learning theories, and theoretical models to understand teachers' knowledge and classroom practices in the use of ICT. This chapter also presents previous studies on mathematics teachers' knowledge and classroom practices as well as barriers to the use of ICT in the classroom.

Chapter 4 develops a conceptual framework for this study. It clarifies the main terminologies used in this study such as ICT, teachers' knowledge, classroom practices and barriers. Furthermore, the methodology used in this study is explored in Chapter 5. It uses mixed methods, involving quantitative and qualitative methods. This chapter also explains the research design, population and sample, research instruments, pilot test, reliability and validity, data collection and data analysis. It ends with a description of the limitations of the research design.

Chapter 6 presents the quantitative results while the qualitative findings are reported in Chapter 7. In Chapter 8, the results are then interpreted and discussed in terms of the related literature. Finally, this thesis ends with Chapter 9 which includes a summary of the findings, the significance of the study, implication for practices, limitations of the study and suggestions for future work.

1.5 Summary

This chapter has introduced the overview of the present study. It has presented gaps in the previous studies as well as research questions to be investigated. The chapter has also discussed the significance of the study in terms of both practical and theoretical aspects. Finally, this chapter has also highlighted the outline of this thesis.

In the following chapter, the literature review elaborates the research context for this study. It includes an Indonesian education system, programme of teacher reform, Indonesian mathematics curriculum and ICT in Indonesian education.

Chapter 2 Research Context

The main aim of this chapter is to put this study in the Indonesian context. The first section of this chapter briefly introduces Indonesia's geographical location and its population. Furthermore, Indonesia's education system and its policy on teacher reform are presented in Section 2 and Section 3 respectively. This chapter also explores the Indonesian mathematics curriculum in order to put this study in the context of Indonesian mathematics education. Finally, it presents the policy on the use of ICT in Indonesian education. This chapter begins by presenting Indonesia's geographical location and its population in the following section.

2.1 Indonesia Geographical Location and Population

Indonesia is an archipelago country and has over 13,000 islands stretching more than 5,000 kilometres west to east across seas. According to the Indonesian Central Bureau of Statistics (BPS), in 2016, the population of Indonesia was about 258,000,000. It has a big diversity regarding the culture, religion, ethnicity and language of the Indonesian people. The country's geographical characteristics, consisting of thousands of widely dispersed islands, have promoted the different cultures across the regions as well as the different languages; there are 350 indigenous languages.

Figure 2-1: Map of Indonesia
Sources: SeaCitymaps.com

Administratively, Indonesia consists of 34 provinces, which are subdivided into regencies and cities. The diversity in Indonesia affects the country's development. For instance, some regions such as Java and Bali are more developed than other regions like Sumatra and Papua. As a result, Thomas (1991) argued that, to some extent, the diversity has influenced the quality of Indonesian education.

One of Indonesia's provinces is Aceh Province where this study was conducted. This province has greater legislative privileges and a higher degree of autonomy from central government than other provinces. The province is located at the northern part of Sumatra Island. According to BPS (2015), Aceh Province consists of 18 regencies and five cities. In 2014, the population of this province was 4.7 million and 10 indigenous ethnic groups occupy it. The province was the closest point of land to the epicentre of the 2004 earthquake and tsunami. Approximately 170,000 Acehnese were killed or went missing in the disaster (Folger, 2014).

Figure 2-2: Map of Aceh Province
Source: mapworld.com

2.2 Indonesian Education System

In terms of student population, Indonesia has the fourth largest education system in the world (Suryadarma & Jones, 2013). Even though the country employs a decentralised education system, the central government still plays a major role in administering most educational policies such as curriculum and national exams.

For instance, the Indonesian government administers a national curriculum imposed on all schools with the exception of international schools.

Table 2-1: Indonesian education system

Age	Grade	Education Level	Academic		Professional			
			MoRA	MoRT&HE	MoRA/ MoRT&HE			
		Higher Education	Religious Doctoral Programme(S3)	Doctoral Programme (S3)	Second Professional Programme (SP2)			
			Religious Master Programme (S2)	Master Programme (S2)	First Professional Programme			
			Religious Bachelor Programme (S1)	Bachelor Programme (S1)	Dipl4			
						Dipl3		
							Dipl2	
								Dipl1

Age	Grade	Education Level	MoRA	MoEC	MoRA	MoEC
18	12	Senior Secondary Education	Religious Senior Secondary School	General Senior Secondary School	Religious Vocational School	General Vocational School
17	11					
16	10					

Age	Grade	Education Level		MoRA	MoEC
15	9	Junior Secondary Education	Compulsory Education	Religious Junior Secondary School	General Junior Secondary School
14	8				
13	7				
12	6	Primary Education		Religious Primary School	General Primary School
11	5				
10	4				
9	3				
8	2				
7	1				
6	K2	Early Childhood Education		Religious Kindergarten	General Kindergarten

Source: adopted from Hendayana, Supriatna, and Imansyah (2011)

The education system in the country is categorised into formal and non-formal education. Table 2-1 outlines the formal education system, which is grouped into two main streams: an academic and a professional (vocational) stream. Each stream includes two types of education namely religious education and general education. Both general and religious educations provide education from the primary to the university level.

In Indonesian, compulsory education is from year 1 to year 9 for ages ranging from seven years old to 15 years old. Both the Ministry of Religious Affairs (MoRA) and the Ministry of Education and Culture (MoEC) are given authority in regard to the compulsory education. MoEC manages general primary schools and general secondary schools while MoRA administers religious primary schools and religious junior secondary schools. Early childhood education, however, is not included in compulsory education in Indonesia although both ministries also administer this level of education.

Senior secondary education, which involves year 10 to year 12, is also administered by MoEC and MoRA. At this level of education, students range in age from 16 years old to 18 years old. Moreover, at this level of education, the government starts providing vocational education. It is important to highlight, as it is shown in the blue shaded rows in Table 2-1, the present study focused on academic streams of senior secondary education administered by both ministries. MoRA secondary schools and MoEC use the same national curriculum for core school subjects such as mathematics, science and languages. However, MoRA schools have additional studies subjects. Hence, this study involved general secondary schools and religious secondary schools.

In terms of higher education, MoRA and the Ministry of Research, Technology and Higher Education (MoRT&HE) are in charge of administering education at this level. Both ministries are responsible for academic and professional (vocational) streams of education from the level of a one-year degree (Dipl1) to a doctoral degree (S3) and Second Professional Programme (SP3). MoRA universities mostly offered programmes on religious studies while MoRT&HE universities offer degrees in the other fields.

2.3 Teacher Reform in Indonesia

With close to four million teachers, Indonesia has one of the largest and the most diverse teacher's population in the world (Chang et al., 2013). Unfortunately, International studies such as TIMMSS and PISA have shown that the Indonesian students' achievements do not satisfy the level of good quality of education (Suryadarma & Jones, 2013). This was one of the indicators that had been a driving force for the government to undertake a comprehensive teacher reform in

Indonesia by passing the 2005 teacher law aimed at radically reforming national teacher development and administrations.

According to Chang et al. (2013), in relation to teachers, there were three main problems identified by the Indonesian government before the enactment of the 2005 teacher law. Firstly, teaching standards were ill-defined: the standard was neither insufficiently detailed nor clearly defined. Secondly, the system of teacher management in Indonesia was characterised by inefficiency and inequality. Lastly, teacher certification did not exist, and teacher professional development for teachers was disorganised (Chang et al., 2013).

The 2005 law covers all aspects of teacher's management and development. These ae as follows:

- The core principle declares that teaching is a 'profession'.
- Teacher requirements: all teachers must meet a minimum standard of a four-year degree.
- Teachers who have four-year degree are qualified to participate in the teachers' certification programme.
- The reform of pre-service teachers' education programmes.
- A systemic professional teacher development programme.

The 2005 teacher law, then, was elaborated in several ministry regulations; one of them is Number 16 in the regulation of Minister of Education and Culture in 2007 on standards of academic qualifications and teachers' competencies. This regulation declares that an Indonesian teacher should know how to use Information and Communication Technology (ICT) in teaching and learning.

Furthermore, as mentioned earlier, one of the main aspects of teacher reform was a teacher certification programme. The largest component of the reform, at least in terms of its funding implications, was the teachers' certification programme. The programme was intended to certify approximately 200,000 teachers each year. As teachers completed the certification process, they were eligible for a certification allowance, which doubles a teacher's take-home pay. Therefore, certification comes with serious national expenditure: if the programme is fully implemented it would cost about a quarter of the education budget (Ree & Jaitze, 2016).

Unfortunately, studies (e.g., Cerdan-Infantes et al., 2013; Ree & Jaitze, 2016) revealed that the teachers' certification programme has not led to substantial improvement in students' learning achievements. For instance, Cerdan-Infantes et al. (2013) conducted a study to determine the impacts of teachers' certification on students' learning at 240 public elementary schools and 120 junior high schools. The study involved teachers and students of science, mathematics, Indonesian Language and English. By comparing students' test scores on the subjects between those who were taught by certified with the same subjects taught by uncertified ones, the study found that there was no significant difference between the two groups or the influences of certified teachers on students' achievements.

Another study was reported by Ree and Jaitze (2016), drawing on six years of collecting micro-level data based on a partnership between the Indonesian government and the World Bank. Samples for this study were 360 Indonesian public primary and junior secondary schools, and academic development of tens of thousands of students was tracked for 2.5 years. The findings of the study showed that paying teachers more, through the certification programme, does not make them teach better.

2.4 Indonesia's Mathematics Curriculum and Students' Performance

As mentioned previously, the Indonesian government administers the national curriculum for all school subjects including mathematics. In terms of curriculum reforms, in the history of Indonesia's modern education, the curriculum had undergone many changes in 1947, 1952, 1964, 1968, 1975, 1984, 1999, 2004, 2006 and most recently in 2013. In 2014, the government postponed the 2013 curriculum and instructed the schools to return to the 2006-curriculum. However, in 2015, the 2013-curriculum was reintroduced and administered in Indonesian secondary and primary schools (MoEC, 2015).

As for Indonesia national mathematics curriculum, Soejadi (1992, as cited in Suryanton et al., 2010) classified this long reform in term of the following eras: before 1975; era of modern mathematics; back to 'traditional mathematics'; and integrated era. Other researchers, Mailizar et al. (2014), classified these reforms into the following eras: pre-modern mathematics curriculum; modern mathematics curriculum; technology integrated curriculum; back to basics curriculum; and content reduced curriculum. The history of the curriculum reform indicates that modern technology has been introduced for a relatively long time in Indonesian mathematics curriculum.

Even though the Indonesian mathematics curriculum has undergone many changes, international studies such as TIMSS and PISA have shown that Indonesian students' performances in mathematics are poor. For instance, in the 2012 Programme for International Student Assessment (PISA), the average score of Indonesian students in mathematics was below the international average placing the country at 64^{th} out of 65 economies/countries. Details of the nation's students' performance in mathematics in PISA and TIMSS assessments are presented in Table 2-2 and Table 2-3.

Table 2-2: Indonesia's ranking in the PISA study (mathematics)

	2000	2003	2006	2009	2012
Indonesia	39^{th}	38^{th}	50^{th}	68^{th}	64^{th}
Number of Participating Countries/Economies	41	40	57	74	65

Table 2-3: Indonesia's ranking in the TIMSS study (mathematics)

	1999		2003		2007		2011	
	4^{th}	8^{th}	4^{th}	8^{th}	4^{th}	8^{th}	4^{th}	8^{th}
Indonesia		35^{th}						38^{th}
Number of Participating Countries/Economies		38	25	46	36	49	52	45

Compared to other Southeast Asian countries, Indonesia's students' performance was significantly below those from Thailand, Malaysia and Singapore.

Although debates on ICT use in education still exist, it is widely believed that integration of ICT in teaching and learning will help to reduce the gap in Indonesian students' performance. Previous studies (Jufri, 2015; Jupri, Drijvers, & van den Heuvel-Panhuizen, 2015; Widjaya & Heck, 2003; Zulkardi, 2002) revealed positive experiences from using ICT for teaching mathematics in Indonesia. For instance, Jufri (2015) argues that even though ICT is not a panacea for the problems, the integration of ICT is expected to enhance the quality of teaching and learning of mathematics, and in particular, to improve students' achievements.

Mathematics Curriculum in Secondary School

As discussed previously, Indonesian secondary education level consists of junior secondary schools and senior secondary schools. The junior secondary level ranges from year 7 to year 9 while the senior secondary level is from year 10 to year 12. This study involves only senior secondary education which includes three programmes of study: language, social science, and mathematics and science. The mathematics curriculum is imposed on all specialisations. However, the mathematics and science specialisation has selective-advanced topics in mathematics that are not offered to students of the other programmes.

In this research, I do not make any distinction between three programmes. According to the curriculum, mathematics topics offered in senior secondary mathematics for these programmes are Geometry, Algebra, Probability and Statistics, Calculus and Trigonometry.

It is important to highlight that according to Sugandi and Delice (2014), since 2007 Indonesian mathematics curriculum has transformed its paradigm from behaviourism to constructivism. This indicated by the use of competency-based curriculum aiming at achieving the competencies which are defined form learning outcomes. However, according to Leung and Ragatz (2010), Indonesia had relatively more mathematics lessons that included goal statement and lesson summaries. Moreover, the teaching strategy most commonly used was teachers explaining whiles students listen and answer closed questions, which made up 52% of all teaching practices. Problem-solving was the second most used technique that made up 20%, followed by discussion, practical work and investigation at 15%, 10% and 3% respectively (Leung & Ragatz, 2010). This finding indicates that constructivism paradigm was not fully enacted in Indonesia' mathematics classroom as it was expected in the curriculum.

2.5 ICT in Indonesian Education

2.5.1 ICT Policy and Infrastructure for Education

The Indonesian government has launched a policy that suggests integrating of ICT in all school subjects, including mathematics (MoEC, 2007). The government has also made various efforts to support the use of ICT in education. For instance, the Centre for Information and Communication Technology for Education (*Pustekkom*) cooperating with the Directorate of Vocational Education and the Directorate of Secondary Education has developed an e-learning programme called '*e-dukasi*'. The objective of this programme is to improve the quality of education at high school and vocational school levels through the use of online resources. This institution also gets support from the Indonesian Telephone Company (*PT Telkom*), Network of School Information and the Office of the Research and Application of Technologies to develop ICT-based learning materials for school subjects including chemistry, biology, mathematics, physics, electronics and information technology. These teaching and learning resources are on an official website called '*Rumah Belajar'*.

In relation to the availability of hardware, as noted earlier, to support the implementation of this policy, the government has launched some programmes to provide ICT infrastructure at schools, such as *OSOL* (One School One Computer Laboratory) and *WANkota* (City-Wide Area Network of Schools) (UNESCO, 2004). In 2007, the Indonesian government also passed a regulation stipulating that schools should be equipped with hardware and software associated with the access of information and communication technology to support learning (MoEC, 2007).

As noted earlier, this study was carried out in one of Indonesia's provinces called Aceh Province. According to the Provincial Office of Education's data (2014), 86% secondary schools in the region were equipped with computer rooms and 9% of them were installed with multimedia labs as well. Unfortunately, this data did not provide the number of schools in the province with the internet connection. However, KOMINFO (2011) conducted a study in schools across 17 cities Indonesia and revealed that 80.53% of the schools are connected to the internet. Hence, the data indicates that not all schools have the internet connection.

2.5.2 The Potential for ICT Use in Indonesian Classrooms

Although the implementation of ICT in Indonesian education is less extensive compared to neighbouring countries such as Singapore, Malaysia and Thailand. Indonesia emerges as having a promising future indicated by the increased use of the technology in the society. For instance, according to Internet World Stats/IWS(2012), Indonesia is in eighth place among the top of 20 countries with the highest number of internet users in the world, with 132 million users. Moreover, 106 million of its population have access to social media with 371 million of mobile connections (IWS, 2012).

Moreover, as mentioned earlier, the Ministry of Communication and Information Technology *KOMINFO* (2011) reported a survey on ICT use in Indonesian classrooms. By surveying 801 schools from 17 cities in Indonesia, the report revealed that 98% of the schools have access to computers and 80.53% of the schools are connected to the internet. This report shows that the government has attempted to provide the infrastructure for ICT in schools.

2.6 Summary

In conclusion, Indonesia has one of the biggest education systems in the world in terms of students and teachers' population. Unfortunately, international studies such as PISA and TIMSS have shown that Indonesian students' performances are far below the average score. This had led the policymaker to pass policies on both teacher reform and the integration of ICT in the classroom. The policymaker has also increased its attention on supplying ICT infrastructure in the schools. Moreover, in terms of the mathematics curriculum, modern technology, such as calculators has been introduced for quite a long time in Indonesia's classrooms. The integration of digital technology even receives more attention in the current curriculum. As noted earlier, the Indonesian government and researchers believe that the integration of ICT in mathematics education in the country has potential advantages to improve students' learning of mathematics.

In the next chapter, a literature review is explored by elaborating on Learning theories, advantages of ICT use in the classroom, theoretical models of teachers' knowledge and classroom practices. Moreover, previous studies on teachers' knowledge, classroom practices and barriers to the use of ICT as well as previous studies on the relationship between teachers' knowledge and their classroom practices are discussed in the chapter.

Chapter 3 Literature Review

In this chapter, learning theories and their implications for the use of ICT are presented in the first section. Advantages of using ICT in mathematics teaching are also discussed and this is followed by the presentation of theoretical models of teachers' knowledge and teachers' use of ICT. Afterwards, this chapter provides reviews of previous studies on teachers' knowledge, classroom practices and barriers to the use of ICT in the classroom. Finally, as one of the most important issues for this study, the previous studies on the relationship between teachers' knowledge and their classroom practices using ICT are also elaborated in this chapter.

3.1 Learning Theories and their Implications for ICT Use in the Classroom

The main goal of ICT use in the teaching process is to help students to improve their learning; the central idea behind this relates to how to make the learning take place effectively. Therefore, it is important to look at learning theories regarding the use of ICT in teaching. In the literature, there are various learning theories about how learning takes place. In this section, the focus is on two prominent views: *Behaviourism and Constructivism*. These theories play important roles in understanding teachers' practice in the classrooms. Moreover, I elaborate on these two theories only in this section as they are two predominant educational theories for the implementation of ICT in the secondary classroom (Ebert, 2009; Koc, 2005).

3.1.1 Behaviourism

Skinner is one of the prominent behaviourists whose views on learning comprise a number of smaller parts that are sequenced (Burton et al., 1996). He believes that learning approaches are built from small to large and from simple to complex. Additionally, Skinner believes in the importance of frequent feedback at each stage of the learning process. However, this does not mean that the learner is a passive receiver.

Furthermore, Skinner believes that students learn by three ways: by doing, by engaging in trial and error and experiencing (Burton, More, & Magliaro, 1996).

According to Burton et al. (1996), one of the teaching approaches underpinned by behaviourism is direct instruction. This approach uses behaviour tenets such as students' response, rapid feedback, and learning mastery as part of the methodology.

Behaviourism theory has an implication for ICT integration in the classroom. As addressed previously, behaviourism highlights the importance of frequent feedback at each phase of a learning process. ICT, with its opportunities, offers features to make it possible for learners to receive feedback as frequently as possible. Feedbacks help students to identify which topic they have understood or which they need to review (Burton et al., 1996).

According to Jonassen (2000), based on the behaviourist perspective, the use of digital technology reflects traditional classroom practices which indicated by learners are relatively passive, and the aim of instruction is the acquisition of facts through repeated practices. Some of the examples of the technology designed based on the perspective of the behaviourist theory are computer-assisted instruction (CAI), drill-practice computer applications and computer-based tutoring systems (Jonassen, 2000).

Technology integration from this perspective is typically used to increase students' motivation (Koc, 2005). For instance, Ertmer, Addison, Lane, Rose and Wood (1999) explored differences in teachers' use of technology and their perceptions of the value of technology in the classroom. This study revealed that the majority of elementary school teachers in the US used technology as an incentive reward. They valued the tool to motivate students to complete their tasks as well as making lessons more interesting to students.

3.1.2 Constructivism

Constructivism is led by Jean Piaget's ideas of the four childhood stages of development. In mathematics education, the constructivist theory has been prominent in research in this field and has provided a basis for reform in mathematics education. Kilpatrick (1987) described constructivism as consisting of two ideas. Firstly, knowledge is actively constructed by cognising subjects not passively received from the environment. Secondly, coming to know is an adaptive process that organises one's experimental world, it does not discover an independent, pre-existing world outside the mind of the knower. According to Lerman (1989), the first of the ideas is generally accepted by mathematics educators and seen to be useful when thinking about students' mathematics learning.

According to Jonassen, Peck and Wilson (1999), constructivist theory emphasises the importance of students' experiences and the students play a fundamental role in the learning process. Consequently, teachers' roles appear to be in directing and supporting students to construct meaning and understand situations. During the learning process, students' activities are considered important and basic for constructing knowledge. Furthermore, they proposed the characteristics of the constructivist classrooms as follows. Firstly, the learning focuses on thoughts instead of facts. Secondly, the learning process takes place in terms of the interaction between students and teachers. Thirdly, the learning focuses on the construction of knowledge instead of repetition, and it encourages and supports discussion within a complicated world involving various representations of knowledge. Finally, students' interests define learning, and learning experiences emphasise on realistic activities.

In relation to ICT integration, Haughey (2002) pointed out that the most common type of pedagogy associated with the success of ICT integration is constructivism. For example, Hernandez-Ramos (2005) conducted a survey of teachers in Silicon Valley and revealed that teachers who had more experiences of using of computers and adopted a more constructivist pedagogy integrated the technology more effectively in classrooms. Furthermore, M. Cox et al. (2003) claim that the constructive use of ICT in the classroom should enable students to connect the mathematical idea with the real world and develop significant mathematical strategies as well as enabling students to emphasise on reasoning rather than on the answer. This claim shows that at least there are two points which should be taken into account when mathematics teachers use ICT in the classroom: connecting with the real world and emphasising on giving reasons rather than answering.

According to McClintock (1992), in a constructivist-learning environment, technology is not the object of instruction yet it supports and scaffolds the learning. Moreover, Jonassen et al. (1999) provided characteristics of a constructivist manner in students' use of ICT: (a) manipulating data; (b) exploring relationships; (c) intentionally and actively processing information; (d) constructing personal and socially shared meaning; and (e) reflecting on the learning process. Technology applications which support learning in such ways are often described as cognitive tools whose critical attribute is the form of learner activity and engagement that they support and encourage (Lajoie & Derry, 1993).

3.2 Advantages of the Use of ICT in the Classroom

Researchers have both positive and negative views toward the integration of ICT in the classroom. From a negative perspective, for instance, Cuban (1986) was very sceptical about technology integration in schools. He claimed that there were no clear indications that instruction is more productive after the introduction of computers, radio, and instructional television. More than ten years later, in a satirical tone, Light (1997) asserted that the only successful example of educational technology is the school bus.

However, several studies from case studies to survey research have shown the importance of ICT. For instance, the advantages of using ICT in teaching practices enable teachers to enrich student learning (Beardon & Way, 2003); assist teachers in providing different learning experiences without adding to their work load (Beardon & Way, 2003); and enable meaningful context (Moore-Hart, 2005). Additionally, along with these advantages, some studies have also shown positive impacts of ICT on students' learning and achievements. Silvin-Kachala and Bialo (2000), for instance, reviewed 311 studies on the effectiveness of technology on student achievements. Their study found that when students were engaged in technology-rich environments there were significant gains and achievements in all subject areas. As this study focuses on the mathematics, the next section reviews the advantages of ICT use in teaching and learning of mathematics.

3.2.1 Advantages of ICT Use in the Mathematics Classroom

In mathematics education, the role of ICT to improve teaching and learning has received attention from researchers and mathematics educators. For instance, ICT has been a theme which is open for debate and receiving an increasing attention in the events organised by the International Commission on Mathematical Instruction (ICMI) (Bussi & Borba, 2010). Moreover, the organisations concerned with mathematics education, such as The National Council of Teachers of Mathematics Education (NTCM) in the United States and Canada also pays attention to this issue. This organisation asserts that "technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (NTCM, 2008).

More specifically, NCTM (2008, p.1) in its statement on ICT asserting that:

> With guidance from effective mathematics teachers, students at different levels can use these tools to support and extend mathematical reasoning and sense making, gain access to mathematical content and problem-solving contexts, and enhance computational fluency.

Furthermore, it is also widely believed that ICT has the potential to create dynamic mathematical representations and, support students' task exploration and to explore the mathematical content.

Overall, ICT has benefits in mathematics education such as: providing feedback that encourages pupils to use conjecture and to keep exploring (Clements, 2000); allow students to focus on strategies and encourage a process of trial and error (Kenneth Ruthven & Hennessy, 2002); and allowing students to use graphics, images and text together to demonstrate their understandings of mathematical concepts (Jarrett, 1998).

In terms of students' learning, studies have also shown that the use of ICT can have positive effects on students' mathematics achievement (Li & Ma, 2010); perception of mathematics (Barkatsas, Kasimatis, & Gialamas, 2009); support students in both expressing and exploring mathematical ideas (Ghosh, 2012); and improve learning of mathematics (Davidson & Elliott, 2007; Selden, 2005; Stacey, 2005).

Researchers have also revealed the advantages of the use of ICT in teaching and learning specific topics of mathematics. For instance, in teaching and learning of Algebra, researchers have reported the positive impacts of ICT use. It can promote students' development of both symbol sense and procedural skills (Bokhove & Drijvers, 2010) and be effective in improving the conceptual understanding and procedural skills of secondary school students (Bokhove & Drijvers, 2012). Moreover, technology has a potential for supporting dynamic student constructions (Mok, Johnson, Cheung, & Lee, 2000); support student's mathematical problem-solving skills and can contribute to their ability to solve informal algebra problems (Kolovou, Van den Heuvel-Panhuizen, & Koller, 2013).

Various forms of technology have gradually been implemented in mathematics classrooms such as computers, calculators, and internet. A wide range of ICT tools is available for mathematics teaching and each tool provides different capabilities and advantages. Here I present some advantages of ICT in mathematics teaching with regard to specific tools commonly used in the teaching.

It has been widely known that the calculator is one of the early-adopted digital tools in the teaching of mathematics. This digital technology is nowadays available in various types including graphing calculators. Some advantages of using this tool for mathematics teachers are that it quickens the graphing process and helps a learner to analyse and reflect on the relationships between data (Clements, 2000; Hennessy, 2000; Hennessy, Fung, & Scanlon, 2001). Furthermore, the use of this tool can decrease the burden on students; therefore, they spend more time on understanding, reasoning, and the applications of mathematics (Streun, Harskamp, & Suhre, 2000). In addition, it can stimulate both the use of realistic contexts in mathematics and exploratory learning approaches (Drijvers & Doorman, 1996). Finally, this tool can also facilitate discover and experimental learning (Drijvers & Weigand, 2010).

Another digital tool that is widely available and adopted in mathematics teaching is the Spreadsheet. According to Jones (2005b), spreadsheets have been used since the early 1980s and have been used in the mathematics classroom since they first become available. Moreover, Friedlander (1998, p. 388) argue that this digital technology builds an ideal bridge between algebra and arithmetic, constructs algebraic expressions, generalises concepts and justifying conjectures. It can also lead students to solve a problem using "trial and improvement" (Dettori, Garuti, & Lemut, 2001).

Computer Algebra System (CAS) is a prominent digital tool for mathematics teaching. Early experimental studies on the use of CAS showed that students who used CAS achieved significantly greater understanding of mathematics than those students in a traditional-oriented classroom (e.g., Heid, 1988; Palmiter, 1991). Moreover, this tool also helps students to address more difficult questions (Stacey, 2005). Furthermore, Stacey (2005, p. 12) called this as "a magic carpet" to take students on a quick tour of all the main ideas of the mathematics topic; therefore, it can be effective in the increasing of students' engagement in mathematics at secondary school levels.

Dynamic Geometry Software (DGS) is another type of mathematical software that is also prominent in mathematics classrooms. The literature has revealed that the use of DGS offers many advantages such as providing deductive reasoning (Jones, 2000) and introducing students to theoretical thinking and the practice of proof

(Mariotti, 2012). Moreover, DGS helps students to manipulate and measure shapes leading to a higher level of learning among them (Hennessy et al. 2001; Clements 2000). In addition, it helps students with their mathematical reasoning in engaging in what are termed naïve empirical, crucial experiments or generic examples (Connor, Moss, & Grover, 2007).

It is important to note that this section presents only some of the studies on the advantages of ICT use in mathematics teaching. However, this brief review shows that different ICT tools offer distinct advantages in mathematics teaching and learning.

Researchers have revealed that whether it is an advantage or a disadvantage to integration ICT in the classroom depends on teachers' ways of using ICT as a mediating tool in the classroom. This means that, while ICT offers many possibilities and advantages for teaching and learning, it also requires heavy demands on the teacher to fully manage and explore these possibilities. Thus, the teacher's role in the classroom has become even more demanding and important (Postholm, 2007).

3.2.2 Teachers as a Main Influencing Factor for ICT Use in the Classroom

A number of studies have identified factors that influence teachers' success in ICT integration. Mueller, Wood, Willoughby, Ross and Specht (2008) classified these into teacher individual and environmental factors. Environmental factors include access to technology, technical issues, time and support, whereas teachers' individual factors are teacher beliefs, attitudes, and knowledge. Research has shown that successful ICT integration requires a holistic approach that addresses both environmental and teachers' individual factors.

Zhao, Pugh, Sheldon, and Byers (2002), for instance, investigated factors needed for ICT integration in teaching. The study found that teacher individual factors (e.g., teachers' knowledge and skills) played a more important role in contributing to ICT integration. This aligns with what Bingimlas (2009) claimed, namely that one of the most influential factors in ICT integration is teachers' competence. Furthermore, Baker, Herman and Gearhart (1996) also claimed that teachers' knowledge is the main factor that influences whether and how teachers use technology. Other researchers, Zhao et al. (2002), revealed three factors related to teachers that influence ICT integration in classrooms, namely ICT proficiency, pedagogical compatibility and social awareness. The first factor refers to not just knowledge of the technology but also its enabling conditions such as knowledge of the ways of how to use it.

Kent (2008) believes that technology alone does not guarantee the lesson will be effective. In order to deliver instruction effectively with technology, teachers must be knowledgeable about how to use equipment and be knowledgeable in the content areas (Kent, 2008). M. Cox et al. (2003), in their literature review study, concluded that effective use of ICT required substantial demands of teachers' knowledge and understanding of a variety of software in order to integrate the activity.

Regarding the studies mentioned above, it is believed that teacher knowledge is a very crucial factor for the effectiveness of ICT integration. Teachers need to be knowledgeable not only in operating ICT itself but also in how to use it in teaching practices. For instance, Keong, Horani and Daniel (2005) argue that the integration of ICT into mathematics lessons requires not only teachers' knowledge of the use of the software but also teachers' sound pedagogical knowledge of how to integrate it.

3.3 Models of Teacher Knowledge

The literature presents several frameworks that have been used to develop and understand teachers' knowledge. A prominent one was initially introduced by Shulman (1986) called *Pedagogical Content Knowledge* (PCK). PCK identifies "the distinctive bodies of knowledge for teaching" (Shulman, 1986, p. 8). He defined pedagogical content knowledge as:

> "Represent blending of content and pedagogy in an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction."

By extending Shulman's framework, researchers (e.g., Angeli & Valanides, 2009; Brantley-Dias, Kinuthia, Shoffner, de-Casto, & Rigole, 2007; Chinnappan & Thomas, 2008; Mishra & Koehler, 2006; Niess, 2005; Pierson, 2001) gain insights to understand and defined teachers' knowledge of the use of digital tools. They argue that, to use technology effectively in the classroom, teachers need knowledge that build on and intersect with those that Shulman (1986) described. This additional knowledge has been conceptualised in various ways including

Technological Pedagogical Content Knowledge (TPCK) (Mishra & Koehler, 2006; Niess, 2005; Pierson, 2001), and ICT-TPCK (Angeli & Valanides, 2009). In the following sections, I present these two models to define and clarify domains of knowledge investigated in the present research.

3.3.1 Technological Pedagogical Content Knowledge (TPCK)

Pierson (2001) believes that teachers would be able to effectively use technology in the classroom when they employ pedagogical knowledge and content knowledge extensively in combination with technology knowledge. He then claims that the combination of the three knowledge areas, namely *technological, pedagogical and content knowledge*, would define effective technology integration. Following Pierson (2001), Niess (2005) refers to the term TPCK as technology-enhanced PCK. The researcher does not consider TPCK to be a new notion of teacher technology integration yet describes it as "the integration of the development of knowledge of subject matter with the development of technology and of knowledge of teaching and learning" (p. 510).

In the same year as Niess (2005), Koehler and Mishra (2005) started to use TPCK as a conceptual framework. Based on their study (Koehler & Mishra, 2005) on collaborative design of online courses by teacher educators and master students, they conceptualised the knowledge a teacher needs to effectively teach with technology. As mentioned previously, *Pedagogical Content Knowledge* (PCK) (Shulman, 1986) constitutes the conceptual basis for Mishra and Koehler's (2006) conceptualisation of *Technological Pedagogical Content Knowledge* (TPCK), which was more recently abbreviated as TPACK by Thompson and Mishra (2008).

According to Voogt, Fisser, Pareja Roblin, Tondeur, and van Braak (2013), the TPACK framework (see Figure 3-1) proposed by Mishra and Koehler (2006) has become well known compared to the other conceptualisations such as Pierson's (2001) and Niess's (2005). The core idea of the TPACK framework is the interactions between three types of knowledge: (a) technological knowledge; (b) pedagogical knowledge; and (c) content knowledge.

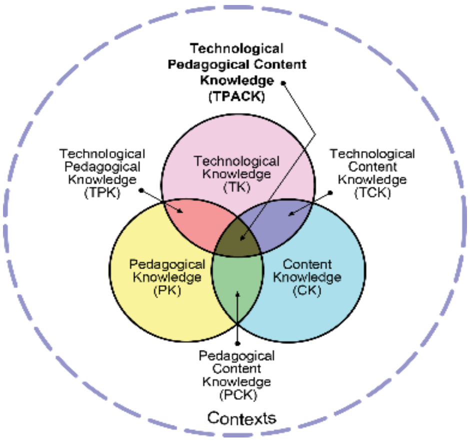

Figure 3-1: The components of the TPACK framework

Source: adopted from (Mishra & Koehler, 2006)

According to Mishra and Koehler (2006), the seven components of the TPACK are defined as presented in Table 3-1:

Table 3-1: Definition of each component of TPACK

Component of TPACK	Definition
Technology knowledge (TK)	"Knowledge about various technologies, ranging from low-tech technologies, such as pencil and paper, to digital technologies, such as the Internet, digital video and interactive whiteboards" (p. 1028)
Content knowledge (CK):	"Knowledge about the actual subject matter that teachers must know about to teach" (p.1026)
Pedagogical knowledge (PK)	"Knowledge about the methods and processes of teaching such as classroom management, assessment, lesson plan development, and student learning" (p. 1026)
Pedagogical content knowledge (PCK)	"Knowledge that deals with the teaching process (Shulman, 1986). Pedagogical content knowledge is different for various content areas, as it blends both content and pedagogy with the goal to develop better teaching practices in the content areas" (p.1027)
Technological content knowledge (TCK)	"Knowledge of how technology can create new representations for specific content" (p. 1028)
Technological pedagogical knowledge (TPK)	"Knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies" (p. 1028)
Technological pedagogical content knowledge (TPACK)	"Knowledge required by teachers for integrating technology into their teaching in any content area. Teachers, who have TPACK, act with an intuitive understanding of the complex interplay between the three basic components of knowledge (CK, PK, and TK)". (p. 1029)

Sources: Mishra and Koehler (2006)

TPACK can be seen as a form of knowledge and a framework. As a form of knowledge, TPACK has been described as situated, complex, multifaceted, integrative and/or transformative (Angeli & Valanides, 2009; Koehler & Mishra, 2008; Manfra & Hammond, 2008). Moreover, as a framework, it has been employed to unpack ICT-integrated lessons, teachers' work with ICT, design teachers' education curriculum and classroom use of ICT as well as to frame literature reviews relating to ICT or educational technology (Polly, Mims, Shepherd, & Inan, 2010). On the top of that, Archambault and Crippen (2009) assert that the TPACK framework is useful for understanding and describing the kinds of knowledge needed by a teacher for effective pedagogical practice in a technology-enhanced learning environment.

There are, however, researchers such as S. Cox and Graham (2009), Angeli and Valanides (2009), and K Ruthven (2014) who are concerned about the confusion among the TPACK constructs due to the overlapping nature of the TPACK framework. For instance, Angeli and Valanides (2009) argue that there is a lack of precision in the framework. The same issue is also raised by K Ruthven (2014) that there are some ambiguities in the notions of TPACK and the way it has been used. According to Ruthven (2014), one of the ambiguities is that it can be particularly difficult to distinguish between TK and TCK where technologies are content-specific such as dynamic geometry software.

Table 3-2: Definition of TPACK constructs

TPACK Constructs	Definition
Technology knowledge (TK)	Knowledge about how to use ICT hardware and software and associated peripherals
Content knowledge (CK)	Knowledge of the subject matter
Pedagogical knowledge (PK)	knowledge about the methods and processes of teaching such as classroom management, assessment, lesson plan development
Pedagogical content knowledge (PCK)	Knowledge of representing content knowledge and adopting pedagogical strategies to make the specific content/topic more understandable for the learners (see Shulman, 1986)
Technological content knowledge (TCK)	Knowledge about how to use technology to represent and create the content in different ways without consideration about teaching
Technological pedagogical knowledge (TPK)	Knowledge of the existence and specifications of various technologies to enable teaching approaches without reference towards subject matter
Technological pedagogical content knowledge (TPCK)	Knowledge of using various technologies to teach and/represent and/ facilitate knowledge creation of specific subject content

Sources: from Chai, Koh, and Tsai (2013, p. 33)

According to Geiger, Forgasz, Tan, Calder and Hill (2012), the increasing complexity and variety of ICT systems (hardware, software, and network/internet) make it difficult to provide a clear and stable definition of what constitutes technological pedagogical content knowledge. It has to take into account the effect of the complex ICT tools available for specific mathematics content, assessment, and curricula. Therefore, it is very crucial to have a distinct definition of ICT in this research in order to address this issue. Hence, this issue is addressed in the chapter of the conceptual framework.

In an attempt to provide a concise definition of TPACK constructs, drawing upon the literature (see S. Cox & Graham, 2009; Mishra & Koehler, 2006; Schmidt et al., 2009), Chai et al. (2013) redefine each construct as presented in Table 3-2. These definitions of TPACK components seem more concise and distinctive for the elements particularly in relation to TCK, TPK and TPCK.

3.3.2 ICT-TPCK

Angeli and Valanides (2009) alter a description of TPCK becoming ICT-TPCK through an interaction of five areas. They renamed the technology domain as Information and Communication Technologies (ICT). Furthermore, they added two knowledge domains: knowledge of student and knowledge of the context within which learning occurs. Hence, in the model (see Figure 3-2), Angeli and Valanides (2009) present five domains of knowledge that teachers need when they integrate ICT in teaching: content knowledge; pedagogical knowledge; knowledge of learners; knowledge of context; and knowledge of ICT.

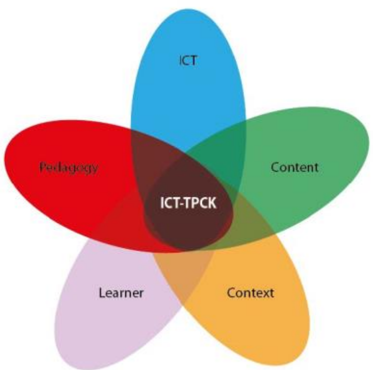

Figure 3-2: ICT-TPCK
Source: adopted from Angeli & Valanides (2009)

Angeli and Valanides (2009) describe knowledge of ICT as “knowing how to operate a computer, how to use a variety of software or tools, as well as troubleshoot in problematic situations”. Moreover Angeli and Valanides (2009, p. 159) describe ICT-TPCK as:

> "the ways knowledge about tools and their pedagogical affordances, pedagogy, content, leaners, and context are synthesised in an understanding of how particular topics that are difficult to be understood by learners, or difficult to be represented by teachers, can be transformed and taught more effectively with ICT in ways that signify the added value of the technology".

From Angeli and Valanides' (2009) ICT-TPCK, there are three important perspectives. Firstly, they argue that the use of the word "technology" is ambiguous; hence, they refine it as Information and Communication Technology (ICT). The word technology refers to a wide range of tools from standard tools such as books, chalk and blackboard to more advanced technology such as the internet and computer. In my opinion, the use of the ICT term is more appropriate in this research as it focuses on digital technology such as computers, tablets and calculators. Sometimes I use the term 'digital technology', which is referring to ICT. Secondly, from Angeli and Valanides' views, teachers need to be equipped with knowledge of ICT pedagogical affordance when they teach with ICT. Thirdly, they added two additional elements, namely, knowledge of context within which learning takes place and knowledge of student (Angeli & Valanides, 2009). In other words, in the use of ICT, teachers should understand what topics are difficult for students to learn and how ICT can help students to overcome this difficulty.

To easily understand the historical development of the models of teachers' knowledge discussed above, I outline their development in the following figure.

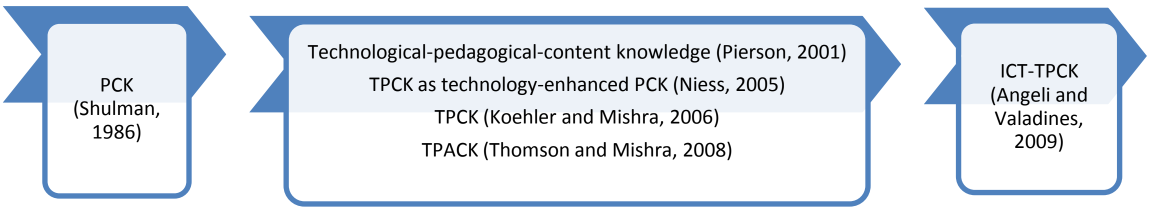

Figure 3-3: Historical development of TPCK

Finally, it is important to note that this study adopted TPACK and ICT-TPCK to investigate teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching. This adoption is further discussed in the conceptual framework chapter.

3.4 Models of Mathematics Teachers' Use of ICT in Teaching

It is widely believed that advantages from ICT integration depend on how the teacher selects and organises ICT resources and how these are integrated into the teaching and learning activities as well as what pedagogical approaches are adopted by the teacher. Mathematics teachers' use of ICT has been studied in many countries at both secondary levels and primary levels and researchers have looked at different aspects of the integration as well as employing various conceptual frameworks.

Some researchers looked at mathematics teachers' choice of hardware and software (e.g., Becker et al., 1999; Bretscher, 2014; Helen J Forgasz, 2002; Kitchen et al., 2007; Loong et al., 2011; Polly, 2014). Other researchers are interested in how teachers use the digital tools in terms of pedagogical orientation (e.g., Bretscher, 2014; Fraser & Garofalo, 2015; Hammond, Reynolds, & Ingram, 2011; Law, Pelgrum, & Plomp, 2008; Lim & Chai, 2008; Manoucherhri, 1999; Petras, 2010; Polly, 2014; Tay, Lim, Lim, & Koh, 2012). In addition, researchers have also attempted to measure the frequency of ICT use in teaching mathematics (e.g., Pelgrum & Voogt, 2009).

Researchers have used various frameworks and approaches to investigate and describe the ways of ICT are used in teaching of mathematics. The approaches are, for example, the student-centred and teacher-centred approach (e.g., Bretscher, 2014; Lim & Chai, 2008; Pelgrum & Voogt, 2009; Polly, 2014); the Learning *with* and Learning *from* framework (e.g., Tay et al., 2012); *routine*, *extended* and *innovative* user (e.g., Hammond et al., 2011).

In relation to the investigation of mathematics teachers' use of mathematical software, Pierce and Stacey (2010) propose *the pedagogical map* framework that describes pedagogical opportunities offered by Mathematics Analysis Software (MAS). In the following section, I present the pedagogical map in further details.

Pedagogical Map for Mathematics Analysis Software (MAS)

According to Pierce and Stacey (2010, p. 2), Mathematics Analysis Software (MAS) is "software with which the user can perform algorithmic processes required when working in one or more branches of mathematics". Moreover, MAS is software for computers or calculators that a user can instruct to carry out arithmetic calculations, symbolic algebra manipulations, statistics calculations, data display, function graph, plotting and construction of geometric figures (Pierce & Stacey, 2010). Furthermore, they state that the main strength and purpose of any MAS is "its functional capacity to be able to carry out routine mathematical procedures such as calculating and drawing quickly and accurately" (p. 4). Moreover, they assert that MAS provides the following functional capacity:

- Improved speed and accuracy for calculations, manipulations and construction
- Improved speed in moving between representation (e.g. functions and their graphs)
- Improved access to representations that would be very difficult or impossible in a paper-based environment

Those functional opportunities of MAS, which underpin the pedagogical opportunities, generate a foundation for school mathematics changes: curriculum changes, assessment changes, and pedagogical changes (Pierce & Stacey, 2010). In other word, MAS provides opportunities for teachers to make changes to what and how mathematics is taught.

Pierce & Stacey's (2010) pedagogical map (Figure 3-4) has been structured at three levels that reflect the opportunities offered by MAS when teachers integrate it into mathematics teaching:

- The tasks they set for their students (the bottom row)
- Their classroom interaction (the middle row)
- The subject (i.e. area of mathematics) being taught (the top row)

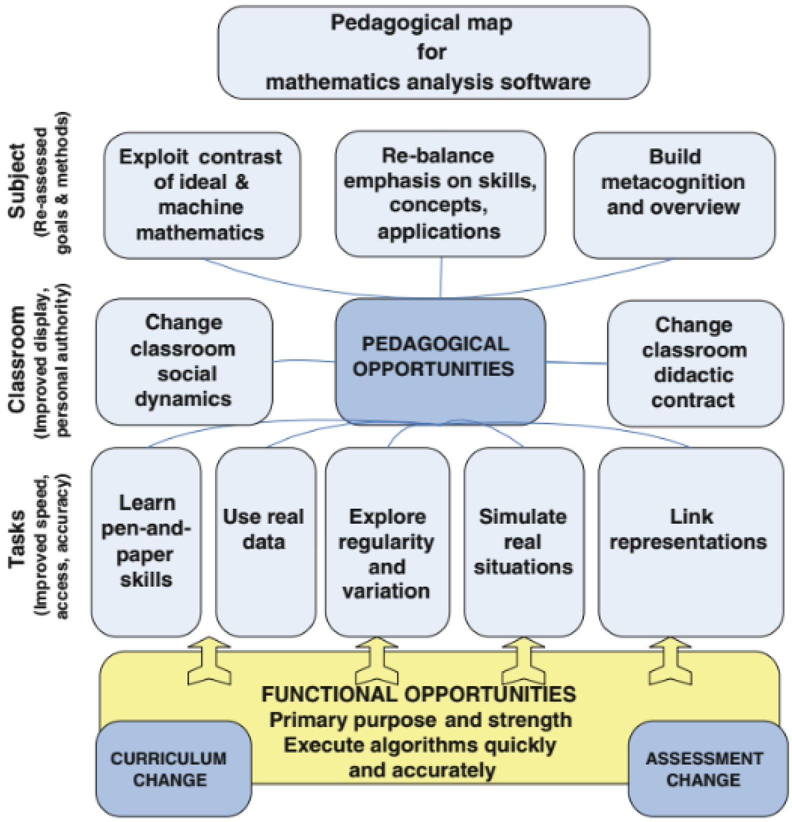

Figure 3-4: The pedagogical map for MAS

Sources: adopted from Pierce and Stacey (2010)

The bottom row of the map considers opportunities for changes in mathematics tasks. The five boxes represent five different ways in which MAS offers opportunities for improving teaching and learning tasks namely learn pen-and-paper skills, use real data, explore regularity and variation, simulate real situations, and link representations (Pierce & Stacey, 2010). The characteristics of each type of task are presented in Table 3-3.

Table 3-3: Characteristics at the task level

Type of task	Descriptors
Learn pen-and paper skills	Using instant 'answers' as feedback in learning processes
Use real data	Working on real problems involving calculations
Explore regularity and variation	Strategically varying computations searches for patterns; observing effect of parameters; Use general forms.
Stimulate real situations	Using dynamic diagrams, draging and collecting data for analysis. Using technology generated statistical data sets.
Link Representation	Moving fluidly between geometric, numeric, graphic and symbolic representations.

At the classroom level, Pierce and Stacey (2010) believe that MAS may change classroom social dynamics and classroom didactic contract. They note that the term ‘change’ means opportunities that contrast with traditional classrooms where the teacher plays the only role and most of the students work individually. These opportunities arise from opportunities in which steps in mathematical processes and the results can be displayed and shared in the classroom. Lagrange, Artigue, Laborde, and Trouche (2003), for instance, reveal that MAS supports the construction of meaning by students linking action and mathematical reflection.

Table 3-4: Characteristics at the classroom level

Classroom Level	Descriptors
Changing classroom social dynamic	Teachers facilitate rather than dictate; teachers encourage group work as well as encouraging students to initiate discussion and share their learning with the class
Changing classroom didactic contract	Teachers allow technology to become a new authority; changing what is expected of students and teachers; Permitting or constraining explosion of available methods

Moreover, as ICT in the classroom introduces a new source of learning other than teachers, students may acquire a sense of personal authority. Consequently, students and teachers may change their expectations, and students could be encouraged to play a more active role in learning (Pierce & Stacey, 2010). These changes are classified into classroom social dynamic and classroom didactic contract as well as their characteristics presented in Table 3-4.

Table 3-5: Characteristics at the subject level

Subject Level	Descriptors
Exploiting contrast of ideal and machine mathematics	Teachers deliberately use ‘unexpected’ error messages, format of expressions, graphical displays as catalysts for rich mathematical discussion
Rebalancing emphasis on skills, concepts, applications	Teachers adjust goals: spend less time on routine skills, more time on concepts and applications; teacher increase emphasis on mathematical thinking.
Building metacognition and overview	Teachers give overview as introduction or summation: link concepts through manipulation of symbolic expressions and use of multiple representations.

Finally, in relation to opportunities at the subject level, three boxes note that ICT offers opportunities to support the change of objectives or methods for mathematics teaching (Pierce & Stacey, 2010). It also provides its users with a new approach to the contents of the mathematics they are teaching. In addition, new teaching approaches can be designed to promote deeper learning. They provide the characteristics of the subject level, which are elaborated in Table 3-5.

I think Piece and Stacey's (2010) pedagogical map proposes relatively comprehensive aspects of opportunities in the use of ICT in mathematics teaching. Therefore, the present study adopted this framework to investigate teachers' classroom practices in the use of ICT in secondary mathematics classrooms. This is discussed in further details in the chapter on the conceptual framework.

3.5 Research Studies on Teachers' Knowledge of ICT and Knowledge of ICT Use in Teaching

The opportunity to integrate ICT in teaching to improve students' learning experiences and outcomes has increased in the last decade. As a result, there has been an increasing demand for teachers to develop and enhance their knowledge and skills that make effective use of it (Kim & Baker, 2008). Regarding mathematics teaching, there have been increasing requests to mathematics teachers to learn the use of ICT in teaching even over the last two decades. For instance, in the United States, National Council of Teachers of Mathematics (NTCM) stated that mathematics teachers need to know how to use ICT tools, including subject-specific educational software and general software (NTCM, 1991). Moreover, teaching with ICT requires teachers to enhance their knowledge of pedagogical practices across multiple aspects (Ertmer & Ottenbreit-Leftwich, 2010). With regard to the aims of this study, the following sections present research studies on teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching. The presentation begins with the previous studies from several countries around the world then it is followed the presentation of the previous studies on these issues in Indonesia.

3.5.1 Teachers' Knowledge of ICT

Shulman's view of Pedagogical Content Knowledge include the appropriate use of technologies when teachers need to think about the way to represent the content that is being taught to students (Shulman, 1986). Moreover, Fuglestad (2007) argues that knowledge of ICT has fast become one of the basic skills of teaching. Thus, it is crucial for teachers to have a substantial knowledge of ICT resources and understanding a range of applications (M. Cox et al., 2003). Therefore, researchers around the globe have conducted research on teachers' knowledge of ICT. Several studies on this issue around the globe are presented as follows.

Kazoka and William (2016) conducted a study in Tanzania, which was not specifically on mathematics teachers, aimed at investigating teachers' knowledge on the use of ICT. The study employed interviews, discussions and observations as instruments for data collection. The findings of this study showed that the majority (75%) of secondary school teachers were able to use Ms Word, and 60% of teachers were able to use MS Excel and only 50% of teachers were able to use MS PowerPoint.

Another study in developing countries was conducted in Malaysia by Kandasamy and Shah (2013). The aim of this study was to explore knowledge level, attitude and the use of ICT by teachers. Data collection was conducted through surveys with 50 respondents. The findings of the study revealed that the majority of the participants were knowledgeable in using applications such as MS Word, MS PowerPoint and Internet exploring. This study also confirmed that, in developed countries, teachers were more knowledgeable about the use of ICT facilities compared to less developed countries.

Tezci (2010) conducted a study in Turkey aimed at determining teachers' influence in the use of ICT at schools. One of variable examined in this study was teachers' knowledge of ICT. There were 1540 teacher participants in this study. One of the findings of this study showed that the most well-known ICT features among teachers were the Internet, e-mail and word processing.

Regarding mathematics teachers' knowledge of ICT, aiming to develop mathematics teachers' competence with ICT and to investigate how ICT tools can be utilised in mathematics teaching, Fuglestad (2007) undertook developmental research. One of the findings was that the participants had some basic knowledge of general software such as spreadsheets. However, they generally lacked knowledge of specific mathematics software such as dynamic software and graph plotters.

The previous studies around the world on teachers' knowledge of ICT showed that teachers had a reasonable knowledge of general ICT software such as Ms Word and Ms PowerPoint. However, it is widely believed that teachers' knowledge of ICT is not adequate for an effective integration of ICT in the classroom. Hence, teachers also need knowledge of how to use the tools in teaching practices. Similarly to the issue of teachers' knowledge of ICT, researchers around the globe have also looked at this issue through various lenses. In the following section, I review several studies that have used the TPACK framework to investigate this issue.

3.5.2 Teachers' Knowledge of ICT Use in Teaching

As mentioned previously, the present study adopted the TPACK framework for investigating teachers' knowledge of ICT use in teaching. Therefore, this section reviews studies looking at teachers' knowledge that employed the TPACK framework. Many studies in different countries have been used the framework for inverstigating teachers' knowledge in the use of ICT for teaching various subjects.

Archambault and Crippen (2009), for instance, carried out a study in the United States aimed at examining K-12 online teachers' knowledge, which was not specific to mathematics teachers, with respect to three key domains of the TPACK framework: technology, pedagogy, content, and a combination of these areas. Samples of this study were 596 K-12 teachers across the country. The findings of this study showed that knowledge levels are highest among the domains of pedagogy, content, and pedagogical content. However, the participants had less confident in their knowledge when it came to their knowledge of technological pedagogical knowledge.

Another study was conducted by Owusu et al. (2015) through employing online survey to assess New Zealand's high school science teachers' technological pedagogical content knowledge. The findings of the study showed that the teacher had high mean scores on all the constructs of TPACK.

Doukakis et al. (2011) conducted a study in Greece to examine computer science teachers' knowledge with respect to three key domains of the TPACK framework and a combination of these areas. Respondents in this study totalled 1127 computer science teachers who teach algorithms and programming in upper secondary education. The findings of the study revelaed that the teachers needed further training in how to integrate technology in their teaching as well as areas of TPACK.

In Saudi Arabia, Al Harbi (2014) conducted a study by employing a sequential mixed method design. In total, 251 teachers participated in the quantitative phase and 12 teachers were involved in the qualitative phase of this study. Data collection was conducted through questionnaires and interviews. The findings of this study revealed that Saudi high school teachers appeared to have low to moderate levels of TPACK knowledge.

In mathematics education, there are several studies that used the TPACK framework. However, most of studies focus on preservice mathematics teachers (Cavin, 2008; Harrington, 2008; Meng & Sam, 2013; Ozgun-Koca, Meagher, & Edwards, 2010; Suharwoto, 2006). For instance, Meng and Sam (2013) carried a study in Malaysia to develop pre-service secondary mathematics teachers' technological pedagogical content knowledge (TPACK) for teaching with Geometer's Skectpad through Lesson Study. This study employed a single-group pretest-posttest design to examine whether there was a significant difference in the teachers' TPACK after participating in Lesson Study. The findings of the study showed there was a significant difference in the teachers' TPACK for all subscale after participating in Lesson Study.

Few studies using the TPACK framework have been conducted for investigating inservice mathematics teachers' knowledge. For instance, Agyei and Voogt (2011) conducted a study to explore the possibility of ICT use in mathematics teaching at senior high school level in Ghana by employing the TPACK framework. Data were collected through interviews and surveys. The findings of this study revealed that teachers in Ghana had a lack of knowledge about the use of ICT in teaching.

Moreover, Handal et al. (2013) conducted a large-scale study to investigate secondary mathematics teachers' knowledge. The study adopted the TPACK's questionnaire items called TPCK-M. The instrument consisted of three constructs: technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPCK).The findings of this study revealed that teachers have low capacity to use ICT across the mathematics curriculum such as creating digital assessment formats. This study was claimed the first attempt at empirical studies to apply the Technological Pedagogical and Content Knowledge (TPCK) model through a questionnaire survey study of teachers' self-reported perceptions (Handal et al., 2013). It indicates that there are not many large-scale studies on mathematics teachers' knowledge of ICT use in teaching have been conducted by employing TPACK framework. Let alone Indonesia, there were a very limited number of publication have reported this issue as presented in the following section.

3.5.3 Indonesian Mathematics Teachers' Knowledge of ICT and Knowledge of ICT Use in Teaching

In the Indonesian context, a very limited number of publications reported about Indonesian mathematics teachers' knowledge of ICT and knowledge of ICT use in teaching. For instance, Marzal (2013) conducted a survey aiming to identify secondary mathematics and science teachers' knowledge of ICT and factors that influence their use of ICT in Jambi City, Indonesia. Participants of this study were randomly selected to answer two types of questionnaire: teachers' self-perceived knowledge questionnaire and teachers' perception of an e-tutorial which was developed by the researcher. By employing descriptive statistic technique, the study reveals that over 60% of participants had knowledge of using the internet, Microsoft Word, and Microsoft PowerPoint. On the other hand, less than 10% of participants were able to use specific software such as Microsoft Access, SPSS, Edmodo, Adobe Flash and Movie Maker. In my opinion, the survey in this study only captured teachers' knowledge of using or operating the general software. It does not reveal knowledge of using specific mathematics software such as Dynamic Geometry Software and knowledge of how to use it into teaching.

Another study was conducted by Puspiratini et al. (2013) in Pasuruan, a regency in Indonesia. This study aimed to identify the most significant factors in Technological Pedagogical and Content Knowledge (TPACK)'s components for mathematics, science and language teachers. Participants in this research totalled 212 teachers, and by employing structural equation modelling, this study revealed that technology knowledge makes the most significant contribution in TPACK. I think this study was not able to provide a comprehensive picture about Indonesian secondary mathematics teachers' knowledge of ICT since it does not focus on mathematics teachers.

Rimilda (2015) carried out a study aiming to investigate pre-service mathematics teachers' TPACK and their use of ICT in the classroom. This study employed a qualitative approach by using three research instruments: classroom observation, questionnaire, and interview. The participants for this study were five pre-service secondary mathematics teachers who had been in school placements for teaching practices. The findings of this study revealed that the pre-service teachers needed to improve their TPACK. However, this study study involved only five participants who were student teachers at placement schools. Consequently, the study did not fully reveal knowledge of ICT integration amongst Indonesian secondary mathematics teachers.

3.6 Research Studies on Teachers' Use of ICT in Mathematics Teaching

This section intends to present studies on how mathematics teachers use ICT in the classroom. In order to gain a comprehensive view on this issue, this review presents not only studies at secondary schools but also studies at primary and secondary levels. Furthermore, studies have looked at aspects of hardware and software used as well as pedagogical aspects of ICT integration in mathematics teaching. In the following sections, I review previous studies looking at those issues in several countries around the world as well as in Indonesia.

3.6.1 Mathematics Teachers' Choice of Hardware and Software

Researchers have investigated many different aspects of teachers' use of ICT in the classroom. Some researchers focus on teachers' choice of hardware and software as it is believed that the type of hardware and software seems to be an important factor in shaping the approach teachers' use of ICT in their teaching practices (Bretscher, 2014).

Kitchen et al. (2007), on behalf of British Educational Communications and Technology Agency (BECTA), conducted a survey of the access and use of ICT in English secondary schools. They revealed that that 53% of mathematics teachers used subject-specific software. However, only 24% of mathematics teachers were more likely to use online subscription services. The study also found 50% of the teachers used digital learning resources created by others at least once a week. However, this survey did not inform about further details on what type of subject-specific software was used.

Forhasz (2002) conducted a study which aimed to determine how computers are currently used in grade 7-10 mathematics classrooms as well as to identify factors associated with the levels and forms of use. A questionnaire, including open-ended items, was employed to this study. The study found that generic software applications such as spreadsheets, word processors, and internet browser were used more frequently than were mathematics-specific applications such as Geometer's Sketchpad and Graphmatica. This study revealed a detailed picture of types of software used by teachers; however, it did not show how frequently the specific software was used.

Loong et al. (2011) reported a study on the use of ICT in the teaching and learning of mathematics in rural and urban primary schools in Victoria, Australia. The study was conducted in six urban and seven rural schools in Victoria, Australia, and 36 teachers and 676 students took part in the study. The study showed that there was little difference across most aspects of ICT use. The study also revealed that the frequency of rural school use of usually exceeded that in urban schools. Moreover, some ranges of software being used were SmarKiddies, Coolmaths for Kids, Maths 300. However, the most frequently used software was PowerPoints, Word, Excel, and Microworld.

Becker et al. (1999) reported teachers' opinion about software performance, and the findings showed that most of the teachers agreed that Geometer's Sketchpad is the best software for mathematics classroom instruction. Another finding in this study confirmed that teachers with computers in their classrooms were three times more likely to use them compared to the teachers who only have access to shared computer rooms.

According to Clack-Wilson (2008), little is reported about what type of software teachers choose to use along with the type of hardware. An international study, for instance, the TIMSS (Mullis et al., 2008) survey, can only give a broad overview of ICT use. Such the study is not sufficient to provide information on the usage of different types of software or hardware at the school level. Large-scale surveys can provide a broad view of ICT use; however, they cannot provide deep insight into the nature of the specific use by the teacher in general or particularly by mathematics teachers (Bretscher, 2014).

3.6.2 Mathematics Teachers Pedagogical Practices Related to ICT

Focusing on mathematics teachers, Pelgrum and Voogt (2009) explored teachers school's factors associated with the frequency of ICT use by the teachers. They used the SITES (Second Information Technology in Education Study) 2006 database to compare countries with a relatively high percentage of frequency of mathematics teachers' ICT use (HIMA) with those with a relatively low percentage of frequently of ICT use by mathematics teachers (LOWA). The findings show that mathematics teachers in HIMA countries applied a student-centred approach more than those in LOWA countries.

In the US, Becker et al. (1999) carried out a national survey on ICT used in American schools which focused on how teachers have incorporated computers in their teaching practices. This survey found that only 37% of the mathematics teachers used computers into their teaching practices. Moreover, secondary mathematics teachers are less likely to have their students' use computers than business and vocational subject teachers. Another researcher, Manoucherhri (1999), employed a survey to explore the extent to which computers were being used by middle and high school mathematics teachers in the state of Missouri, USA. The findings of this study showed that the teachers only use computers for drill and practice. This was because of lack of sufficient knowledge about how computers could be used in teaching practices. As the studies were undertaken a long time ago, things may have changed in the last few years.

In investigating mathematics and science teachers' perspectives about their use of ICT in teaching and learning in Tanzania, Kafyulilo and Keengwe (2014) undertook a quantitative study which utilised a questionnaire as a means of data collection. This study found that the teachers' use of ICT in teaching was very limited while the majority of the teachers use computers for administrative purpose. Moreover, the study also revealed teachers have lack of confidence in using ICT to facilitate students' learning of specific concepts and support students to learn complex topics.

Bretscher (2014) carried out a survey of English secondary mathematics teachers' ICT use. This study aimed to develop an understanding of how and why mathematics teachers use ICT in teaching by examining the gap between the actual use of ICT by teachers and the potential for the use of ICT suggested by the literature. In total, 188 teachers who were involved in this study were asked about their access to hardware and software; perception of the impacts of hardware on students' learning; the frequency of use of ICT resources; and the teachers' pedagogical practice related to ICT. This study is quite unique compared to other studies as it makes a clear differentiation between hardware and software used by providing insight into types of software mathematics teacher choose to use in relation to particular types of hardware. More specifically, the researcher posed research questions separately regarding the following issues. First, teachers' use of software with interactive whiteboards (IWBs) or data projectors in a whole class context. Second, teachers' use of software in the context of a computer suite or laptop usage where students work individually or in small groups. This study revealed that over 75% of responding teachers use computer suites shared with the other departments once or twice in a term. On the other hand, IWBs were used almost every lesson by 85% of the teachers. This study further addressed the quantitative gap in software use in both classroom contexts. Use of mathematical analysis software is relatively rare in both classroom contexts. IWB use was dominated by presentation-oriented software while the MyMaths dominated teachers' use of computer suites. In addition, from the data on teachers' self-reported pedagogic practices in both contexts, teacher-centred was the most frequently occurring across the classrooms.

Fraser and Garofalo (2015) conducted a study to look at what extent pre-service teachers continue to integrate ICT in their first and second years of teaching. There were 14 participants comprising two cohorts of a graduate programme of secondary mathematics teacher education at an American university. Data were collected through observations, interviews and artefacts and analysed using Erickson's analytic induction. The findings indicated that the novice teachers successfully used ICT for the purpose of students' attainment of higher-level mathematical skills and conceptual understanding. They use ICT to model all levels of mathematics from algebra to calculus, and the teacher used these models to have students conjecture about parameters of equations; explore assumption about mathematical concepts and to predict behaviours to allow for generalisations of concepts. The teachers also used ICT to access students' understanding of mathematical concepts. These practices were integrated across all stands of the common core standards.

Hennessy, Ruthven and Brindley (2005, p. 157) used the theory of mediated action to determine how ICT as a cultural tool can alter the various affordance and constraints to change teaching and learning. From this perspective, in order to modify teaching practices, teachers must first come to accept the new "rebalancing of the system" of these factors. By interviewing mathematics and other subject teachers in 18 focus groups, this study found that most teachers failed to use ICT in revolutionary ways. However, the majority of teachers integrated ICT to "enhance and extend existing classroom practices" (p.152).

Petras (2010) investigated eighth grade science and mathematics teachers' pedagogical orientation when using ICT. The researcher claimed that this descriptive study was conducted due to a lack of information in terms of pedagogical orientation related to ICT use in American mathematics and science classrooms. The SITES-2006 teacher questionnaire was used to understand science and mathematics teachers' pedagogical orientations, their ICT use in teaching practice, and how ICT impacted on teachers' teaching practices. The findings of this study showed that mathematics and science teachers hold to traditional pedagogy.

Studies on mathematics teachers' use of ICT have not only been conducted at secondary school levels but also at elementary school levels. Although the present study focuses on the secondary level, I think it is also important to review studies on secondary level as both levels of education have strong connectivity. At an elementary school mathematics level, for instance, Lim and Chai (2008) investigated the degree to which a group of elementary mathematics teacher integrated ICT in teaching. The study found that 14 out of 18 teachers integrated computers in what appeared to be constructivist ways. However, when it was explored more closely, most of the classes used ICT only to support teacher-centred practices.

Another study at a primary education level was done by Polly (2014). He observed three primary schools teachers' use of ICT in mathematics teaching over a year in a school in the south-eastern United States. Teachers in the school had recently been part of a professional development programme related to ICT integration and mathematics pedagogies. Each teacher was observed between 25 and 30 times during the school year. The study inductively analysed the type of technologies used as well as the type of mathematical tasks and problems that the teacher posed while teaching with technology. The findings of the study indicated that mostly the participants used presentation technology such as document camera or interactive whiteboard. They seldom used computer-based technology or interactive technology. Moreover, in terms of types of technology used and mathematical tasks, this study found that the use of iPads resulted in low-level tasks in which the tasks focuses on computation or using an algorithm to find an answer. On the other hand, a limited number of high-level tasks were used when the interactive white boards were used.

Tay et al. (2012) administered a case study at elementary school level in Singapore. This study investigated the pedagogical approach for the teaching mathematics and English with ICT. The Learning *with* and learning *from framework* was used in reporting and analysing how ICT was used during the teaching. Data were gathered through document reviews and lesson plans; interviews with teachers; group interviews with students, and questionnaire surveys of students. This study indicated that different pedagogical approaches were adopted by mathematics and English teachers. Moreover, mathematics teachers used ICT less than English teachers and they primarily adopted the learning *from* ICT pedagogy while English teachers facilitated students to learn *from* and also learn *with* ICT. In addition, this study revealed the utility of *the learning with and from ICT* conceptual framework as guiding teachers and researchers to be aware of the pedagogical implications when ICT is integrated into the teaching and learning process.

All of the studies mentioned above were conducted in developed countries. Nevertheless, research in this field has also emerged in developing countries. For instance, Agyei and Voogt (2011) explored the feasibility of ICT use in mathematics teaching at senior high school levels in Ghana. A total of 180 mathematics teachers consisting of 60 in-service and 120 pre-service teachers participated in this study. The teachers were selected from 16 senior high schools ranging from government to private and international schools. Through interviews and surveys to collect the data, the study found that mathematics teachers in Ghana did not use ICT in their mathematics teaching.

Another important thing needs to be addressed in this review that international comparison studies on ICT use in mathematics classes have also emanated from the literature. For instance, Law et al. (2008) reported a large-scale study, the Second Information Technology in Education Study (SITES) 2006, which raised a central question on how ICT is changing teaching and learning practices in secondary schools worldwide in the 21st-century. Twenty-two education systems took part in this study, which investigated several themes; one of the themes was teachers' pedagogical orientations on mathematics and science and the use of ICT. The study found that the most frequently adopted pedagogical activities were ones that teachers have long been practising. The pedagogical activities included exercises to allow skills/procedure practices and teachers' lectures. On the other hand, mathematics principles and discovering of concepts were the least frequently practised pedagogical activities that had emerged only in recent years and which tended to be promoted as advantageous activities to the development of 21st-century abilities such as extended projects and open-ended scientific investigations. The results of the SITES 2006 study also revealed that, overall, mathematics teachers tended to use a narrower range of pedagogical activities than science teachers did. The frequencies of the use some of emerging activities that were more subject-matter such as extended projects, product creation, and looking up information, were higher for science teachers than for mathematics teachers in nearly all of the participating systems. The highest mean percentage of ICT-use in most systems was for looking up ideas and information, processing and analysing data and doing short tasks and extended projects.

The researchers have presented some important studies on mathematics teachers' use of ICT at primary and secondary school level in developed and developing countries. All of the studies related to in-service teachers. Moreover, it is also worth briefly looking at what the literature says about this topic in relation to pre-service teachers, as they also play a very important role in education.

Focusing on pre-service secondary mathematics teachers who had experience of doing and practicing mathematics teaching in a technology-rich environment, Fraser, Garofalo and Juersivich (2011) investigated how the teachers used this technology when planning lessons and how the use of technology affected other aspects of their quality of classroom practices. By collecting data through observations, interviews, and artefacts, the study found that technology enhanced the teachers' quality of classroom practices by facilitating their lesson planning, helping them stay on track and reducing their stress.

Another study on pre-service teachers was reported by Hammond et al. (2011). They examined how and why pre-service teachers made use of ICT during an initial programme of teacher education. The study employed a survey and a series of semi-structured interviews with a sample of 21 student teachers and explored several aspects, namely the nature of student teachers' use of ICT, variation in ICT use and constraints in using it. The study found that nearly all the participants were more receptive to ICT use more than their in-service counterparts, and more frequently used ICT during their internship experiences. The participants' use of ICT was categorised on three levels: routine users, extended users and innovative users.

As a final point, the previous studies on mathematics teachers' use of ICT in the classroom presented above have shown that researchers have identified types of hardware and software as well as pedagogical approaches used by teachers in developed countries such as the United States, United Kingdom and Australia. However, very limited information about studies on this issue in developing countries, especially Indonesia, is available in the literature. The previous studies on this issue in Indonesia are discussed in Section 3.8. Furthermore, in terms of mathematics teachers' pedagogical practices, the previous studies have not looked at the pedagogical practices at three levels namely the classroom level, the subject level and the task level.

3.6.3 Indonesian Mathematics Teachers' Use of ICT in Teaching

When it comes to studies on ICT in mathematics education in Indonesia, a very limited numbers of publications have reported on this. Among those studies, some of them are part of international studies. For instance, TIMSS 2007 provides a brief overview of ICT use in mathematics teaching in the classrooms. For Indonesia, Mullis et al. (2008) reported that only 16% of mathematics students have access to computers in the classrooms. However, the number increased significantly in 2011 so that now 87% of the teachers have access to at least one computer for teaching six or more students (Mullis et al., 2011). This report also revealed that the percentages of students whose their teachers have them a use computer at least monthly as follows: 5% to explore mathematics principles and concepts; 7% to look up idea and information; 5% to process and analysis data, and 6% to practice skills and procedures (Mullis et al., 2011). This report, at least, provides preliminary information about this issue. Since this international study was conducted six years ago, it may be that many changes have taken place in the last few years. In addition, this study does not reveal what type of software and hardware Indonesian mathematics teachers' use and how they utilise them in teaching practices.

Rimilda's (2015) study aimed to investigate pre-service mathematics teacher's TPACK and their use of ICT. This study reported that the participants used geogebra, cabri 3D, SketchUp and Microsoft power point in teaching mathematics. Moreover, when ICTs were being used, the participants incorporated different teaching approaches such as direct instruction, Think Pair Share and Student Teams Achievement Division. Direct instruction was the most common teaching approach incorporated in teaching practices.

3.7 Research Studies on Barriers to the Use of ICT in the Mathematics Classroom

When it comes to the integration of ICT in the classroom, barriers to integration are always worth discusing. It is important to explore this issue in this review, as it is one of the domains investigated in this study. Along with the classifications of barriers to the use of ICT, researchers also went further to look at what barriers teachers dealing with in general. They identified the barriers such as lack of appropriate software (Ertmer, 1999; Pelgrum, 2001); lack of time for training computer-aided instruction (Ertmer, 1999; Hew & Brush, 2006; Pelgrum, 2001);

and lack of technical support (Bingimlas, 2009; Hew & Brush, 2006; Pelgrum, 2001).

Studies have been dedicated to uncovering barriers to ICT integration in secondary mathematics classrooms. For example, Assude, Buteau, and Forgasz (2010) note the similarity of factors inhibiting mathematics teachers' use of ICT across a number of countries. By summarising previous surveys, they raise issues at school levels such as access to hardware and software, professional development needs, technical support, and resources and individual level factors such as teachers' confidence.

Through an empirical study, Keong et al. (2005) investigated the barriers preventing Malaysian mathematics teachers from fully utilising ICT in their teaching. The study unveiled six major barriers to ICT integration as follows: lack of time in schools; insufficient teachers' training; inadequate technical supports; lack of knowledge of how to integrate ICT and lack of resource at homes for the students. In total, 38% of the participants perceived that they lack knowledge that is the main barrier, and 51% of the teachers perceived it as a minor barrier, and only 11% of the respondents revealed that the lack of knowledge of how to use ICT was not a barrier.

Inadequate teachers' knowledge and professional development in ICT integration existed not only in developing countries such as Malaysia but also in developed countries. For instance, Forgasz (2006) conducted a study in Australia aimed at investigating factors that encourage or inhibit computer use for secondary mathematics teaching. By surveying a large sample of teachers twice over a three-year period, the researcher found that access to software and hardware, technical support, and professional development were significant factors influencing the teachers' use of ICT in mathematics teaching.

Hudson, Porter and Nelson (2008) conducted a study to examine the barriers to using ICT amongst Australian secondary mathematics teachers in the classroom. By using a survey questionnaire, this study collected data from 114 mathematics teachers from public secondary schools in New South Wales (Australia). The study reported that lack of access to computer labs was the number one barrier to using ICT in the classroom. A further analysis of this study showed that lack of a lesson plan as a barrier was significantly higher for teachers who did not use technology than teachers who used technology in the classrooms.

A lack of teachers' knowledge as a barrier to ICT integration was also found in the U.S. Manoucherhri (1999) employed a survey to investigate the extent to which computers were being used by secondary school mathematics teachers in Missouri state. The study revealed that the teachers only use computers for drill and practice. He argued that this was because of lack of adequate knowledge about when and how computers could be used in mathematics instruction.

Indonesian Teachers' Barriers to Using ICT in the Classroom

In Indonesia, whilst not specific to mathematics teachers, some researchers have revealed barriers to ICT integration. For instance, Marwan (2008) revealed that lack of knowledge and skills, and lack of technical support are two main barriers to ICT integration,

Harendita (2013) examined Indonesian teachers' resistance to ICT integration which may be rooted in many interlinked factors. One of them is that Indonesian teachers, to some extent, are digital migrants who are dealing with a range of challenges in this digital era (Harendita, 2013). Moreover, she also claimed that the high expectation of ICT integration might conflict with some pedagogical issues that teachers deal with in classroom practices. Another issue that Indonesian teachers encounter is the limited amount of software in Bahasa Indonesia (Indonesian language). This barrier is interesting, as it might not be found in other countries especially in developed countries.

Although the Indonesian government has stipulated a policy of providing ICT resources in education, access is still a concern in the country. Quah (2007) revealed that insufficient hardware and software in Indonesian schools is one of the barriers to some schools integrating ICT. Quah (2007) pointed out further that the Indonesian government is concerned about the low use of ICT in teaching and learning.

Regarding mathematics teaching, I did not find any study that particularly reported barriers for the mathematics teachers in using ICT in teaching this subject. In teaching this subject, the case is quite different as nowadays there is a lot of open source software for mathematics teaching such as GeoGebra which is available free and it is in the Indonesian language. Thus, it is worthwhile to investigate the barriers to mathematics teachers using ICT in the classrooms.

3.8 Research Studies on the Relationship between Teachers' Knowledge and Classroom Practices

In terms of the relationship between teachers' ICT knowledge and classroom practices, researchers have found a significant positive correlation. For instance, Kandasamy and Shah (2013) analysed knowledge, attitude and use of ICT among ESL teachers, and found that most of the participants believed that a computer is a valuable tool for teachers as it can change the way students learn in classes. This study also confirmed that there is a significant correlation between the level of knowledge of ICT and the use of ICT in the classroom.

Another study was carried out by Tezci (2010) aiming to determine primary school teachers' influence in the use of ICT at schools. One of the variables analysed in this study was the level of teachers' knowledge. The results revealed that teachers had a high level of knowledge about software such as word processing, spreadsheet, and presentation software. However, the teachers have a low level of knowledge about modelling software, simulation, webpage authoring and concept map software. The main finding of this study confirmed that there is a positive correlation between the levels of knowledge about ICT and the use of ICT in education.

Buabeng-Andoh's (2012) study investigated secondary school teachers' knowledge, perceptions, and practices in second-cycle institutions in Ghana. This study collected data through questionnaires which were distributed to 270 teachers of different subjects; 241 were returned, and 231 were valid for data analysis. The findings of this study show a positive correlation between teachers' competence and ICT use in the classroom. This study also revealed negative correlation between ICT use, age, and teaching experience. In addition, the descriptive results of this study indicated that teachers' knowledge of basic applications and knowledge of ICT integration into teaching was low.

Kafyulilo et al. (2012) examined the extent to which teachers' Technological Pedagogical Content Knowledge (TPACK) has an impact on their technology use and classroom practices. The study involved 12 in-service science teachers and 40 students from a secondary school in Tanzania. Data were gathered through teacher questionnaires, student questionnaires, an observation checklist, and teacher interviews. The findings suggested that after learning TPACK, teachers' classroom practices shifted from teacher-centred instructions to student-centred approaches to the use of ICT.

Al Harbi (2014) conducted a study, which adopted a sequential mixed method design, to examine Saudi high school teachers' level of ICT use and variables including the Technological Pedagogical Content Knowledge (TPACK) construct. This study found that TPACK was the best predictor of the effectiveness of ICT implementation. This study did not distinguish teachers' technical knowledge and teachers' knowledge of ICT use in teaching.

Based on the findings of the previous studies presented above, it can be concluded that there are positive correlations between teachers' knowledge and classroom practices in the use of ICT in the classroom. However, the previous studies did not make a distinction between teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching. Therefore, the previous study failed to show the different magnitude of the positive correlations regarding teachers' knowledge of ICT and teachers' knowledge of ICT in teaching. In addition, most of the previous study did not focus on teachers of a specific subject such as mathematics.

3.9 Summary

In the last three decades, researchers have shown rapidly growing interest in the field of ICT integration in the classroom. The earlier research in this field focused on the outcome from students' perspectives, while recent studies have shifted focusing on the teachers' knowledge and classroom practice. Internationally, many studies have explored mathematics knowledge and use of ICT in teaching. However, most of the previous studies were carried out in developed countries. This issue of teachers' knowledge and use of ICT in mathematics teaching has not intensively been explored in developing countries, let alone Indonesia. With regard to the relationship between teacher knowledge and classroom practices using ICT, previous studies did not distinguish teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching, and they did not focus on teachers of a specific subject such as mathematics.

In the next chapter, a conceptual framework of the study is developed by explaining the definition of ICT, teachers' knowledge, teacher classroom practices and barriers to the use of ICT.

Chapter 4 A Conceptual Framework for the Research

To address the research questions, it is important to clarify key concepts and develop a conceptual framework for this research. The conceptual framework was developed based on the research context and literature review discussed in Chapter 2 and Chapter 3 respectively. First, I clarify the term 'ICT' that leads to establishing a taxonomy of ICT in mathematics teaching. In the next section, I explain the main terminologies in this study, namely teachers' knowledge, classroom practices and barriers. Following this section, constructs of the domains investigated in this study are elaborated. Finally, this chapter ends with a conceptual framework that guides this study.

4.1 What is ICT?

Before I go further, it is necessary to have an operational definition of the term ICT (information and communications technology-or technologies) in this research. It is a challenge to define such a term, as it exists within several contexts and evolves from time to time. Selwin, Gorard, and Furlong (2006, p. 20), in their study on adult learning in the digital age, argue that:

> The umbrella term 'ICT' refers to a range of different definitions, there is a tendency to use either too narrow a definition of ICT in terms of specific technologies and or else too broad a definition as a homogeneous concept.

Therefore, it is crucial to examine the existing definitions of ICT in order to define it in the context of the present study.

Tinio (2000, p. 4) defines ICT as a "diverse set of technology tools and resources used to communicate, create, disseminate, store and manage information". These technologies include of computers, the internet, radio, television and telephony. According to Zuppo (2012), in a broad manner, ICT could include PCs, desktops, laptops, handheld devices and other types of wireless and/or cable connected equipment. He then came up with the primary definition of ICT related to the devices that facilitate the transfer of information through digital resources (Zuppo, 2012). The definitions of ICT by both researchers have a similarity in that they define ICT in relation to hardware. I think these definitions do not capture all aspects of ICT as it also relates to software.

Definitions of ICT are not only specified by researchers but also by international organisations. UNESCO, for instance, established a definition of ICT that is "the combination of Informatics technology with other related technology, particularly communication technology" (UNESCO, 2002). In my opinion, this definition is very broad. Thus, it is not applicable to use it in the present research. For research purposes, it is necessary to narrow the definition of ICT in an operationalised and concise way.

Cooke and Dawson (2012, p. 138) defined ICT as "desktop, laptop, and handheld computers that run the software and can enable access to the internet, along with software and use the internet itself". This definition incorporates there main resources of an information system which are software, hardware and the internet. It has a good scope in adding software as one of the elements of ICT.

Hennessy et al. (2005, p. 155) provide a more comprehensive definition of ICT. The term ICT refers to:

> The range of hardware (desktop and portable computers, projection technology, calculators, data logging and digital recording equipment), software applications (generic software, multimedia resources) and information systems (Intranet and Internet) available in school.

This definition seems comprehensive and it was established for the purpose of research in a school context. However, it appears a little out of date by not including the handheld devices such as tablets. It might be that when this definition was established the use of the handheld devices had not flourished in the society.

In the present study, I have adopted Hennessy et al.'s (2005) definition of ICT. As this definition is too broad, I define it as more specific in relation to teaching mathematics. ICT is defined as hardware, software and the internet (online resources) which are used or potentially used for mathematics teaching and learning. Moreover, this term is limited to hardware (calculator, computer/laptop, and handheld device); software (general software and mathematical software); and internet (learning management system and web-based applications). These concepts are elaborated in the next sections. In addition, in this study, the term ICT is interchangeably used with digital technology.

4.1.1 Hardware

In this study, the hardware refers to calculators, computers/laptops and handheld devices. This boundary is due to the fact that these tools have been widely used in mathematics teaching, and they are potentially used in Indonesian secondary mathematics classrooms. These three types of hardware were included in this study for the following reasons. Firstly, the literature (e.g., Mailizar et al., 2014; Ruseffendi, 1988) indicates that modern technology such as calculators were introduced a long time ago in Indonesia's mathematics curriculum. Secondly, computers/laptops were included in this study since the data from Aceh Provincial Office of Education shows that most of the schools have such facilities. Finally, another type of hardware addressed in this study was handheld devices such as tablets or mobile phones because I assumed that teachers and students have access to this hardware since it is widely available at a reasonable price. However, it is important to note that I did not include other hardware such as *Smartboards*. This was due to the Provincial Office's data showing that such tools were not available in the secondary schools in Aceh Province.

4.1.2 Software

In Webster's New World Telecom Dictionary, Horak (2008) defines software as "the programme, routines, and symbolic languages that control the functioning of the hardware and direct its application". Systems software is a set of instructions that serves primarily as an intermediary between computer hardware and application programme and may be directly manipulated by knowledgeable users. Application software is a set of computer instructions that provide specific functions to a user. In this study, the term software refers to application software that is potentially used in mathematics teaching. Moreover, in this study, the terms *apps* and *software* are used interchangeably. Since software is a broad term, in this study, I classify it into general software and mathematical software.

General Software

The term of *general software* and *generic software* are used interchangeably in this study. Nevile (1995) defined generic software as the tool such as text processing, image processing, spreadsheets, LOGO etc. Johnston-Wilder and Pimm (2004) provided broader examples of generic software that are available for mathematics teaching such as presentation software (e.g., PowerPoint); word processing software (e.g., MS Word); mind-mapping software (e.g., Inspiration and Kidspiration). Moreover, other well-known general software potentially used in mathematics teaching is Google Earth and SketchUp.

Mathematical Software

Researchers have different approaches to define and classify software intended for teaching and learning mathematics. For instance, as mentioned in Section 3.4, Pierce and Stacey (2010, p. 2) use the term *Mathematics Analysis Software* (hereinafter referred to as MAS). They define MAS as "software with which the user can perform algorithmic processes required when working in one or more branches of mathematics". These tools are those such as computer software (e.g., spreadsheets, dynamic geometry packages) or handheld calculators (e.g., scientific calculators, graphic calculators, CAS with or without geometry). However, in this study, a calculator is specified as hardware instead of software.

Other researchers such as Drijvers and Trouche (2007) and Fuglestad (2005) clarified software for mathematics teaching and learning into two types, namely *Computer Algebra System* (CAS) and *Dynamic Geometry Software* (DGS). Each of the types of software has its own advantages for handling certain mathematical topics or enhancing certain instructional approaches. Fuglestad (2005) describes how such tools can provide learning situations to experiment and explore with mathematical connections and provide new ways of approaching tasks. Computer Algebra Systems (CAS) is intended to enable the manipulations of mathematical expressions in symbolic form. Examples of computer algebra systems are Derive, Maple, and Mathematica. Moreover, Dynamic Geometry Software is a type of software which is mostly used for the construction and analysis of problems and tasks in elementary geometry (Straber, 2002). Examples of dynamic geometry software are Cabri Geometry and Geometer's Sketchpad.

Another type of educational software for mathematics teaching and learning is called Dynamic Mathematics Software (DMS). DMS is designed to combine certain features of computer algebra systems, dynamic geometry software, and also spreadsheets in a single set (Schumann & Green, 2000). This tool can be used for a wider range of mathematical contents and grade levels. Examples of dynamic mathematics software are GeoGebra and GEONExT.

The third category of mathematical software is Statistical Software. Examples of this software are Tinkerplots, Fathom and SPSS. This type of software may not be very familiar in mathematics education compared to dynamic geometry and computer algebra systems.

In the quantitative phase of this study, the use of both general software and mathematical software were included in the investigation. Furthermore, in the qualitative stage, I focused on the specific type of mathematical software called Mathematics Analysis Software (Pierce & Stacey, 2010). This was for the following reasons. Firstly, general software is widely available and used by teachers in pedagogical activities and administrative tasks. Secondly, I focused on MAS in the qualitative phase as it offers many advantages for teaching and learning mathematics. MAS are cognitive tools, as described by Zbiek, Heid and Dick (2007), in that the technology facilitates the technical dimension of mathematical activity and allows the user to take action on mathematical objects or representation of those objects (Pierce & Stacey, 2010). The main features of MAS are that the users must be able to use the software to accomplish selected algorithms of mathematics with the user's own input. Moreover, MAS is adaptable which means that the users determine what the software will do (Pierce & Stacey, 2010).

4.1.3 The Internet

The term of 'Internet' refers to online resources used for teaching and learning mathematics. I classify this term into two categories: learning management system and web-based applications. Learning management system is an application for administration, reports, documentation, and delivery of electronic courses. There are applications such as Moodle and Blackboard. According to *technopedia dictionary,* a web-based application refers to "any programme accessed over a network connection using HTTP, rather than existing within a device's memory". For mathematics teaching, these applications are such as Hotmath, SMILE, *Rumahbelajar,* and *m-edukasi*. Moreover, in this study, online video resources such as Youtube and KhanAcademy were also classified as web-based applications.

Rumahbelajar and *m-edukasi* are web-based and mobile learning resources resource developed by the Indonesian Ministry of Education and Culture aiming to increase the use of ICT in teaching and learning in Indonesia. They offer learning and teaching resources for most of the school subjects including mathematics. In this study, for learning management systems I included *Moodle* and *Blackboard* as these are two well-known platforms. Moreover, for online resources, I included *rumah belajar and m-edukasi.* This is because, as mentioned previously, these two resources have been developed by the Indonesian government to increase the use of ICT in Indonesian education. Moreover, I also included Youtube and KhanAcademy as they are prominent online video resources for teaching and learning.

4.1.4 Taxonomy of ICT for Mathematics Teaching

To simplify all classifications of ICT mentioned above, I developed taxonomy of ICT for mathematics teaching. This taxonomy might not be comprehensive since it was developed for the purpose of this study. Therefore, it was adapted to the context in which this study took place. For instance, the hardware types only included computers/laptops, tablets and calculators. I did not include other hardware such as *Smartboards* since according to data from the Aceh Provincial Office of Education the tool was not available in secondary schools in the province.

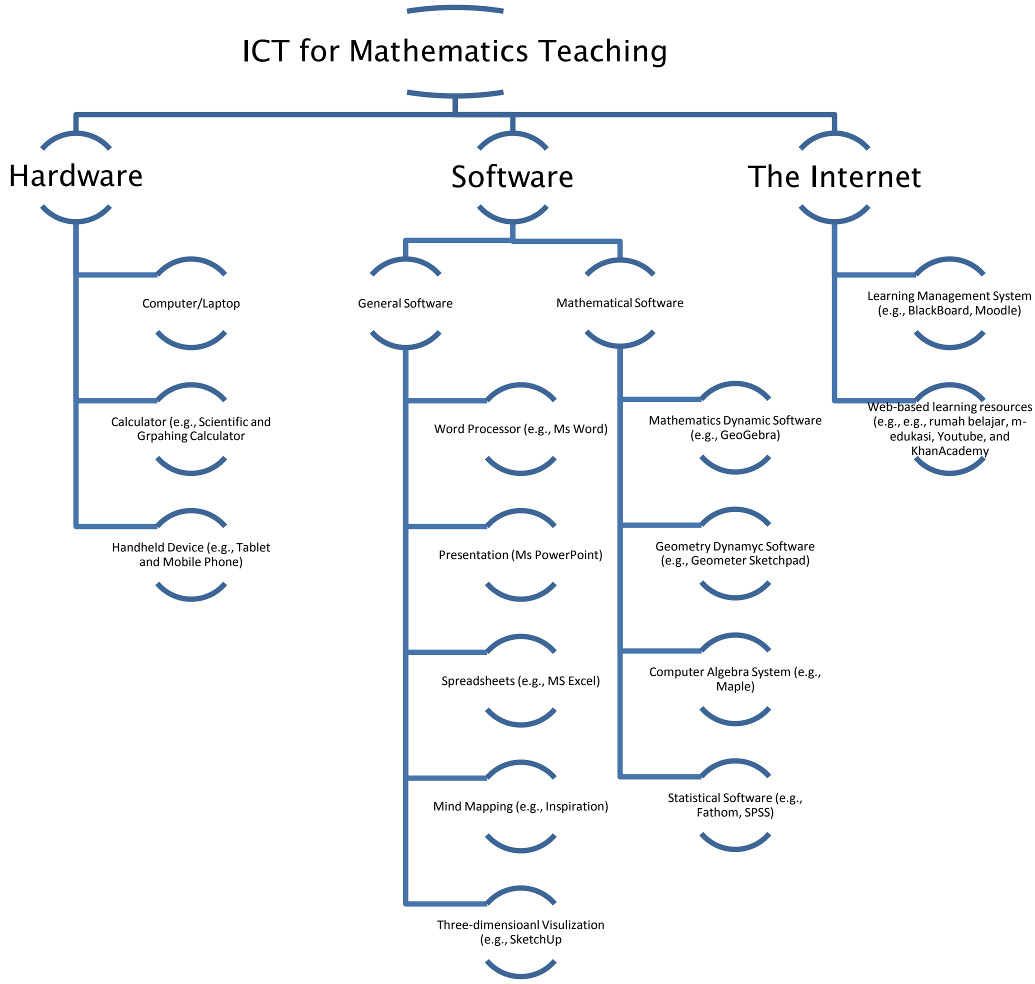

Figure 4-1: Taxonomy of ICT for mathematics teaching

4.2 Knowledge, Classroom Practice and Barriers

This section is devoted to clarifying key terminoly used in the study: knowledge, classroom practice and barrier in relation to the use of ICT in teaching. Two main key notions for this study is teacher knowledge and teacher classroom practice are discussed first. A discussion of barriers to the use of ICT then follows.

4.2.1 What is Knowledge?

Knowledge is a complex concept; therefore, it is essential to clarify some key notions such as knowledge, teachers' knowledge, teacher's pedagogical knowledge, and teacher knowledge of ICT and teacher knowledge of ICT use in teaching. According to the Oxford Dictionary (2015), knowledge is "the theoretical or practical understanding of a subject". Another definition from this dictionary is that knowledge is "the sum of what is known". Furthermore, to give a systematic description of knowledge, researchers have frequently attempted to describe it from different points of views. Some descriptions have been based on cognitive perspective (e.g., P. A. Alexander & Judy, 1988; Snow, 1989). Others have formulated to serve as a basis for instructional design theories (e.g., de Jong & Ferguson-Hessler, 1996) as well as from an epistemological point of view (e.g., Fan, 2014).

Fan (2014, p. 38) defines knowledge from an epistemological perspective: "a subject's knowledge of an object is a mental result of a certain interaction of the subject and the object". In this research, the definition of knowledge is referred to Fan's definition. This is for the following reason. From this definition, it is easy to recognise that knowledge can be knowing that (e.g., a belief), knowing things (e.g., a memory), and knowing how (e.g., understanding) (Fan, 2014). As already mentioned, regarding knowledge investigated in this study, there are two main aspects: knowledge of ICT and knowledge of how to use ICT in mathematics teaching. Hence, knowing how is the main concept investigated in this research.

Type of Knowledge

Apart from the attempts to provide a definition of knowledge, researchers (e.g. P. A. Alexander & Judy, 1988; Scardamalia & Bereiter, 2014) have also attempted to distinguish types of knowledge from different perspectives. From the perspective of cognitive theories, P. A. Alexander and Judy (1988), for instance, distinguish three types of domain-specific knowledge, namely declarative (factual information), procedural (compilation of declarative knowledge in functional units that incorporate domain-specific strategies) and conditional (understanding when and where to access certain facts or employ particular procedures). Regarding this, this research focuses on procedural knowledge to what extent a teacher knows how to perform certain activities related to ICT.

Moreover, Scardamalia and Bereiter (2014) distinguish types of knowledge from a pragmatic standpoint, which are *knowledge about* and *knowledge of* something. They reveal that knowledge *about* consists of declarative knowledge people can retrieve when prompted to state what they know about something, while knowledge *of* something implies an ability to participate in the activity of something. Knowledge *of* consists of both procedural knowledge and declarative knowledge (Scardamalia & Bereiter, 2014). Moreover, they argue that knowledge *of* entails not only knowledge that can be explicitly stated or demonstrated but also implicit or intuitive knowledge. Thus, knowledge *about* is approximately equivalent to declarative knowledge, while knowledge *of* is much richer than procedural knowledge. In this study, which is investigating teacher knowledge of ICT and knowledge of ICT use in mathematics teaching, knowledge investigated belongs to the category of *knowledge of.*

Teacher Knowledge or Teachers' Knowledge

According to Fan (2014), 'teacher knowledge' and 'teacher's knowledge' are used interchangeably by researchers. In this research, I also use them without distinction. Moreover, as pointed out by Fan (2014), from the perspective of the knower and the known of knowledge, in 'teacher knowledge' or 'teacher's knowledge' or 'teachers' knowledge, teachers are the knowers, and what teachers know are the known.

4.2.2 What is Classroom Practice?

In this section, I present some terminology commonly used in relation to teachers' classroom practices such as *pedagogy, pedagogic approaches, pedagogic strategies,* and *teaching practices.*

It is important to review the use of the term 'pedagogy' and explain its relationship to practices that may be observable in the classroom. Watkins and Mortimore (1999, p. 3) define pedagogy as "any conscious activity one person designed to enhance learning in another". Another scholar, Bernstein (2000, p. 78) defines pedagogy as:

> A sustained process whereby somebody acquires new forms or develops existing forms of conduct, knowledge, practices and criteria from somebody or something deemed to be an appropriate provider and evaluator.

Other researchers, Westbrook et al. (2013), define the pedagogic approach as teachers' thinking and the ideas they have to plan and implement one or more instructional strategies. Implicitly, pedagogical approaches are informed by theories of learning such as behaviourism and constructivism, while pedagogic strategy is a more concrete expression of pedagogic approach. Alexander (2001, p. 540) sees teaching as "an act while pedagogy is both act and discourse". In other words, pedagogy is what teachers actually think, do and say in the classroom and teaching practices are "the specific actions and discourse that take place within a lesson and that physically enact the approach and strategy" (Alexander, 2001, p.540). In conclusion, this study looks at teaching practice with the specific aspect of teaching, which is the use of ICT in teaching of secondary mathematics.

Da Ponte and Chapman (2006) noted that the early use of the term 'practice' in mathematics education research was mostly related to individual's 'actions', 'acts', or 'behaviour'. In this study, I also use the term 'practice' related to teacher 'actions', 'acts, or 'behaviour' in the use of of ICT in mathematics teaching. In addition, in this study, teaching practice is used interchangeably with teachers' practice, teachers' classroom practice, and teachers' instructional practice.

The following addresses some key terminology in terms of the use of ICT. According to Lloyd (2005), the term 'integration' is often used interchangeably with more the popular term "use". To integrate is to combine components, parts or elements in a complex but harmonious whole (Lloyd, 2005). In the present study, I also use term both terms of 'use' and 'integration' interchangeably.

For some scholars, ICT integration was examined in terms of types of teachers' computer use in the classroom (e.g., students doing internet searches, doing a multimedia presentation, and collecting and interpreting data for projects) (e.g., Cuban, Kirkpatrick, & Peck, 2001). For other researchers, ICT integration was examined in terms of how teachers use technology to carry out regular activities more productively and reliably (e.g., Hennessy et al., 2005). Other researchers, such as Sandholtz, Ringstaff and Dwyer (1997), define ICT integration as the use of ICT tools to support student problem solving, inquiry, collaboration and communication. Hence, the present study examined the use of ICT in term of types of ICT used as well as functional and pedagogical activities of ICT used. Finally, despite the lack of a clear standard definition of technology integration, the present study views ICT integration as the use of computing devices such as desktop computers, calculators, software, or internet at schools for teaching practice “to accomplish specific teaching or learning activities and to meet certain certain instructional objectives” (Lim, 2007, p. 85).

4.2.3 What is a Barrier?

The integration of ICT in teaching and learning is a complex activity thus many teachers may encounter a number of difficulties. These difficulties are also known as ‘barriers’ (Schoepp, 2005). According to the Oxford Dictionary (2015), a barrier is “a fence or an obstacle that prevents movement or access”. The dictionary also provides another definition of barriers that is “a circumstance or obstacle that keeps people or things apart or prevents communication or progress”. Furthermore, another definition of a barrier is offered by Schoepp (2005, p. 2), which is “any condition that makes it difficult to make progress or to achieve an objective”. In this study, I use Schoepp’s (2005) definition of the barrier.

4.3 Domains of the Research

This section intends to clarify the construct of each domain investigated in the study, namely teachers’ knowledge, teachers’ classroom practices, and teachers’ barriers based on the review of the literature in the previous chapter. In addition, the relationship between teachers’ knowledge and classroom practices is also discussed in this section. As a result, by the end of this chapter, the conceptual framework of the study has been presented.

4.3.1 Teachers’ Knowledge

As discussed previously, in terms of teachers’ knowledge, this study looked at teachers’ knowledge of ICT and teachers’ knowledge of ICT use in teaching. Hence, this section clarifies the construct of knowledge of ICT and Knowledge of ICT use in teaching for the purposes of this research. In Chapter 3, I have discussed two models of teacher knowledge in the use of ICT. This study is not intended to verify the validity of the two models but it employs the principle elements from the two models to investigate and explain teachers' knowledge in terms of the use of ICT in secondary mathematics teaching in Indonesian.

The two models share some common principle elements. Firstly, they strongly address the existing various components of digital technology and their affordance for teaching and learning. This requires teachers to understand ICT broadly enough to apply it productively in the classroom and to recognise when ICT can assist them in achieving the goal of teaching and learning. As a result, in the present study, I included a broad range of digital tools potentially used for mathematics teaching.

Secondly, the integration of ICT requires teachers to understand not only the existence of various ICT tools but also their pedagogical affordance (see Angeli & Valanides, 2009; Mishra & Koehler, 2006). Finally, the models also address knowledge of pedagogical strategies and ability to apply those strategies for the use of ICT for a specific learning tasks or contents. Drawing upon those two models, I classify constructs of knowledge investigated as follows:

Knowledge of ICT

In this study, to define knowledge of ICT, I adopted Angeli & Valanides's (2009, p. 158) definition, which is:

> Knowing how to operate a computer and knowing how to use a multitude tools/software as well as troubleshoot in problematic situation.

This is similar to how technology knowledge is defined by Chai et al. (2013), which is knowledge about how to use hardware and software and associated peripherals. Thus, the definition of knowledge of ICT in this study is knowing how to operate hardware as well as knowing how to use software and the internet. The terms of hardware, software and internet have been defined in Section 4.1. I did not use the definition of technology knowledge defined by Mishra and Koehler (2006) since it covers broad range of technology from low-tech technology such as pencil and paper to digital technology such as the internet and interactive smart boards.

Another important issue needs to be taken into account; it is a challenge to distinguish knowledge of ICT and ICT-Content Knowledge when it comes to specific mathematics software designed for teaching and learning purposes (see K Ruthven, 2014). To address this issue, in this study, knowledge of ICT is defined without consideration of any mathematical contents and teaching approach. In short, regarding specific mathematics software, knowledge of ICT relates to the ability to use the functional capacities of the software such as for drawing, calculation, manipulation and construction.

Knowledge of ICT Use in Teaching

Knowledge of ICT use in teaching is a complex notion. Thus, it is a challenge to develop a concise definition of this concept. In this study, I define this term based on two theoretical models discussed in Section 3.3: ICT-TPCK (Angeli & Valanides, 2009) and TPCK (Mishra & Koehler, 2006). Nevertheless, Mishra and Koehler's TPACK played a major role in defining the construct of knowledge ICT use in teaching.

As presented in Chapter 3, TPCK has seven components namely TK, CK, PK, PCK, TCK, TPK, TPCK. Handal et al. (2013) adopted the TPCK model (Mishra & Koehler, 2006) to investigate secondary mathematics teachers' knowledge through administration of an instrument called TPCK-M. The instrument consisted of three major theoretically-based constructs: technological content knowledge (TCK), technology pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPCK).

In terms of knowledge of ICT use in teaching, the present study also emphasised on knowledge-related ICT. Therefore, components of Content Knowledge (CK), Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK) were not included in this study. Therefore, the instrument of teachers' knowledge for the present study consisted of TCK, TPK and TPCK, which I then reframed as: ICT-Content Knowledge (ICT-CK), ICT-Pedagogical Knowledge (ICT-PK) and ICT-Pedagogical Content Knowledge (ICT-PCK).

As mentioned previously, it is important to remind the reader that TPCK and ICT-TPACK models have been used in the previous studies to examine and understand teacher instructional practices in the use of ICT. However, in this study, I did not employ these models to understand and describe teachers' instructional practices, as those models are too general and do not fit to the aims of this study. Therefore, a framework to examine and understand teacher's use of ICT in mathematics teaching in this study is explored in the following section.

Finally, based on the discussion above and the review of models of teacher knowledge in Section 3.2, the definition of the construct of teachers' knowledge investigated in the present study is presented in Table-4.

Table 4-1: Construct of knowledge of ICT and knowledge of ICT use in teaching

Construct of Knowledge	Description
Knowledge of ICT	Knowing how to operate hardware as well as knowing of how to use software and the internet without consideration of any mathematical content and teaching approaches
Knowledge of ICT use in teaching	
o ICT-Content Knowledge	Knowing how to use ICT to represent, communicate, solve and explore mathematical contents, ideas, or problems without consideration of teaching approaches.
o ICT-Pedagogical Knowledge	Knowing how to use ICT to provide advantages to specific aspects of teaching approaches without reference to subject matter
o ICT-Pedagogical Content Knowledge	Knowing how to use ICT to teach, represent and facilitate learning of specific content of mathematics with specific teaching approaches to enhance teaching and learning

4.3.2 Teachers' Use of ICT in the Classroom

It is important to note that this study used the terms of 'teachers' use of ICT in the classroom' and 'teachers' classroom practices in the use of ICT' interchangeably. Regarding this issue, this study looked at two aspects: type of ICT as well as functional and pedagogical activities. In order to clarify those aspects, this section discusses each aspect briefly.

Firstly, as previously presented in Section 4.1, the type of ICT consists of three main components: hardware, software and the internet. Hardware consists of computers (laptops), calculators, and handheld devices while software constitutes general software and mathematical software. In addition, the Internet comprises of online learning resources and software for learning management system.

Secondly, the present study adapted Piece and Stacey's (2010) pedagogical map for investigating functional and pedagogical activities,. The map proposes functional and pedagogical opportunities offered by Mathematics Analysis Software (MAS). It is important to note that the quantitative phase of this study not only focuses on MAS but also other software. I believe it is still acceptable and meaningful to adopt this pedagogical map to investigate teacher classroom practice in the use of not only MAS but also other types of ICT tools as it proposes a relatively comprehensive level of ICT use in the classroom, namely at task level, classroom level, and subject level. Therefore, regarding teachers' functional and pedagogical activities in the use of ICT, the quantitative phase of the present study investigated the following aspects.

As mentioned earlier, in terms of functional activities, this study adopted Pierce and Stacey's (2010) pedagogical map. The functional activities of ICT are related to carrying out routine mathematical procedures. As a result, they included doing arithmetic, drawing graphs, solving equations, factorising, differentiating, and construction of diagrams, and measurement of lengths and angles.

Pedagogical activities are also based on Pierce and Stacey's (2010) pedagogical map which consists of three levels, which are task level, classroom level, and subject level. For the quantitative phase of this study, I made some minor changes in order to ensure that they were measurable through a quantitative research instrument. The adaptions of the map for the investigation of teacher classroom practices at each level are as follows.

Firstly, at subject level, the pedagogical map does not only emphasise on areas of mathematics being taught but also goals for the teaching of subjects. Regarding the subject level, the quantitative phase of this study only investigates subjects being taught, which include Geometry, Algebra, Statistics and Probability, Calculus and Trigonometry. These mathematics subjects were included in this study because it was noted in the chapter on research context that the Indonesian mathematics curriculum offers these topics at senior secondary schools.

Secondly, in terms of classroom level, Pierce and Stacey's pedagogical map emphasises on classroom social dynamics and the classroom didactic contract. In terms of the classroom level, the pedagogical map looks at the classroom social dynamics and classroom didactic contract. In the quantitative phase of this study, I slightly altered the emphasis by looking at classroom activities and teaching approaches.

Thirdly, regarding the task level, the pedagogical map proposes five types of tasks which are "learn pen-and-paper skill", "use real data", "explore regularity and variation" "simulate real situations", and "link representation". Without any change, the quantitative phase of the present study looks at those types of tasks.

It is important to note that Pierce and Stacey's (2010) pedagogical map was fully employed as a framework to understand and describe teachers' classroom practices in the qualitative phase of this study. The methodology chapter discusses this in further details.

4.3.3 Teachers' Barriers

Researchers have different ways of classifying barriers to ICT integration. Pelgrum (2001), for instance, identified material and non-material barriers. Material barriers refer to a lack of ICT resources while and non-material barriers relate to teachers' knowledge and skills. Another way of classifying barriers was reported by Balanskat, Blamire and Kefafa (2006) in the ICT impact report. In the report, which was prepared in 2006, the barriers were grouped into teacher level, school level and system level. Ertmer (1999) has identified two sets of barriers, namely first order and second order barriers. First order barriers include problems involving hardware, access, and technical support while the second order obstacles relate to issues such as the change in pedagogy, belief or personal preference**.**

The barriers in terms of teacher level barrier included: lack of teacher confidence (Bingimlas, 2009; Schoolnet, 2006; Scrimshaw, 2004); teachers' unwillingness to change their practice (Hew & Brush, 2006; Scrimshaw, 2004); teachers' not realising the advantages of using ICT in their teaching (Scrimshaw, 2004); and teachers' attitudes and beliefs to ICT (Ertmer, 1999; Hew & Brush, 2006). Moreove, the barriers in terms of assessment include difficulty in planning the technology–based tools in evaluation and students' assessments are not in line with ICT use (Hew & Brush, 2006). The barrier in terms of subject is that the structure of a subject does not support technology-based application (Hew & Brush, 2006).

Based on the literature, I classify teachers' barriers in the use of ICT into the following levels: the school level, the teacher level and the curriculum level. This classification was adopted from (Pelgrum, 2001). The school-level barrier mostly relates to the availability of hardware and software, access to the internet connection, school policy while on the ICT integration, and teachers' time to prepare lessons, textbooks and technical support. Furthermore, the teacher-level barrier includes teachers' knowledge, confidence, experience and belief (Bingimlas, 2009; Marwan, 2008; Scrimshaw, 2004). It is important to note that, in this study, teachers' knowledge was not included as a barrier at teacher level since teachers' knowledge was investigated in a separate domain. Moreover, regarding the curriculum-level barriers, the items included the structure of content (Hew & Brush, 2006) and assessment (Hew & Brush, 2006). Finally, the classification of barriers in this study is presented in Table 4-2.

Table 4-2: Classification of barriers faced by teachers in using ICT

Type of Barrier	Description
School Level	Including: availability of software and hardware, internet, textbooks, and school policy, time and technical support
Teacher Level	Including: confidence, belief and experience
Curriculum Level	Including: structure of contents and assessment

4.4 Relationship between Teachers' Knowledge and Classroom Practice

Researchers have argued that being successful mathematics teachers requires strong content knowledge as well as a solid foundation in pedagogical content knowledge (e.g., Wilson, Floden, & Ferrini-Mundy, 2002; Wilson, Shulman, & Richert, 1987). Furthermore, the literature has shown that teacher knowledge has a significant impact on their classroom practices (e.g., Cochran-Smith & Lytle, 1999; Copur-Gencturk, 2015; Gilbert & Gilbert, 2013; Shechtman, Roschelle, Haertel, & Knudsen, 2010).

When it comes to the relationship between teacher knowledge and classroom practices in the use of ICT, the literature has also shown a positive correlation between knowledge of ICT and the use of ICT in the classroom with (e.g., Buabeng-Andoh, 2012; Kandasamy & Shah, 2013; Tezci, 2010). Moreover, regarding teacher knowledge of ICT use in teaching – which has been defined in different terms such as TPCK- the literature has also shown that this type of knowledge has a positive impact on their use of ICT in the classroom (e.g., Al Harbi, 2014; Kafyulilo et al., 2012).

Finally, based on the literature review and the conceptual framework presented above, a concise view of the conceptual framework of this research is presented in Figure 4-2.

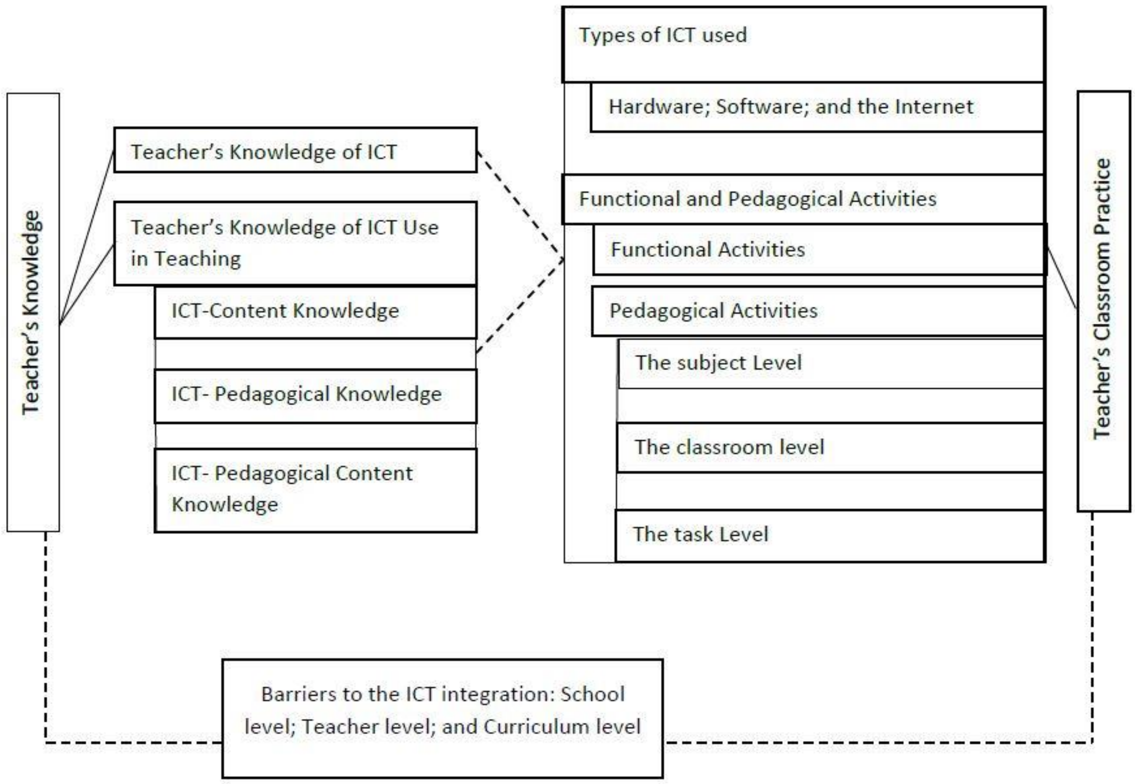

Figure 4-2: A conceptual framework for the study

4.5 Summary

To investigate teachers' knowledge, classroom practices and barriers to the use of ICT in mathematics teaching as well as the relationship between teachers' knowledge and classroom practices, I have established a conceptual framework based on the research context and the literature review. The framework presents three domains investigated in this research and the relationship between teachers' knowledge and their classroom practices. To end this chapter, I would like to point out that this research seems broad enough as those three domains are studied together. However, I think it is important to study them together to gain a complete picture of the current state in Indonesian mathematics education with respect to the use of ICT in mathematics teaching.

In the following chapter, the research methodology is elaborated by explaining philosophical underpinning the research, the research design, population and sample, research instruments, a pilot test, data collections and data analysis, research ethics and limitations of the research design.

Chapter 5 Research Methodology

As mentioned in Chapter 1, the aims of this study were to investigate Indonesian teachers' knowledge and classroom practices in the use of ICT in secondary mathematics classrooms as well as to examine the relationship between teachers' knowledge and their classroom practices. In addition, this study sought to reveal barriers faced by teachers to using ICT in their classrooms. Based on the literature review presented in Chapter 3 and the conceptual framework developed in the previous chapter, a methodology has been designed for the purpose of this study. The first section of this chapter presents the philosophical assumption underpinning the study. Following this, the research design is discussed in the second section while the description of population and sample is elaborated in the following section. Furthermore, the research instruments and a pilot test of the instruments are explained in Section 4 and Section 5 respectively. Data collection procedures are discussed in the sixth section and it is then followed by a presentation of techniques of data analysis. Finally, ethical issues and limitation of the methodology are explored in the last two sections respectively.

5.1 The Philosophical Underpinning of the Research

According to Mertens (2005), "A paradigm is a way of looking the world, it is composed of certain philosophical assumptions that guide and direct thinking and action". Moreover, the debate surrounding research paradigms have a long history. According to Creswell and Plano Clark (2011), one of the common paradigms associated with the use of mixed methods is pragmatism. It is a set of ideas articulated by many people, from historical figures, such as John Dewey, William James, and Charles Sanders Peirce (Creswell & Plano Clark, 2011). It draws on many ideas, including employing what works, using diverse approaches, and valuing both objective and subjective knowledge. Moreover, according to Shirish (2013, p. 68):

> Pragmatic researchers, therefore, grant themselves the freedom to use any of the methods, techniques and procedures typically associated with quantitative or qualitative research. They recognise that every method has its limitations and that the different approaches can be complementary.

Pragmatism is essentially practical rather than idealistic (Cohen, Manion, & Morrison, 2011), and it is "practice-driven" (Denscombe, 2008, p.280). It argues that “there may be both singular and multiple versions of the truth and reality, sometimes subjective and sometimes objective, sometimes scientific and sometimes humanistic” (Cohen et al., 2011). It suggests that what works to answer the research questions is the most useful approach to the investigation (Cohen et al., 2011). Other researchers, Onwuebuzie and Leech (2005), also argue that mixed methods research works beyond quantitative and qualitative exclusivity, and in a “pragmatist paradigm”. It is pluralistic and oriented toward “what works” and practice (Creswell & Plano Clark, 2011).

Mixed methods research recognises the fact that the world is not exclusively quantitative or qualitative, but a mixed world (Cohen et al., 2011). It integrates both numeric and narrative approaches and data, quantitative and qualitative methods as necessary and relevant, to meet the needs of the research rather than the commitment or preferences of the researcher, and in order to answer research questions fully (Johnson, Onwuebuzie, & Turner, 2007).

According to Creswell and Plano Clark (2011), the main principle of pragmatism is that quantitative and qualitative methods are compatible. Therefore, both numerical and text data, collected concurrently or sequentially, can help better understand the research problem. As a result, in mixed method research, researchers construct knowledge based on a pragmatist worldview that focuses on the primary importance of research questions rather than the methods, and on the use of multiple methods of data collection to examine the phenomenon being studied (Creswell & Plano Clark, 2011).

5.2 Research Design

As mentioned previously, the aims of this study were to investigate Indonesian teachers’ knowledge and classroom practices in the use of ICT in secondary mathematics classrooms as well as to examine the relationship between teachers’ knowledge and their classroom practices. In addition, this study sought to reveal barriers faced by teachers to using ICT in their classrooms. After an extensive review of the most suitable methodology with which to approach the research, I believe such phenomena can be better understood through a mixed methods approach, which combines both quantitative and qualitative research traditions. In relation to this idea, Creswell (2009, p. 14) pointed out that “recognising that all methods have limitations, researchers felt that biases inherent to any single method could neutralise or cancel the biases of other methods”. Quantitative and qualitative research traditions can be complementary and the combination of both approaches might add more credibility to the findings of the research.

5.2.1 Definition of Mixed Methods

Johnson, Onwuegbuzie, and Turner (2007, p. 118) synthesised the opinions from 31 scholars in the mixed method field about the definition of mixed methods research, and they concluded that:

> Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purpose of breadth and depth of understanding and corroboration.

This definition is almost similar to that defined by Creswell and Plano Clark (2011, p. 5):

> Mixed methods is a research design with philosophical assumptions as well as method inquiry. As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis and the mixture of qualitative and quantitative approaches in many phases of the research process. As a method, it focuses on collecting, analysing, and mixing both quantitative and qualitative data in a single study or series of studies.

The main idea of each definition is that mixed methods use both quantitative and qualitative approaches.

In further details, Creswell and Plano Clark (2011, p. 5) reveal what a researcher does in a mixed method study as follows:

- Collects and analyses persuasively and rigorously both qualitative and quantitative data (based on research question);
- Mixes (or integrates or links) the two forms of data concurrently by combining them (or merging them), sequentially by having one build on the other, or embedding one within the other;
- Gives priority to one or to both forms of data (in terms of what the research emphasises)

5.2.2 Type of Mixed Method Design

Researchers use different approaches for designing their mixed method studies. There is a wide range of classifications of types of mixed method designs that researchers have established. For instance, Creswell and Plano Clark (2011, p. 69) classified mixed methods in six major designs: (a) Convergent parallel design; (b) Explanatory sequential design; (c) Exploratory sequential design; (d) Embedded design; (e) Transformative design; and (f) Multiphase design. With regard to the aims of using mixed methods in this study, it is appropriate to employ the explanatory sequential design in this research.

The explanatory design - also known as the explanatory sequential design - is a two-phase mixed methods design whose overall purpose is based on the idea that qualitative data helps explain or build upon quantitative data (Creswell, Plano Clark, Gutmann, & Hanson, 2003). The design starts with collection and analysis of quantitative data. This phase is followed by sub-sequential collection and analysis of qualitative data (Creswell & Plano-Clark, 2007). Because this design begins quantitatively, researchers typically put greater emphasis on the quantitative methods than the qualitative methods (Creswell & Plano-Clark, 2007). In this study, I also place more emphasis on the quantitative data than the qualitative ones.

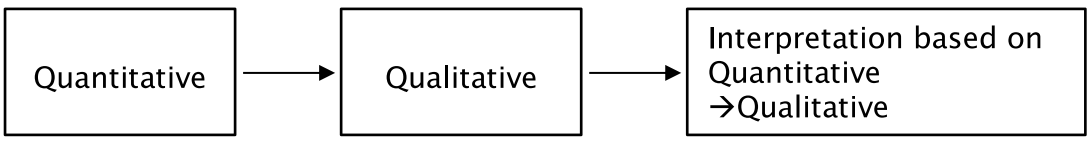

Figure 5-1: Sequential explanatory research design
Source: from Creswell and Plano-Clark (2007)

This design can be used when a researcher wants to form groups based on quantitative results and follow up with a group through subsequent qualitative research (Tashakkori & Teddlie, 1998) or to use quantitative participants characteristics to guide purposeful sampling for a qualitative phase (Creswell et al., 2003). These approaches align with this study, as qualitative participants are purposely selected based on their type of ICT used and level of knowledge specified in the quantitative phase of the research.

5.2.3 Rationale for the Use of Mixed Methods

It is widely believed that the purpose of a mixed methods approach is to build on the strength that exists between qualitative and quantitative research designs to understand a phenomenon more fully than is possible using either a qualitative or a quantitative method alone. For instance, Reams and Twale (2008, p. 133) argue that "mixed methods are necessary to uncover information and perspective, increase collaboration of the data, and render less biased and more accurate conclusion". Greene (2008, p. 22) also claims that a single approach will only yield a partial understanding of the phenomenon being explored. According to Denscombe (2010, p. 144), "the use of more than one method can enhance the findings of research by providing a fuller and more complete picture of the phenomenon being studied". Hence, mixed methods research frequently results in superior results (Johnson & Onwuegbuzie, 2004).

Denscombe (2008, p. 273) suggests that mixed methods research has the following advantages. It increases the accuracy of data and provides a complete picture of the phenomenon under study than would be yielded by a single approach. Furthermore, it enables the researcher to develop the analysis and build on the original data. In addition, it helps sampling, for instance, where a questionnaire might be used to screen potential participants who might be approached for interview purposes. Other researchers, Creswell and Plano Clark (2011, p. 8) argue that:

> Problems suited for mixed methods are those in which one data source may be insufficient, result need to be explained, exploratory findings need to be generalised, a second method is needed to enhance a primary method, a theoretical stance needs to be employed, and overall research objective can be best addressed with multiple phases.

Gorard & Taylor (2004) indicate that both qualitative and quantitative approaches have different strengths but the combination of the two can add even more strength to the findings of a study. For example, the use of quantitative methods is considered to provide more reliability, validity, objectivity and generalisability to the findings. Moreover, questionnaire, one of the instruments of the quantitative method, may be administered to a large number of participants. If the researcher collects data based on a representative sample of the population, they are more able to generalise statements made about the topic being examined (Fraenkel & Wallen, 2009). However, the survey data has several disadvantages. The data that is collected is likely to lack depth on the topic being examined. Moreover, focusing on the collection a large amount of data may hinder the researchers' ability to check the reliability of the responses (Fraenkel & Wallen, 2009).

In contrast to the quantitative approach, the main benefit of a qualitative approach is that researchers can use a variety of qualitative research instruments to collect descriptive narrative data, which allows them to deeply understand the topic being investigated (Gay, Mills, & Airasian, 2012). However, one of the criticisms of this approach is that it usually involves a smaller sample size than for the quantitative approach, thus the qualitative findings are less able to be generalised to a large population (Fraenkel & Wallen, 2009). Moreover, a qualitative method allows more flexibility in the interaction with the participants and provides more detailed findings.

As mentioned previously, the present study adopted a sequential mixed methods design that had a quantitative phase was followed by a qualitative phase. In this study, both quantitative and qualitative approaches were employed to investigate teacher classroom practices and examined the relationship between teachers' knowledge and classroom practices in the use of ICT. Hence, there are several reasons for using a mixed method in the present study.

Firstly, using both quantitative and qualitative approaches to examine teachers' classroom practices and the relationship between teachers' knowledge and their classroom practice offers more confidence in the validity and reliability of the study findings. Moreover, it can also support the generalisability of the finding and provides a significant enhancement that is to maximise the interpretations and understanding of the issue being addressed (see Collins, Onwuegbuzie, & Sutton, 2006).

Secondly, the quantitative instrument was used to collect data about teachers' knowledge, classroom practices, and barriers to the use of ICT. Moreover, the quantitative data were also used to examine the relationship between teachers' knowledge and their classroom practices as well as to examine differences in teachers' knowledge and their classroom practices in terms of teacher's demographic backgrounds. This instrument allows this study to collect data from a large number of the participants. Therefore, the results of the study are considered to provide generalisability. Furthermore, data from the qualitative method were used to describe teachers' classroom practices in the use of a specific type of ICT called MAS and to deeply understand the relationship between teachers' knowledge and their classroom practices in the use of the digital tool.

Thirdly, as discussed in Section 1.2 and Section 3.6, most of the previous studies on teacher's classroom practices in the use of ICT relied on teachers' self-reports by employing questionnaire surveys. According to Rosenfeld, Booth-Kewley, Edwards, and Thomas (1996), a common problem of studies based on self-reported data is that participants usually have correct ideas about socially desirable answers, which can be referred to as the tendency to provide answers that cause them to look good. This kind of responding has long been viewed as a potential source of error variance in self-reporting measures (Hancock & Flower, 2001). Moreover, researchers (e.g., Hew & Brush, 2006) suggest that mixed methods research studies are the type of studies needed in this field. Hence, Hew and Brush (2006) suggest that mixed methods research needs to underpin future study on ICT integration, examining teachers in actual practice through observations, and not merely relying on teacher self-report.

5.2.4 Strengths and Challenges of the Explanatory Design

According to Creswell and Plano-Clark (2007), the explanatory design is the most straightforward of the mixed method designs. The advantages of this design are: (1) it is straightforward to implement because the researcher conducts the two method separate phases and collects only one type of data at a time; (2) the final report can be written in two phases, making it straightforward to write and providing a clear demarcation for readers (Creswell & Plano-Clark, 2007).

However, the use of the explanatory design may face some challenges such as (a) the design requires a lengthy amount of time to implement in two phases; (b) the researcher must decide whether to use the same individuals for both phases or to draw participants from the same population for the two phases. The second issue is addressed in Section 5.3.

Finally, Figure 5-2 illustrates the design of the present study. It presents the numbers of the participants in each phase as well as the instruments and data analysis used to answer the research questions.

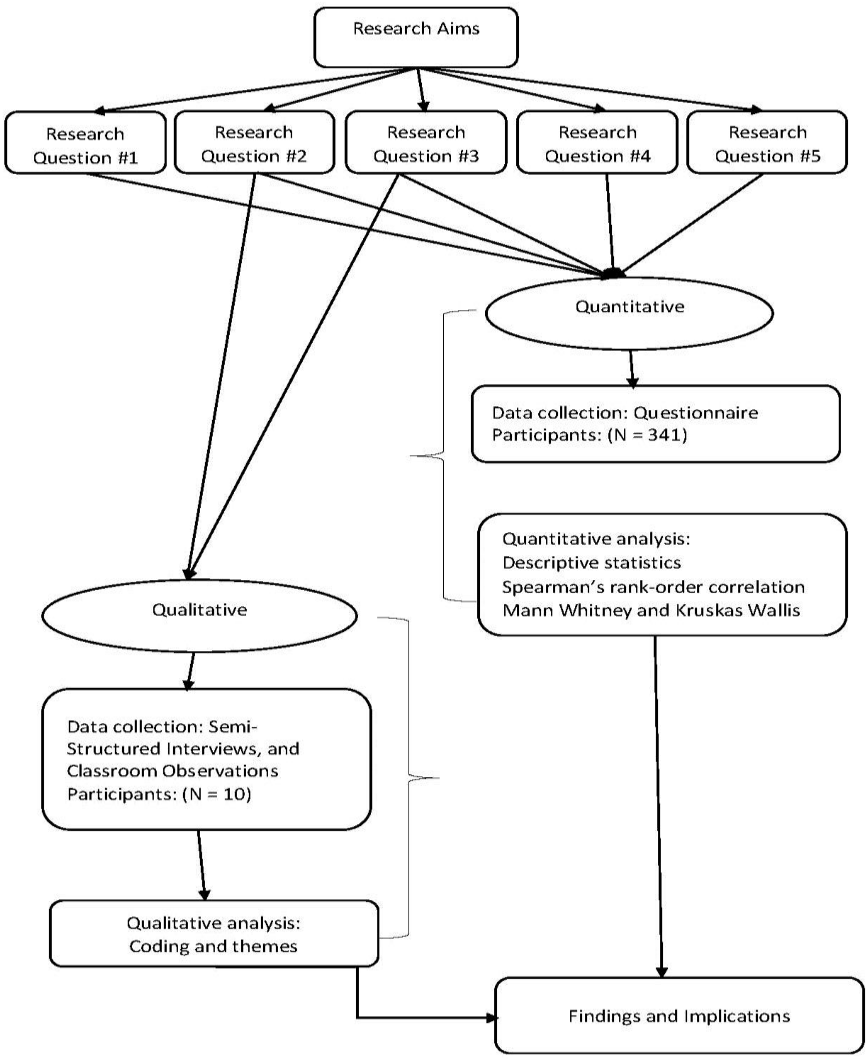

Figure 5-2: Research design

5.3 Description of Population and Sample

5.3.1 Identification of the Population

Best and Kahn (1993, p. 13) define a population as "any group of individuals that have one or more characteristics in common that are of interest to the researcher". Another definition of population is proposed by Fraenkel and Wallen (2009, p. 91) emphasising on the target population and the accessible population. They define a target population as the actual population for which a researcher would really like to generalise. Unfortunately, the target population is rarely available. Therefore, the population for which a researcher is able to generalise is called the accessible population (Fraenkel & Wallen, 2009).

As discussed in Chapter 2, secondary schools in Indonesia are divided into two levels: junior secondary and senior secondary. This study looked at only the senior secondary level as the Indonesian government pays more intention to this level of education compared to both the junior secondary and the primary level. This is because, at this level, the students are preparing to take the National Examination and the University Entrance Examination. Therefore, in the country, teaching mathematics at this level is regarded as very important. In addition, the previous studies in the field of ICT integration in Indonesia have emphasised on the junior secondary level. Hence, less attention has been given to the integration of ICT at the senior secondary level.

Moreover, as mentioned in Chapter 2, secondary schools in Indonesia are administered by two ministries, namely the Ministry of Education Cultures (MoEC) and the Ministry of Religious Affairs (MoRA). This study investigated teachers from both ministries as they are subject to the same mathematics curriculum.

Indonesia is a large country. Hence, I was unable to carry out the research throughout the country. Therefore, the population for this study was secondary mathematics teachers in one of Indonesia's provinces called Aceh Province. The reason I choose this province was that it was manageable for me to conduct the fieldwork as I studied and worked there. Moreover, this province is interesting compared to other provinces. Firstly, it was hit by the tsunami in 2014; since then many international organizations have implemented many programmes including teaching professional development in the use of ICT. In addition, this province also has a big expenditure for education compared to the other provinces. On the other hand, the quality of education in this province is still relatively low as it is indicated by the human development index (HDI) which places the province at 18th out of the 33 provinces (BPS, 2015).

According to BPS (2015), this province has five cities and 18 regencies. Regions that have either city or regency status have the same level of authority in running the education. The province has 367 senior secondary schools and 1,443 mathematics teachers. Thus, the number for the populations was 1,443, which is presented in details in Table 5-1.

Table 5-1: Population for the study

Regency/City	Number of mathematics teachers	Regency/City	Number of Mathematics teachers
Regency of Aceh Besar	99	Regency of Nagan Raya	43
Regency of Pidie	143	Regency of Aceh Jaya	17
Regency of Aceh Utara	155	Regency of Aceh Barat Daya	39
Regency of Aceh Timur	77	Regency of Gayo Lues	31
Regency of Aceh Tengah	70	Regency of Bener Meriah	46
Regency of Aceh Barat	57	Regency of Pidie Jaya	71
Regency of Aceh Selatan	62	City of Sabang	14
Regency of Aceh Tenggara	40	City of Banda Aceh	109
Regency of Simeulue	18	City of Lhokseumawe	52
Regency of Bireuen	156	City of Langsa	36
Regency of Aceh Singkil	29	City of Subulussalam	17
Regency of Aceh Tamiang	62		

Source*:* Provincial Office of Education of Aceh Province (2015)

5.3.2 Determining the Sample Size

Fraenkel and Wallen (2009, p. 90) define sample as "the group information that is obtained". In other words, a sample is a subset of a population. It is essential to take sampling scheme into account in research as Cohen et al. (2011, p. 143) argue that the quality of pieces of research not only depends on the appropriate methodology and instrumentation but also the suitability of the sampling strategy that has been adopted.

Sampling is an important step in a research process as it helps to convey the quality of inference made by a researcher. A sampling design helps to decide the extent to which findings can be generalised by researchers (Tashakkori & Teddlie, 2003). In a mixed method study, a researcher needs to decide numbers of participants as well as how to select the participants in both quantitative and qualitative phases. Therefore, according to Onwuegbuzie and Collins (2007), the sampling can be more difficult for studies in which both quantitative and qualitative research approaches are combined either sequentially or concurrently.

The first important step was to decide the size of the sample. With respect to the explanatory mixed methods design, I needed to consider the size of the sample for both the quantitative phase and qualitative phases. According to Creswell and Plano Clark (2011), having two samples of different sizes with the size of the quantitative sample much bigger than the qualitative sample helps the researcher obtain a rigorous quantitative examination of the research problem and an in-depth qualitative exploration (Creswell & Plano Clark, 2011).

To determine the sample size, I referred to the table for determining minimum returned sample size developed by Barlett, Kotrlik, and Higgins (2001). In the present study, the number of the population was 1,443 mathematics teachers, with a confidence interval (margin of error) of +/- 5%, and a confidence level of 95%. Thus, according to the table, it needs about 306 participants were required for the sample. Therefore, since poor response rates are typical in survey research, I distributed 440 copies of the questionnaire.

It is a more challenging to determine the sample size for the qualitative research (Collins, Onwuegbuzie, & Jiao, 2007). However, in qualitative research, the sample size should not too small since that would make it difficult to acquire data saturation. At the same time, it should not be so large as it loses the ability to achieve a deep and rich understanding of the phenomenon being studied (Collins et al., 2007). According to Guest, Bunce, and Johnson (2006), twelve cases is sufficient sample size for qualitative research. Hence, in the present study, the ideal sample size of the qualitative phase was 12 teachers.

This different sample size for the quantitative and the qualitative phase may raise the question of how to compare or integrate the two data sets in any meaningful way when the size is so different. Creswell and Plano Clark (2011) claim that the differences in sample sizes are not a problem due to the fact that the purpose of the data collection is different for the two data sets: quantitative data gathering aims to make generalisations while qualitative data collection seeks to develop an in-depth understanding from a few participants. In the following section, the sampling technique for this study will be discussed.

5.3.3 Sampling Method

As mentioned previously, the present study employed *the explanatory design*. According to Creswell and Plano Clark (2011), there are two options for selecting participants in quantitative and qualitative phases for a sequential explanatory design; the sample can include different individuals or the same individuals. For this study, the participants who participated as the qualitative sample were the same individuals who participated in the quantitative phase. Furthermore, the sampling method for the quantitative and the qualitative phases are presented as follows.

Sampling method for the quantitative phase

In order to draw a representative sample for the quantitative phase of the present study, stratified random sampling techniques were adopted. This sampling approach is “a process in which certain subgroups are selected for the samples in the same proportion as they exist in the population” (Fraenkel & Wallen, 2009, p.94). This sampling technique was employed because it was not manageable to collect data in all the regencies and cities. Thus, stratified random sampling increases the likelihood of representative data (Fraenkel & Wallen, 2009).

As mentioned in Chapter 2, the present study took place in Aceh Province which consists of five cities and 18 regencies. The cities and the regencies have the same level of authority in managing the education system. Therefore, in the stratified random sampling technique, I first grouped the region into three regions (High, Middle and Low) based on the Human Development Index (HDI). Moreover, I randomly selected about 70% of the cities or regencies from each the region. Therefore, three cities and 13 regencies were randomly selected which are presented in Table 5-2.

Table 5-2: Selected cities/regencies

High		Middle		Low	
1	City of Banda Aceh	6	Regency of Aceh Besar	12	Regency of Aceh Selatan
2	City of Lhokseumawe	7	Regency of Aceh Utara	13	Regency of Aceh Jaya
3	Regency of Bireuen	8	Regency of Pidie	14	Regency of Bener Meriah
4	City of Langsa	9	Regency of Aceh Barat	15	Regency of Nagan Raya
5	Regency of Aceh Tengah	10	Regency of Aceh Barat Daya	16	Regency of Aceh Tamiang
		11	Regency of Pidie Jaya		

Moreover, I randomly selected schools from each city and regency. The numbers of schools in each city and regency were different. For instance, the city of Banda Aceh had 22 senior secondary schools while the city of Langsa only has nine senior secondary schools. Hence, I randomly selected different numbers of school in each area. Therefore, in Banda Aceh, for instance, I randomly selected eight schools to distribute the questionnaire. Hence, in total, there were 93 secondary schools selected for the distribution of the questionnaires.

It is important to note that, in Indonesian, the size of senior secondary schools divers from a very small school that only has 30 students to a big one that has more than 1,000 students. Thus, the average number of teachers varies for each school. Consequently, the numbers of the questionnaires were different for each school depending on the number of mathematics teachers. Such circumstance resulted in a challenging task for the collection of quantitative data, which is addressed in Section 5.6.

Table 5-3: Number of selected schools

No	Regencies/Cities	Number of School	Number of Selected School
1	City of Banda Aceh	22	8
2	City of Lhokseumawe	11	4
3	Regency of Bireuen	28	10
4	City of Langsa	9	3
5	Regency of Aceh Tengah	17	6
6	Regency of Aceh Besar	29	10
7	Regency of Aceh Utara	25	9
8	Regency of Pidie	17	6
9	Regency of Aceh Barat	16	6
10	Regency of Aceh Barat Daya	9	3
11	Regency of Pidie Jaya	10	4
12	Regency of Aceh Selatan	17	6
13	Regency of Aceh Jaya	8	3
14	Regency of Bener Meriah	13	5
15	Regency of Nagan Raya	10	4
16	Regency of Aceh Tamiang	16	6

Sampling method for the qualitative phase

For the qualitative phase, a purposive sample of teachers was selected from participants who provided their consent to participate in classroom observations and interviews. To select participants in this phase, at the end of the questionnaire, I provided a section asking participants to write down their contact details if they were willing to participate in the second phase of this study. In that section, I also asked participants about ICT tools or software they would plan to use in the observed class. Sixty-four participants indicated that they were willing to participate in this phase by providing their email addresses and phone numbers. Nevertheless, some of them did not provide the necessary information in order to be selected at this stage. Seventeen participants did not provide information on the type of software they would plan to use. In addition, three participants did not provide contact details and four participants specified that they would use PowerPoint instead of Mathematics Analysis Software. Consequently, only 40 teachers were available for selection. Therefore, the sampling frame for the qualitative phase was all 40 teachers.

Based on the results of the quantitative analysis for the level of teachers' knowledge, the 40 teachers were grouped into two groups: teachers with sufficient knowledge and teachers with insufficient knowledge. As discussed in Section 5.3.2, the ideal sample size for the qualitative phase is 12 teachers. Therefore, I selected 12 participants out of the 40 teachers. I randomly selected an equal number of participants from both groups of the teachers. However, one of them withdrew from the study and another one was not analysed since the teacher only used PowerPoint instead Mathematics Analysis Software in the classroom. Therefore, only 10 participants were analysed in the qualitative phase of this study. The participants' characteristics and detailed data collection procedure are presented in Section 5.6.

5.4 Research Instruments

This research project combines quantitative and qualitative methods of data collection; therefore it uses several instruments namely questionnaire-surveys, classroom observations and semi-structured interviews. Since the fieldwork took place in Indonesia, it is important to state that the questionnaire and interviews were translated into the Indonesian language. Those instruments were intended to answer the following research questions.

Table 5-4: Research instruments

Research Questions	Research Instruments
Research Question #1	Questionnaire
Research Question #2	Questionnaire, Classroom Observation, and Interview
Research Question #3	Questionnaire, Classroom Observation, and Interview
Research Question #4	Questionnaire
Research Question #5	Questionnaire

The structures of the research instruments are presented in the following sections.

5.4.1 Questionnaire

For the collection of the quantitative data, I used a four-part self-report questionnaire, designed for this study (see Appendix B.1). The sections are entitled: Part I: Teachers' demographic characteristics; Part II: Teachers' knowledge of ICT and its use in teaching; Part III: Teachers' classroom practices; and Part IV: Teachers' barriers to using ICT. I developed the questionnaire based on the literature review and the conceptual framework for this study. Moreover, some questions were adopted from existing questionnaires. The following section will discuss the questionnaire in further details.

Part I: Teachers' demographic characteristics

The first section of the questionnaire was used to collect data about participants' background information. Items included gender, teacher certification, and level of education, teaching experience, and school type (MoRA or MoEC schools). This section also inquired about whether participants had undertaken any ICT training programmes, and if so, what training programs they had participated in. All demographic data were necessary with regard to the research question number four. Demographic questions appeared at the beginning since these data are important in this study. Lodico, Spaulding and Voegtle (2006) pointed out that if participants' completion of demographic questions is important to the study, then demographic questions should appear at the beginning of the questionnaire.

Part II: Teachers' knowledge

The aim of this part was to gather self-reported data about teachers' knowledge of ICT and teachers' knowledge of ICT use into teaching. With regard to teachers' knowledge of ICT, as previously discussed in the conceptual chapter, this study refers to the definition proposed by Angeli & Valanides's (2009, p. 158). Furthermore, in this study, the classification of ICT has been presented in Section 4.1.

Based on the definition and the classification of ICT, I developed questions about knowledge of ICT. There were four questions regarding this issue (Q12, Q13, Q14 and Q15). Question 12 was about knowledge of the use of hardware that consisted of three types of hardware: computers, calculators, and handheld devices. Question 13 was about general software which consisted of items related to the word processor, presentation, spreadsheets, mind mapping, animation, and three-dimensional visualisation. Question 14 was devoted to collecting data about knowledge of the use of mathematics software which included items relating to Dynamic Geometry Software, Algebra Computer Systems, and Statistical Software. Finally, question 15 was related to knowledge of the Internet which focused on knowledge of the use of learning management systems and web-based teaching and learning resources. This question consisted of two items.

Regarding knowledge of ICT use in teaching, as previously discussed in Section 4.3, this study refers to Mishra & Koehler's TPACK (2006) and Handal et al.

(2013). Thus, questions about knowledge of ICT use into teaching were adopted from Handal et al. (2013) and Schmidt et al. (2009). There were three questions relating to teacher knowledge of ICT use into teaching (Q16, Q17 and Q18). Each question had several items and dealt with different scales. Question 16 was devoted to investigating ICT-content knowledge while question 17 was about ICT-pedagogical knowledge. Finally, question 16 aimed to gather data about ICT-pedagogical content knowledge.

Part III: Teachers' classroom practices

As previously discussed in Section 4.3, with regard to teachers' classroom practices, this study looks at types of ICT used, and functional and pedagogical activities enacted in the classroom. Moreover, functional and pedagogical activities were defined based on Pierce and Stacey (2010). There were 12 questions related to teachers' classroom practices in the use of ICT. The first three questions (Q19, Q20 and Q21) were about general information for ICT use; these questions were adopted from Law et al. (2008).

The following questions (Q22, Q23, Q24 and Q25) dealt with the frequency of use of software, hardware and online resources. Question 22 was about the frequency of hardware used which consisted of three types of hardware. Moreover, question 23 dealt with the frequency of general software use while question 24 was about the frequency of mathematics software use. In addition, question 25 was about the frequent use of online resources. I developed those four questions based on the definition of knowledge of ICT and classification of type of ICT as discussed in the chapter on the conceptual framework.

Moreover, question 29 was about functional activities of ICT use, which was developed based on Pierce and Stacey's (2010) Pedagogical Map of MAS. Functional activities of ICT use include doing arithmetic, drawing graphs, solving equations, constructing diagrams, measuring lengths and angles, and creating three-dimensional visualisations.

In terms of the pedagogical activity of ICT, there were four questions related to this aspect; questions 26, 27, 28, and 30. These questions were designed based on Pierce and Stacey's (2010) Pedagogical Map of MAS which consists of three levels namely subject level, classroom level, and task level. Question 28 was about the use of ICT at subject level. The list of mathematics topics was based on the Indonesian secondary mathematics curriculum as it was previously presented in Section 2.4. Moreover, questions 26 and 27 dealt with the use of ICT at the classroom level which looked at two aspects, namely teaching approaches and classroom activities. Items for both questions were adapted from Law et al. (2008). Question 30 was the last question regarding pedagogical activities related to ICT use. This question was about tasks set by teachers designed based on the pedagogical map.

Part IV: Teachers' barriers to using ICT

As previously discussed in Section 4.3, barriers to the use of ICT consist of three levels, namely teacher level, school level, and curriculum level. There were three questions (Q31, Q32 and Q33) devoted to this issue. Question 31 and question 32 were adapted from Thomas (2006) and items from question 33 were developed based on Hew and Brush (2006).

With the exception of background information's questions, all the questions were measured on Likert items, and each question consisted of more than one item. According to Krosnick and Presser (2010), when designing a rating scale, a researcher must state the number of points on the scale. In this questionnaire, I used a five-point scale ranging from (5) 'strongly agree' to (1) 'strongly disagree' for items about teachers' knowledge and barriers. Regarding the items on teachers' use of ICT, I used a five-point scale ranging from (1) 'never' to (5) 'always'. Finally, Table 5-5 summarises each construct of the questions.

Table 5-5: Distribution of questions

Constructs	Questions
Background information	
• Personal information	Q1, Q2, Q3
• Education background	Q4, Q5, Q6
• Information about school and class	Q7, Q8, Q9
• Professional development	Q10, Q11
Teachers' Knowledge	
• Knowledge of ICT	Q12, Q13, Q14, Q15
• Knowledge of ICT use in teaching	Q16, Q17, Q18,
Teachers' use of ICT	Q19, Q20, Q21, Q22, Q23, Q24, Q25, Q26, Q27, Q28, Q29, Q30,
Barriers to ICT use	Q31, Q32, Q33

5.4.2 Classroom Observation

Classroom observations were utilised in this study because teaching is a complex activity and teaching practice can only be fully reflected and brought to light in actual classroom contexts (see Fan, 2014). Thus, in the present study, classroom observations were devoted to investigating teachers' classroom practices in the use of ICT, particularly in the use of Mathematics Analysis Software in secondary mathematics teaching.

As previously discussed in Section 4.3, Pierce and Stacey's (2010) pedagogical map was employed as a framework to look at teachers' classroom practices. Therefore, the classroom observations focused on three aspects: subject level, classroom level, and task level. Classroom observations were carried out with the observation sheet for documenting important data regarding the pedagogical map (see the observation sheet in Appendix C.3). In addition, in order to ensure all the classroom activities were recorded, a video recorder was also used during the classroom observations. The videotapes were mainly focused on the teachers. Procedures for classroom observation are explained in further details in Section 5.7.

5.4.3 Semi-Structured Interview

According to McQueen and Knussen (1999), semi-structured interviews are the most commonly used approach in qualitative research. This method typically starts with a few general questions. Moreover, it allows the researcher to follow the interests and thought of the participants. This method is considered to generate the richest data, particularly if the interviewer is inexperienced (Smith, Harre, & Van Langenhove, 1999). They also claim that semi-structured interviews allow the researcher and participants to be more flexible than the other methods (e.g. structured interviews). Semi-structured interviews provide participants with the chance to express their views and describe their experiences. Thus, in the qualitative phase of this study, the semi-structured interview is a suitable method for following up classroom observations since it provides me with more control over the issues being interviewed. For example, I may decide to alter some of the questions depending on the flow of the conversation. I can also decide to add more questions in order to explore the issues more deeply.

Semi-structured interviews were carried out with an interview guide linked with topics (see Interview Protocol in Appendix C.1). As mentioned earlier, the qualitative phase focused on teachers' classroom practices. Hence, the interview questions emphasised teachers' classroom practices based the three levels of the pedagogical map, which are subject level, classroom level, and task level. Procedures for the interviews are explored in further details in Section 5.7.

5.5 Pilot Test of the Instruments

According to Brace (2004), the aim of a pilot study is to validate the instrument and to test its reliability. In this research, a pilot test was conducted for both the quantitative and qualitative instruments. The following sections report on the pilot test of this study.

5.5.1 Quantitative Instrument

As mentioned previously in the instrument section of this chapter, the first step was designing the instrument based on other instruments, the literature review and the conceptual framework alongside continuous feedback from the research supervisors. The draft of the survey instrument was also reviewed by an expert from Southampton Education School in order to gain more feedback and to improve it. Moreover, a researcher who works at a public university in Indonesia was also invited to review the draft.

Feedback from the reviewers helped me to reshape and reformulate the questions and add new questions relating to the context of Indonesian secondary mathematics and ICT. Based on the feedback, some questions were rewritten because of ambiguous terms such as ‘dynamic mathematics software’ and ‘drill and practice software’. Moreover, six items were deleted because some of them did not align with the conceptual framework of the study. The questions that were deleted mostly related to the teacher access to ICT resources in the schools. In addition, four questions relating to the Indonesian context were added.

Once the draft of the questionnaire in the English version had been finalised, I translated it into the Indonesian language. According to Sperber (2004), several methods can be used to validate translation such as evaluation by teams of experts, bilinguals, or focus groups of potential research participants. Thus, to validate this translation, the translated version was reviewed by the Indonesian researcher who previously reviewed the English version. In addition, a colleague who has a degree in applied linguistics also reviewed it. Both reviewers were bilingual people. In the next step, the translated questionnaire was reviewed by three Indonesian mathematics teachers then they provided some comments on the clarity of the direction of the questionnaire and some unclear terms in the questionnaire.

The last stage is to check the reliability of the questionnaire by testing it with a small group of mathematics teachers in Indonesia. Due to the geographical distance and time and funding constraints of travelling to Indonesia for the pilot study, the questionnaire was administered through an online survey. I contacted the participants via email and sent them a link to the online questionnaire. The questionnaires were sent to 25 mathematics teachers, and 19 of them completed it. Those who participated in the pilot study were not included in the main study. This aligns with Bryman (2008) who says that a pilot study participant should not be used with participants who might become participants for the main study. Detailed demographic information of the participants in the pilot study is shown in Table 5-6.

Table 5-6: Demographic characteristics of the participants in the pilot study

Demographic		Percentage of Participants
Gender	:	Female: 63% and Male: 37%
Teaching Experience	:	1-5 Years: 42%; 6-10 Years: 42%; 11-20 Years: 16%; 21-30 Years: 0%; and over 30 Years: 0%
Level of Education	:	Bachelor Degree: 68%; Master degree or above: 32%; and post-secondary degree: 0%
Teaching Certificate	:	Yes: 58% and No: 42%

The data showed that participants in the pilot study did not represent all the demographic groups of the teachers. For instance, there were no participants from the group of teachers with a post-secondary degree and teachers with teaching experience over 20 years. However, for the other groups, the participants represented all categories.

5.5.2 Qualitative Instrument

The pilot study for the qualitative phase took place in Indonesian and in an actual classroom setting. The observation and the semi-structured interview were piloted one time with a secondary mathematics teacher. The characteristics of the participant in the qualitative phase of the pilot study are highlighted as follows.

The participant for the pilot test for the qualitative instrument was a female secondary mathematics teacher who had been teaching for five years. She holds a bachelor's and master's degree, both in mathematics education, yet she did not hold a teaching certificate. Her school was located about 25 miles away from the capital of Aceh province. The school was equipped with a computer room that was available for teaching and learning of mathematics. The teacher used the computer room and GeoGebra software when the observation took place.

The pilot study aimed to test the interview questions. Moreover, this piloting also aimed to decide whether the seating arrangement, place and timing of interviews were suitable. It was also important to mention that, in the pilot study, I tried out using devices for audiotaping and the videotaping, and a found the good position for the devices to avoid distractions they may have caused in the classroom.

5.6 Reliability and Validity

Reliability and the validity are two factors that determine the quality of the measurement instrument. Reliability deals with the ability to produce similar results when repeated measurements are conducted under identical conditions while validity refers to the extent to which the measurement is free of measurement errors (Muijs, 2004). The following section discusses the reliability and validity of the quantitative and qualitative instruments.

5.6.1 Quantitative Phase

With respect to reliability, this study used internal consistency reliability to examine the instrument's reliability. Internal consistency refers to consistency within the instruments. The inter-item correlation was assessed by using Cronbach's coefficient alpha of over 0.7 (Muijs, 2004). The analysis provides information on which items need removal from the scale. Final analysis of data produced an alpha coefficient as presented in Table 5-7.

Table 5-7: Cronbach's alpha

Scales	Cronbach's alpha
Teachers' Knowledge	.974
Teachers' Classroom Practices	.968
Teachers' Barriers	.778

The table shows that the alpha coefficients for all scales were over 0.7. Therefore, all the scales have alpha coefficients in the acceptable range.

In terms of the validity of the instrument, content and construct validity were established in evaluating the validity of the questionnaire. According to Muijs (2004), researchers should make sure of the content validity of instruments by looking at its accordance to a theory of how the concepts work. As mentioned previously, the developing of the questionnaire was based on the literature review and conceptual framework as well as the existing instruments. Moreover, the process of development took several stages involving the research supervisors and experts reviewing the instrument. This aimed to ensure content validity of the instrument.

Construct validity was assessed by clarifying the relationship between the internal structure of the instrument's theoretical knowledge of domains measured. To do this, confirmatory factor analysis was used to ensure whether each item measures the subscale that was supposed to measure. According to Muijs (2004), factor loading for survey items helps to show a correction between the item and the overall factor.

Table 5-8 illustrates the outputs of the *Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy* and *Bartlett's test of sphericity*. The KMO statistic varies between 0 and 1. Kaiser (1974) recommends values greater than 0.5 as acceptable. According to Hutchenson and Sofroniou (1999), values between 0.5 and 0.7 are mediocre, between 0.7 and 0.8 are good, between 0.8 and 0.9 are great and above 0.9 are superb.

Table 5-8: KMO and Bartlett's test

Scales	KMO	Bartlett's Test
Teachers' Knowledge	.944	.000
Teachers' Classroom Practices	.924	.000
Teachers' Barriers	.737	.000

Values of scales of teachers' knowledge and teachers' classroom practice are .944 and .924, which fall into the range of being superb. The value for data barriers is .737, which falls into the category of being good. Therefore, it can be concluded that the dataset had adequate correlations between items for factor analysis.

In terms of teachers' knowledge, all items were grouped into one of the four factors. Factor analysis of the data revealed four factors (eigenvalues of 17.3, 2.9, 2.1 and 1.0) and 75.5% of total variation was explained by these factors. This scale had high factor loading (ranging from .634 to .822, .756 to .816, .614 to .874, and .556 to .645 on these fours factors).

Regarding items on teachers' classroom practices in the use of ICT, all items were grouped into one of the five factors with eigenvalues of 18.6, 2.4, 2.2, 1.4, and 1.1. Furthermore, 69.6% of total variation was explained by these factors. Factor loadings for this scale were clear, with reasonably high factor loadings (ranging from .490 to .786, .492 to .868, .660 to .778, .462 to .847, and .460 to .742 on these five factors).

In relation to teachers' barriers to the use of ICT, factor analysis of the data revealed three factors with eigenvalues of 3.6, 1.7, and 1.2. Moreover, 64.8% of total variation was explained by these factors. This scale had reasonably high factor loading ranging from .603 to .793, .535 to .625, and .562 to .562 on these three factors.

5.6.2 Qualitative Phase

Many qualitative researchers disagree with the notion of validity and reliability. They propose new terms with which to discuss validity and reliability (Seidman, 2006). As a result, there are several terms used in judging the quality of qualitative research. For instance, Lincoln and Guba (1985) substitute the term validity with "authenticity", "trustworthiness", "credibility" (replacing the quantitative concept of external validity), "dependability" (replacing the quantitative concept of reliability), and "confirmability" (replacing the quantitative concept of objectivity) (Cohen et al., 2011).

In the qualitative phase, validity or credibility was emphasised in the process. Hence, researchers conducting qualitative research assess the credibility of their data by judging their transparency, consistency, coherence and communicability (Rubin & Rubin, 1995). In the present study, to judge transparency, I recorded all the interviews and classroom observations carefully, besides taking written notes, as well as providing an interview's transkrip for each participant. This allows others to read the transkrips or play back the recordings. Moreover, Rubin and Rubin (1995) also state that the validity of interviews can be ensured by preparing extensive background information to help formulate specific and detailed information for inclusion in the interview questions. In this study, specify information was provided in the interview questions in order to ensure the participants understood the questions well.

Moreover, according to Creswell (2007) one of the strategies to validate a qualitative study is triangulation in which different sources and methods are used to provide supporting evidence. In the qualitative phase of the present study, I conducted methods for triangulation involving classroom observations and interviews in order to enhance the trustworthiness of the qualitative phase of the study. Moreover, reliability in qualitative research refers to the stability of responses to multiple coders of a data set (Creswell, 2007). Therefore, in this study, reliability was enhanced by obtaining detailed field notes and developing a codebook of codes that represent the coding analysis.

5.7 Procedure for Data Collection

As mentioned previously, this study employed an explanatory sequential mixed method design. According to Creswell and Plano-Clark (2007), sequential data collection is employed in this design in which quantitative data is collected first which and then followed by the qualitative phase. Thus, the two data sets were collected independently and in different forms. The questionnaires were administered first which was then followed by classroom observations and semi-structured interviews. The following sections present the procedures for data collection for both the quantitative and qualitative phases.

5.7.1 Quantitative Phase

The quantitative phase of this study employed a cross-sectional survey approach. This approach is employed to gather information through the questionnaire. According to Creswell (2009), the survey approach collects data at a single time from a group and it is mainly used to gather information concerning individuals' opinions, beliefs, perceptions, or practices. Hence, a cross-sectional survey approach was appropriate for the collection of the quantitative data for the present study. In this section, the procedure for quantitative data collection is discussed in further details.

It is important to note that before I started data collection, I submitted a research ethics application to the Provincial Office of Education in Aceh Province. It is a requirement to obtain research approval from the government before collecting data for any research in the country. The office issued an approval letter (see Appendix A.4) that I then attached it to each questionnaire. Having the approval letter attached to the questionnaire was important in the Indonesian context since the teachers will not participate in any research if there is no proof or evidence that the study has been approved by the authority.

As mentioned in Section 5.3, I distributed the questionnaires to 440 teachers in 93 Schools in 16 regencies/cities. Moreover, has also been previously mentioned that it was a challenging task to distribute 440 questionnaires in 93 senior secondary schools. Thus, to overcome this challenge, I contacted coordinators of the mathematics teachers from 16 selected regencies/cities. This communication was necessary because I needed their support in distributing the questionnaires.

In the Aceh province, mathematics teachers are involved in a teacher forum in each city or regency that holds monthly meetings aimed at teacher development. The mathematics coordinators granted me the access to distribute the questionnaires to the teachers from the selected schools who were attending the meeting. It is important to note that the questionnaires were not distributed to all teachers attending the meeting since they were intended for the teachers from the selected schools. Moreover, teachers from selected schools who did not attend the meeting received the questionnaires from either their colleagues or their coordinators. This procedure aimed to ensure the participants in this study represented the population well. Moreover, to ensure the confidentiality, all participants were asked to return the completed questionnaires in the envelopes and they returned them to either the researcher or the mathematics coordinators.

By having the mathematics teacher coordinator’s support in distributing the questionnaire, fortunately, a total 355 of the questionnaires were returned which resulted in a response rate of 78.8%. Furthermore, there were 14 questionnaires found incomplete, leaving 341 questionnaires for the analysis. I think that this reasonably high response rate is due to the following factors. Firstly, I attached the research approval letter from the Provincial Office of Education in Aceh Province to each questionnaire as a way of informing the participants that the government has approved of this data collection. In addition, coordinators of mathematics teachers from each selected regency/city helped by granting me access to distribute the questionnaires in the meetings; therefore, most of the participants received the questionnaires directly. I believe this approach has not influences the independence of the participant in questionnaires responses since the approval letter only mentioned that the research has been approved by the government. Moreover, I am also confident that the distribution of the questionaires through the teacher forum did not ruin the norms of the random sampling approach as I only used the forums as a way to deliver the questionnaires once I had randomly selected the schools for the study.

5.7.2 Qualitative Phase

As discussed earlier, the qualitative data were collected through classroom observations and semi-structured interviews. Furthermore, the qualitative phase attempted to provide a detailed description of teacher classroom practices in the use of a specific type of ICT tool called of Mathematics Analysis Software, and the relationship between teachers' knowledge and their classroom practices. Qualitative data collection commenced after the questionnaire results were analysed. As mentioned earlier in Section 5.3, a purposeful sample of 12 teachers was selected from participants who expressed interest in participating in the classroom observations and interviews. However, it is important to note that one of the participants withdrew from the research and one participant did not satisfy the criteria. Therefore, 10 participants were involved in the qualitative phase of the study. Table 5-9 highlights the characteristics of participants in classroom observations and interviews.

Table 5-9: Demographic information of selected participants in the qualitative phase

Participant	Gender	T. Experience	Level Of Education	T. Certificate	Type of School
Rina	Female	1 Year	Bachelor Degree	No	MoEC
Mir	Female	2 Years	Bachelor Degree	No	MoEC
Muti	Female	17 Years	Master Degree	Yes	MoRA
Anton	Male	10 Years	Master Degree	Yes	MoEC
Abu	Male	11 Years	Master Degree	Yes	MoEC
Laila	Female	13 Years	Bachelor	Yes	MoEC
Din	Male	20 Years	Bachelor Degree	Yes	MoEC
Hari	Male	14 Years	Master Degree	Yes	MoEC
Alfin	Male	8 Years	Bachelor Degree	No	MoEC
Bute	Female	4 Years	Master Degree	No	MoEC

I observed one lesson for each participant ranging from 60-90 minutes. Participants were free to choose topics they taught based on their teaching's syllabus and schedule. As an observer, I sat at the back of the classes taking notes on teachers' classroom practices (see Appendix C.3). Moreover, in order to ensure that I captured all the classroom practices regarding the use of ICT, with the participants' approval, I recorded all the observed classes.

Furthermore, classroom observations were followed up by semi-structured interviews for which the participants were free to decide time and place for the interviews. All the participants wanted to be interviewed right after the classroom observations. Nine interviews took place in teachers' offices while the other one happened in the school's park. The interviews last for about 30 to 35 minutes. By getting participants' approval, the interviews were audiotape recorded.

5.8 Data Analysis

According to Onwuebuzie and Teddlie (2003), mixed method data analysis incorporates analytical techniques applied to both qualitative and quantitative data as well as to the mixing of the two types of data concurrently and sequentially in a study. It also involves analysing both sets of data using the technique that combines quantitative and qualitative data and results (Creswell & Plano Clark, 2011, p. 203). Once analyses are completed, mixed methods interpretation occurs looking across the quantitative results and qualitative findings. The final step is in making an assessment of how the findings address the questions in a study (Creswell & Plano Clark, 2011). As previously discussed in this chapter, my methodological approach was sequential mixed method design within which I collected data in two phases and analysed them in two consecutive phases and then the results were connected and integrated.

Several techniques were employed for analysis of the data in this study. Data collected from the questionnaires were analysed using the quantitative technique while data gathered from classroom observation and interviews were analysed using the qualitative analyses. Further details of the quantitative and the qualitative data analysis are discussed in the following sections.

5.8.1 Analysis of Quantitative Data

Two main steps were employed in the process of quantitative data analysis. This involved preparing the data for analysis and conducting the data analysis. To prepare the data for analysis, numeric scores were first assigned to the data, selecting a statistical program, entering the data into the selected software, cleaning and accounting for missing values. The second step was performing data analysis: this included descriptive and inferential statistical analysis to answer the research questions. The next sections present these steps in more details.

Preparation of the data

Scoring the data: the first step in preparing the data for analysis was scoring the data, creating a codebook and determining the type of scores to use (Gay et al., 2012). I began by assigning a numeric score to each responses category or choice for each question on the questionnaire used to collect the data. For the scales of teachers' knowledge, classroom practices and barriers, I consistently scored each item on this scale using the same numbering system as the questionnaire. For instance, in the teachers' knowledge scale, the answers ranged from 'Strongly' Agree" to 'Strongly Disagree' and were scored as a '5' to '1'. For categorical scales, for instance, gender, I arbitrarily assigned numbers, that is, 1= Male, 2 = Female.

Data entry: regarding statistical programs, there are various programs available for conducting data analysis. To determine the appropriate program, I followed the guideline suggested by Ormrod and Leedy (2005) when choosing a statistical program. Hence, I selected the *Statistical Package for the Social Science (SPSS) V.22* to use for conducting the quantitative data analysis. After selecting the Statistical Software, I entered the quantitative data from the questionnaires into an SPSS dataset. This step is known as entering or imputing the data (Gay et al., 2012). I used the data scores discussesed earlier for values of the variables in SPSS.

Data cleaning: among the 355 returned questionnaires, I found 14 questionnaires not completed. I assumed that the reason for not completing the items by the participants might be that they had just ignored the items, or they wanted to finish the task quickly, or the might have been carelessness. I therefore considered those cases as missing completely at random (Little & Rubin, 2002). I employed a 'listwise deletion' approach. According to this method, I deleted the 14 incompleted questionnaires and conducted analysis with 341 sets of completed responses. As 14 out of 355 questionnaires was not a significant number, there was a minimum risk of any biased measurement and analysis.

Analysis of the data

Quantitative data analysis serves several purposes. Firstly, this study used descriptive statistics to describe, summarise, and explain participants' background information. Secondly, this data analysis technique was used to answer research question #1, research question # 2, and research question # 4.

Research question # 1: *What knowledge do Indonesian secondary mathematics teachers have about ICT and its use in teaching?.* As has been previously mentioned in Section 5.2, this research question was investigated quantitatively. Regarding the quantitative analysis, to answer this question, a frequency distribution of responses on all items of teachers' knowledge was presented in charts. Furthermore, all responses on teachers' knowledge were coded in a 5-point scale. Means of all items were also described by using Handal et al.'s (2013) questionnaire score range as presented in Table 5-10. A repeated measure

ANOVA and paired- t test were employed to examine significant differences in teachers' knowledge across survey items.

Moreover, those categories were grouped into two main categories that are sufficient and insufficient knowledge. The categories of very high, high, moderately high and slightly above average were categorised into sufficient knowledge while the categories of average, slightly below average, moderately low, low and very low were classified as insufficient knowledge.

Table 5-10: Questionnaire score range

Score Range	Qualitative Descriptive	Level of Knowledge
$1.0 \le X < 1.5$	Very Low	Insufficient Knowledge
$1.5 \le X < 2$	Low	
$2.0 \le X < 2.5$	Moderately Low	
$2.5 \le X < 3.0$	Slightly below average	
3.0	Average	
$3.0 < X \le 3.5$	Slightly above average	Sufficient Knowledge
$3.5 < X \le 4.0$	Moderately high	
$4.0 < X \le 4.5$	High	
$4.5 < X \le 5.0$	Very high	

Source: adapted from Handal et al. (2013)

Research question # 2: *How do Indonesian secondary mathematics teachers use ICT in their teaching practices?*. As it mentioned earlier in Section 5.2, this research question was investigated in the quantitative and the qualitative phase of this research. Regarding the quantitative data analysis, frequency distributions of all items were presented in charts. Moreover, mean scores of all items were also presented. A repeated measure ANOVA and paired- t test were employed to examine significant differences in teachers' classroom practices across categories. These aimed to gain a broad overview of teachers' classroom practices which were then followed by classroom observations and semi-structured interviews. The analysis of classroom observation data and interview is presented in the next Section 5.8.2.

Research question #4: *What barriers do Indonesian secondary mathematics teachers face in using ICT in the classroom?.* This question was solely investigated through the quantitative data. As it mentioned in Section 1.2, this is not the main research question for this study. To answer the research question, the frequency distribution of participants' responses for each item was presented in charts. Moreover, mean scores were also described to determine what barriers the teachers mainly encountered. A repeated measure ANOVA and paired-t test were employed to examine significant differences in teachers' barrier across categories.

Research question #3: *What is the relationship between teachers' knowledge and classroom practices in the use of ICT in mathematics teaching?.* The variables in this question were teachers' classroom practices and their knowledge. As mentioned in the conceptual framework, in this study, teachers' knowledge was classified into knowledge of ICT and knowledge of ICT use in teaching. Thus, I used data gathered from the questionnaire (Part III (Q22-Q30)) and (Part II (Q12-Q18)). To answer the question, I employed Spearman's correlation. There are several assumptions that need to be satisfied in order to produce valid results from a Spearman's correlation test. Those assumptions are presented in Section 6.5.

Research Question #5: *Are there significant differences in terms of teachers' knowledge and classroom practices according to their backgrounds?.* As discussed in Section 1.2, this study was also designed to examine differences in teachers' knowledge and classroom practices in the use of ICT according to their background (gender, level of education, teacher certification, teaching experience, and type of school). Thus, the statistical tests used in the analysis are presented in Table 5-8.

The Mann-Whitney U test is a rank-based nonparametric test that can be used to determine if there are differences between two groups on a continuous or ordinal dependent variable. According to Sheskin (2004), there are four assumptions which need to be satisfied in order to produce a valid result for this nonparametric test. The assumptions are explained in details in Section 6.5.

The Kruskal-Wallis H test is a rank-based nonparametric test that can be employed to examine if there are statistically significant differences between two or more groups of an independent variable on an ordinal or continuous dependent variable. To produce a valid result for this test, there are four assumptions which need to be met (Sheskin, 2004). The assumptions are explained in further details in Section 6.5. Furthermore, Dunn's pairwise tests were carried out to examine significant difference of teachers' knowledge and classroom practices across pairs of the groups.

Table 5-11: Statistics tests

Dependent Variable	Independent Variable	Statistics Test
Teachers' Knowledge (Ordinal) and Teachers' Practice (Ordinal);	Gender	Mann-Whitney
	Level of Education	Kruskal-Wallis and Dunn Pairwise
	Teacher Certification	Mann-Whitney
	Teaching Experience	Kruskal-Wallis and Dunn Pairwise
	Type of School	Mann-Whitney

5.8.2 Analysis of Qualitative Data

In the analysis of the qualitative data, I followed the similar steps for the procedure of the quantitative data analysis in terms of preparation of the data and analysis of the data.

Preparation of the Data

Data entry: I transcribed the interviews in Indonesian language. Moreover, videotapes focusing mainly on teachers were also transcribed in Indonesian language. The transcripts were not intended to be a replacement for the viewing of classroom observation and videotaped teachers' classroom practiced; however, the transcript served as an aid in the coding and analysis of teachers' classroom practices. Therefore, the transcription of the videotaped data mainly focused on teachers' spoken words and activities during the lesson. The transcriptions of the interview and videotaped data were composed in Microsoft Word file and imported in the NVivo software.

Data cleaning: As I transcribed and translated the interview simultaneously, after transcribing one interview I re-checked the content and revised the translated texts whenever necessary. These processes were carried out for all the interviews. Moreover, I tried to ensure that the translation properly contained the meaning of the original data. Finally, after composing the transcripts in MS Word files, I formatted the page layout so that the participants' responses were clearly comprehensible.

Analysis of the Data

For analysis of the qualitative data, a thematic analysis approach was employed. According to Braun and Clarke (2006), thematic analysis is a method for identifying, analysing, and reporting patterns (themes) within data. Moreover, in the thematic analysis, themes or patterns within data can be identified in one of two main ways: an inductive way, or a theoretical or deductive way (Braun &

Clarke, 2006). An inductive way means the theme identified is strongly linked to the data themselves. On the other hand, a 'theoretical' thematic analysis tend to be driven by the researcher's theoretical interest in the area (Braun & Clarke, 2006). In the theoretical approach, the research can code for a specific research question. In addition, with a theoretical approach, the researcher may focus on particular features in coding the data. Therefore, the present study employed a deductive qualitative analysis approach to analyse classroom observation and interview data.

Classroom observation: for the domain of teacher's practice, themes were analysed based on Piece and Stacey's (2010) pedagogical map (see Figure 3-3) which consists of three levels.

Table 5-12: Themes of teachers' classroom practices

Task Level	Descriptors
Learn pen-and paper skills	Using instant 'answers' as feedback when learning processes
Use real data	Working on real problems involving calculations
Explore regularity and variation	Strategically varying computations search for patterns; Observing effect of parameters; Using general forms.
Stimulate real situations	Using dynamic diagrams, dragging and collecting data for analysis; Using technology generated statistical data sets.
Link Representation	Moving fluidly between geometric, numeric, graphic and symbolic representations.
Classroom Level	**Descriptors**
Change classroom social dynamic	Teachers facilitate rather than dictate; Teachers encourage group work as well as encouraging students to initiate discussion and share their learning with the class
Change classroom didactic contract	Teachers allow technology to become a new authority; Change what is expected of students and teachers; Permit or constrain explosion of available methods
Subject Level	**Descriptors**
Exploit contrast of ideal and machine mathematics	Teachers deliberately use 'unexpected' error messages, format of expressions, graphical displays as catalyst for rich mathematical discussion
Rebalance emphasis on skills, concepts, applications	Teachers adjust goals: spend less time on routine skills, more time on concepts and applications; teachers increase emphasis on mathematical thinking.
Build metacognition and overview	Teachers give overview as introduction or summation: link concepts through manipulation of symbolic expressions and use multiple representations.

Teachers' classroom practices were analysed using the pedagogical map, which consists of three levels: task level, classroom level and subject level. Guidelines of characteristics of classroom activities for each level were based on the pedagogical map and presented in Table 5-12.

Semi-structured interviews: as discussed earlier, classroom observations were followed by semi-structured interviews, mostly directly following the lessons to help clarify the observation and to collect information about teachers' typical classroom practices when teachers use ICT in mathematics teaching. Note and audio recording from these sources provide additional data to triangulate the actions of the participants expressed in the classroom. Regarding teacher classroom practices, interview data were also analysed based on the themes of the pedagogical map as presented in Table 5-12.

Triangulation of classroom observation and interviews: as mentioned in earlier, methodological triangulation combining classroom observation data with interview data were carried out in the qualitative phase of this study. According to Kopinak (1999, p. 171), methodological triangulation is:

> Gathering information pertaining to the same phenomenon through more than one method, primarily in order to determine if there is a convergence and hence increase validity in research findings.

Moreover, in such a triangulation procedure, the way data are analysed plays important role (Meijer, Verloop, & Beijaard, 2002).

According to Smaling (1987) (as cited in Meijer et al., 2002), there are three approaches for conducting of analysis of methodological triangulation. The first is an intuitive approach: an individual researcher intuitively relates data from various instruments to each other. The second is a procedural approach: the focus is on documenting each step that is taken in the triangulation procedure in order to make it transparent. The third approach is the intersubjective approach in which a group of researchers tries to reach agreement about the steps to be taken in the triangulation procedure. In the present study, I employed the procedural approach to conduct analysis of triangulation.

Search patterns of the relationship between teachers' knowledge and classroom practices: after triangulating classroom observation and interview data for teachers' classroom practices, I searched for a pattern of teachers' classroom practices based on the level of their knowledge to identify the relationship between teachers' knowledge and their classroom practices.

Levels of both teachers' knowledge of ICT and teacher's knowledge of ICT use in teaching are referred to in Table 5-10. Therefore, levels of teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching were classified into sufficient knowledge and insufficient knowledge. The next step involved comparing teachers' classroom practices at the subject level, the classroom level and the task level between teachers with sufficient and teachers with insufficient knowledge of ICT and knowledge of ICT use in teaching.

5.9 Research Permission and Ethical Issues

In conducting an educational study, a researcher has to carefully consider the ethical issues. Denscombe (2010, p. 329) argues that "social researchers are expected to approach their task in an ethical manner". He then continues by claiming that "researchers have no privileged position in the society that justifies them pursuing their interest at the expense of those they are studying no matter how valuable they hope the finding might be". Walliman (2011) makes a stronger argument that the value of research depends on its ethical validity as much as on the novelty of its discoveries.

Research permission for this study was approved by the Research Governance Office of Southampton University on 23rd February 2016 through Ethics and Research Governance Online (ERGO) (see Appendix A.3). The application form contained a description of the researcher, the project, the rationale, aims of the study, the design of the study, research participants. Moreover, the application was submitted along with consent forms, participant information sheets, risk assessment forms, and an assessment for international travel form. In addition, the research instruments included in the application were the questionnaire and the interview protocol.

In the quantitative phase, there was no consent form attached to the questionnaire, since by completing it the participants agreed to participate in the study. The information provided on the cover page of the questionnaire informed them about the purpose of the study, confidentiality, length of completion and the use of information for research purposes only. On the other hand, in the qualitative phase, the classroom observation and interview participant information sheets were distributed to selected participants in order to ask them to voluntarily take part in the study. In addition, they received a consent form to be signed.

Anonymity and confidentiality were a priority in the process of data collection, storing, analysis and writing up. Participants were informed about the anonymity and confidentiality of the study verbally and in writing in the information sheets. All the data such as notes and recordings were kept in a safe place, in a password protected computer. Moreover, any hard copies of data were kept locked with a key in a safe.

The questionnaires were anonymous, and participants did not have to give their names or any other information that may enable anyone to identify them. Even I did not know who returned the questionnaires except for those of respondents who agreed to participate in the qualitative phase since they were required to provide their name and contact details on the questionnaire. In the observations and interviews, I did not expose the real names of the participants; therefore, pseudonyms were used. Moreover, personal descriptions may be altered if necessary so that no one can identify individuals. This was done to protect them and to ensure that they could freely express their opinions.

5.10 Limitations of the Research Design

There were several limitations in this research design. Firstly, data collection for the study took place in only one province in Indonesia. Thus, its findings might not be generalisable to all Indonesian provinces since Indonesia is a large and diverse country. Secondly, the classroom observation was only conducted one time for each selected teacher and that may not have provided a complete picture of what actually happens in the classroom. Thirdly, the classroom observation also involves methodological concerns that can interfere with the drawing of valid conclusions. One of the primary methodological concerns of classroom observations is that observers' effects may change teachers' behaviours.

5.11 Summary

To summarise, a sequential mixed methods design was employed for which both quantitative and qualitative data collections took place sequentially. This type of design assisted in providing rich and deep data about Indonesian secondary mathematics teachers' knowledge and classroom practice in the use of ICT. In total, 341 teachers participated in the quantitative phase and 10 of them were volunteered to participate in the qualitative phase. This research administered three research instruments: the questionnaire, the classroom observation and the semi-structured interview. Data analysis incorporated techniques for both qualitative and qualitative data in sequence. Once analyses were completed, findings from both data were integrated. The design of this study, however, has limitations such as that classroom observations were carried out once for each selected participant and the data collection was conducted only in one province of Indonesia.

In the next chapter, I present quantitative results. It consists of demographic information, results of descriptive analysis and results of the inferential statistical analysis.

Chapter 6 Quantitative Results

The aim of this chapter is to present results of the quantitative analysis. The chapter consists of five main sections that begin with participants' demographic information. The following section provides the descriptive analysis of teachers' knowledge and it is then followed by a presentation of the descriptive analysis of teachers' use of ICT. In addition, descriptive analysis of teachers' barriers to ICT integration is also explored in section 6.4. Finally, this chapter presents results of inferential statistics tests in relation to the relationship between teachers' knowledge and their classroom practices as well as differences in knowledge and classroom practices based on teachers' background.

6.1 Demographic Information

This section reports participants' characteristics such as gender, age, teaching experience, the highest level of education, type of school, and professional development. In order to determine whether the participants well represented the population, data of the population published by Aceh Provincial Office of Education in 2014 are also provided in this section.

6.1.1 Gender

The majority of the participants (62.6%) were male teachers while female participants constituted 37.4% of total participants. As presented in Figure 6-1, regarding gender, the participants did not well represent the population. According to Aceh Provincial Office of Education's data, there were 54.35% of male teachers, while female teachers constituted 45.65% of the population.

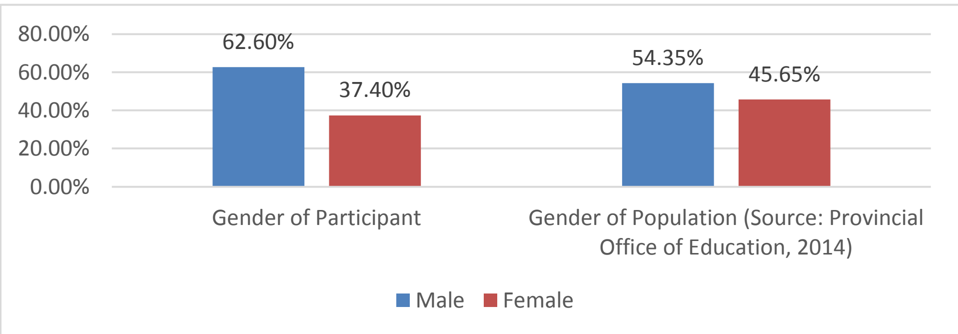

Figure 6-1: Distribution of the participants according to gender

6.1.2 Age and Year of Teaching Experience

Age: Participants' age group fell into five categories: (1) 30 years old or less; (2) 31 to 35 years old; (3) 36 to 45 years old; (4) 46 to 55 years old; and (5) over 55 years old. The majority of participants (29.4%) were between 46 to 55 years old. Moreover, the group of 36 to 45 years old was ranked second (27.5%) while the group of 31 to 35 years old was the third one which constituted 20.8% of the participants. The age category of 30 years old or less had the smallest number of participants (5%) while the age category over 55 years old was the second lowest one (17.3%).

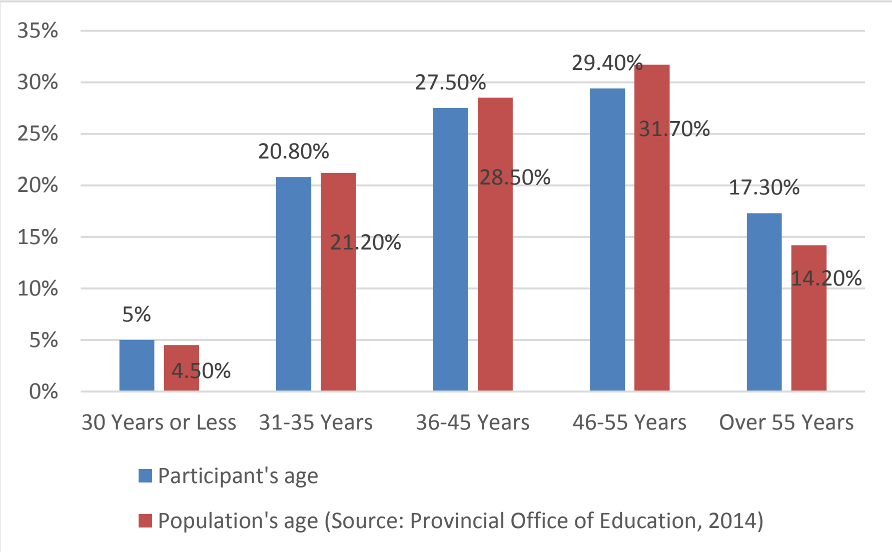

Figure 6-2: Distribution of the participants according to age

The age categories and the representations of participants in this study mirrored the data released by Provincial Office of Education of Aceh province (2014). According to the data presented in Figure 6-2, the majority of mathematics teachers was between 46 to 55 years old (31.7%), and 36 to 45 years old was ranked second (28.5%). The third biggest number of the participants (20.8%) was from the group of 31 to 35 years old, and it is then followed by the group of over 55 years old (14.2%). The smallest one was the group of 30 years old or less (4.5%). Thus, regarding the distribution of the participants by age, the participants of this study well represented the population.

Years of Teaching Experience: Figure 6-3 shows that the majority of the participants (27.2%) had been teaching for 21 to 30 years. Groups of teachers with teaching experience of 6 to 10 years and 11 to 20 years occupied the second and the third rank which constituted (24.6%) and (21.9%) of the participants respectively. Meanwhile, the group with teaching experience of 1 to 5 years had the smallest number of the participants (9.5%) while the group of over 30 years had the second smallest number of participants (16.9%).

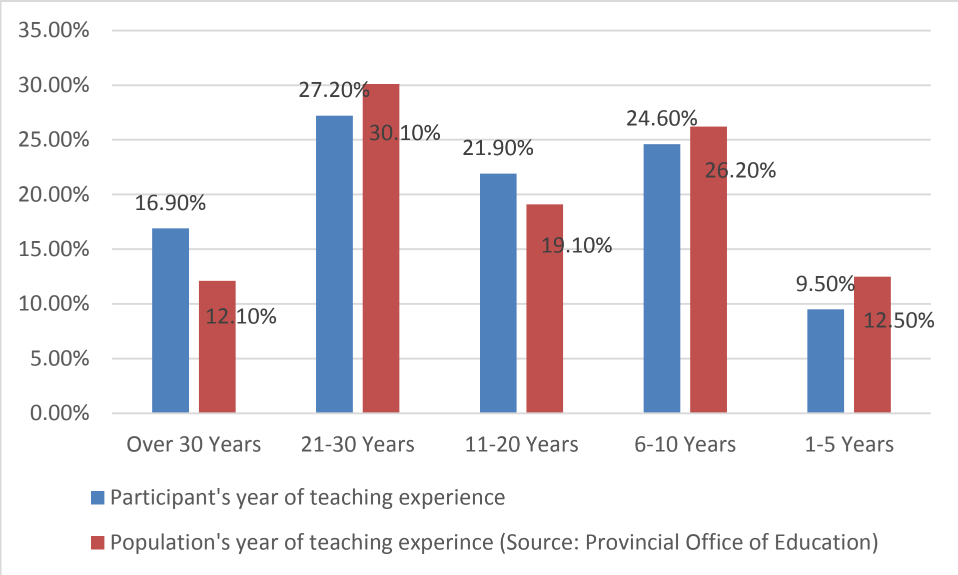

Figure 6-3: Distribution of the participants according to years of teaching experiences

The categories of the number of years of teaching experiences reflected the data published by Aceh Provincial Office of Education. Overall, Figure 6-3 shows that the participants represented the population well. The only big difference is in the age group of over 30 years. For this group, the proportion of the population was 12.1% while the participants of this group constituted 16.9% of the total participants.

6.1.3 Types of School

As mentioned in Chapter 2, both Ministry of Education and Culture (MoEC) and Ministry of Religious Affairs (MoRA) administer Indonesian education. Therefore, teachers from both ministries were involved in this study. Figure 6-4 shows that the majority of participants (85.67%) of this study were teachers from MoEC schools. It was relatively reflected the actual numbers of teachers (81.8%) from the ministry. Furthermore, the figure shows that participants from MoRA schools constituted 14.33% of the total participants. This number of the participants relatively well represented the teacher population from the ministry (18%).

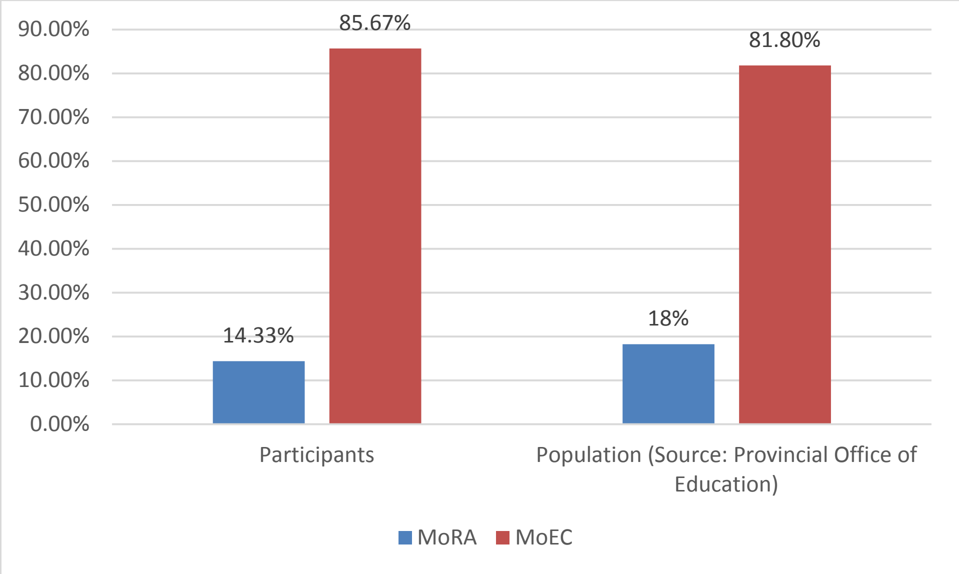

Figure 6-4: Distribution of the participants according to types of school

6.1.4 Level of Education and Certification

This study captured three aspects in terms of teachers' education, namely the highest level of education, type of degree and teachers' certification. Distribution of participants' highest level of education is presented in the following section.

Level of Education: Figure 6-5 shows that the majority of participants (90.77%) held an undergraduate degree which is the lowest degree required by the Indonesian law to be eligible to teach at a secondary school. However, there was a small number of the participants (0.59%) who held a post-secondary degree. This indicated that the regulation had not been fully implemented yet. The number of participants (90.77%) well represented the population of the undergraduate degree group (93.4%). However, for the other groups, participants were not fully mirrored the population.

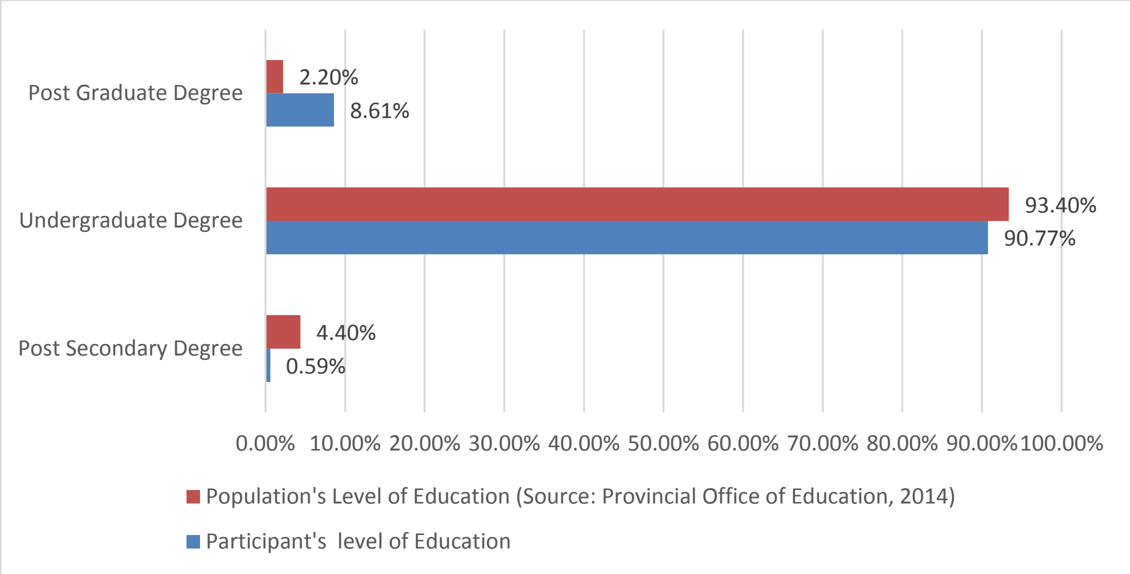

Figure 6-5: Distribution of the participants according to the level of education

Type of Degree: Along with participants' level of education, the questionnaire also collected data about types of degree the participants hold. The majority of participants (87.57%) had a degree in mathematics education while only 6.51% of the participants earned a degree in mathematics. However, there were a small number of the participants (5.92%) who hold a degree in neither mathematics nor mathematics education.

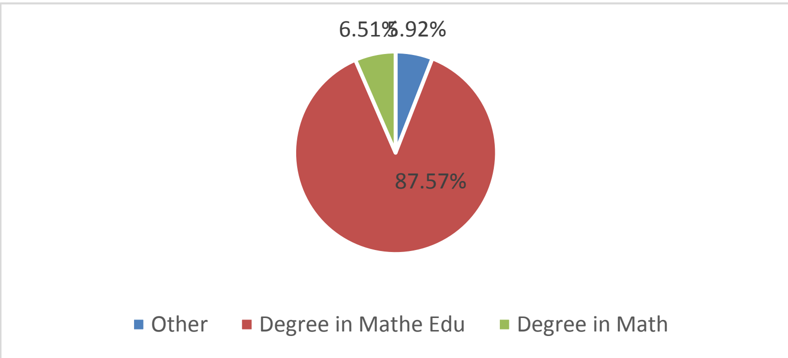

Figure 6-6: Distribution of the participants according to type of degree

Teachers' Certification: As mentioned in Chapter 2, the Indonesian government has stipulated teachers' certification programme. It requires all teachers to take a training course and pass a test in order to be awarded a teaching certificate. However, as Indonesia has a huge number of teachers, this programme has been implemented gradually since 2010. Figure 6-7 shows that only about half of participants (52.94%) had a teaching certificate. However, according to the government data (2014), teachers who had the teaching certificate were 33.7% of total teachers. Hence, the distribution of participants did not fully represent the population. I assume this happened because both data were not collected at the same time. The data collection of this study took place in early 2016 while the government's data was published in 2014. Therefore, there was a two-year gap, and I believe more teachers have been certificated during those two years.

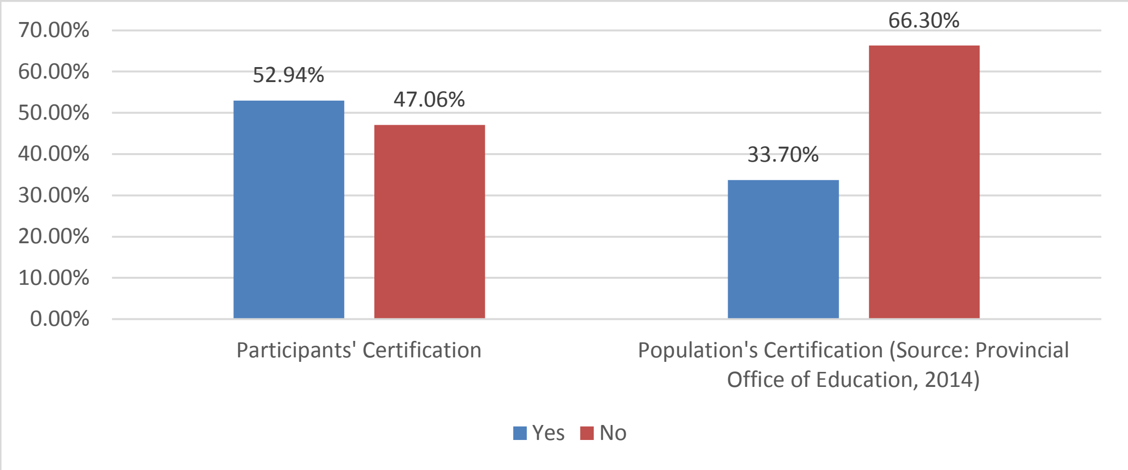

Figure 6-7: Distribution of the participants according to teacher's certification

6.1.5 ICT Training Courses

Figure 6-8 shows that the majority of the participants (64.81%) had participated in a training course of ICT at least once. However, it is surprising that a moderately large numbers of the participants (35.19%) did not participate in any ICT training course.

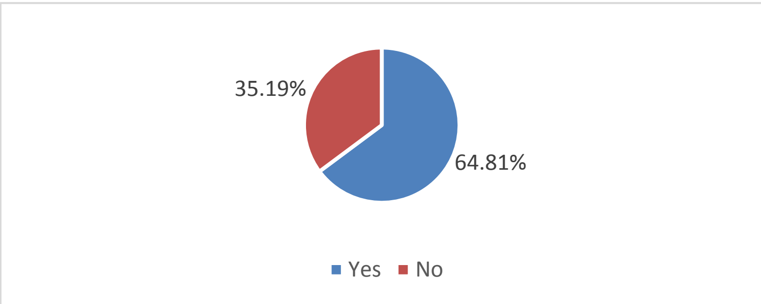

Figure 6-8: Distribution of the participants according to training of ICT

To obtain detailed information, the questionnaire also sought information about training courses the participants had participated. The most common training courses were the use of general software and the integration of ICT into teaching which had been undertaken by 83.7% and 85.1% of the trained participants respectively. Moreover, about half of the trained participants (56.6%) had participated in a training course on the use of mathematical software. On the other hand, training courses in the use of the graphic or the scientific calculator (25.5%) and the use of the Internet (8.6%) received less attention indicating by a small number of participants had participated in both training courses.

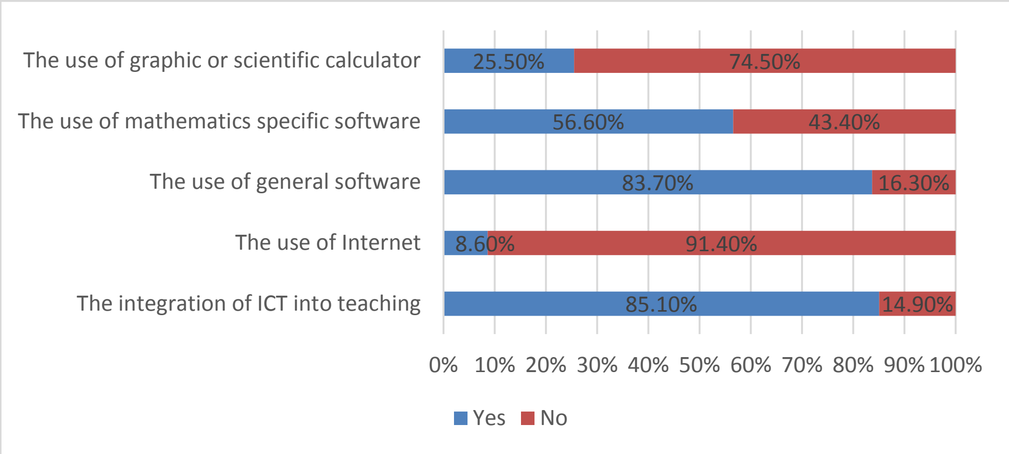

Figure 6-9: Distribution of the participants according to types of training course

6.2 Descriptive Analysis of Teachers' Knowledge

This section reports the findings of the analysis of the frequency distribution, mean and standard deviation of the items about teachers' knowledge. Teachers' knowledge consisted of knowledge of ICT and knowledge of ICT use in teaching. Teachers' knowledge of ICT; including hardware, general software, mathematical software and online resources. Moreover, knowledge of ICT use in teaching involves ICT-Content Knowledge, ICT-Pedagogical Knowledge and ICT-Pedagogical Content Knowledge.

6.2.1 Knowledge of ICT

As mentioned earlier, knowledge of ICT consists of hardware, general software, mathematical software and online resources. Descriptive results of these items are provided in the following sections.

6.2.1.1 Hardware

Percentage of Frequency Distribution

Question 12 of the questionnaire (see Appendix B.1) was about teachers' knowledge in operating hardware. This question consisted of three items, namely computers/laptops, tablets/handheld devices and graphing calculators. Figure 6-10 summarises teachers' responses by displaying the percentage of the distribution of participants' responses about their knowledge of hardware.

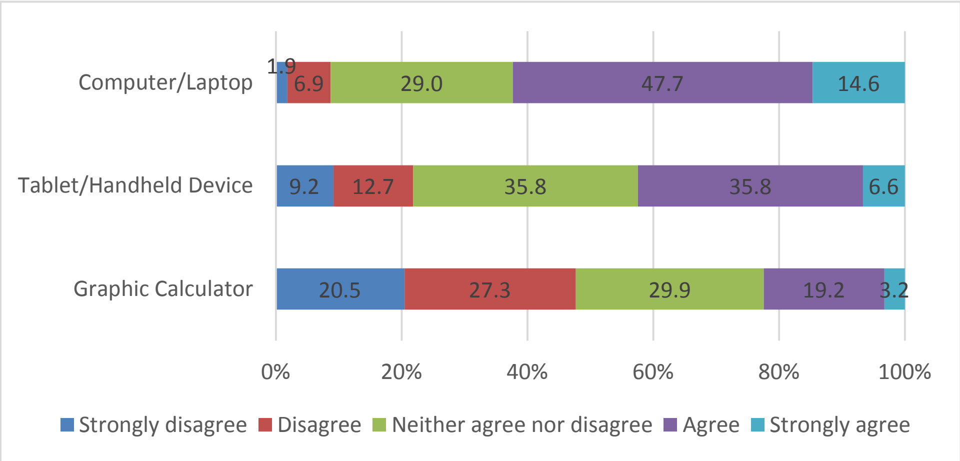

Figure 6-10: Distribution of participants' answers to items regarding knowledge of hardware

Regarding the knowledge of graphing calculator, the statement was "I know how to operate graphing calculator". Figure 6-10 shows that the majority of the participants were unsure about this item. Moreover, 20.5% of the participants strongly disagreed and over a quarter of the participants (27.3%) disagreed with the statements. On the other hand, only (3.2%) of the participants strongly agreed and 19.2% of the participants strongly agreed with the statement.

The second item was about knowledge of the use of tablets/handheld devices, which states "I know how to operate tablet/mobile device. The results show that a large number of the participants (35.8%) were unsure about the statement while the same number of the participants (35.8%) strongly agreed with the statement. Moreover, 9.2% of the participants strongly disagreed and 12.7% of the participants disagreed with the statement. On the other hand, a small number of the participants (6.6%) strongly agreed with the statement.

The last item dealt with knowledge of the use of Computer/Laptop. The majority of the participants (47.7%) agreed and 14.6% of the participants strongly agreed with the statement. On the other hand, only 1.9% of the participants strongly disagreed and 6.9% disagreed with the statement. In addition, a moderately large number of the participants (29%) were unsure about the statement.

Mean and Standard Deviation

The participants' average scores are also provided in order to determine which category of the teachers' knowledge fall into. Table 6-1 shows mean scores across the items in terms of knowledge of hardware.

Table 6-1: Mean scores of participants' responses to items regarding knowledge of hardware

Knowledge of hardware	Mean	Standard Deviation
a. Graphing Calculator	2.57	1.22
b. Tablet/Mobile Device	3.18	1.04
c. Computer/Laptop	3.66	0.88
Mean	3.14	

Teachers' knowledge categories have been classified in Table 5-10 in Section 5.8. The first item had the lowest score on this scale (Mean = 2.57), indicating the participants perceived their knowledge of graphing calculator was slightly below average. The second item revealed teachers' knowledge of Tablet/Mobile devices with a mean score was 3.18. This indicates that the participants' knowledge of this tool was slightly above average. The highest mean score (3.66) was found for the third item stating, "I know how to operate computer/laptop". This indicates that participants perceived a moderately high level of knowledge of laptop/computer.

A repeated measures ANOVA was run in order to determine if there was statisticaly significant difference in teacher knowledge of hardware across the items. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(2) = 28.07,\ p = 0.00$, therefore degree of freedom were corrected using Huynh-Feldt estimate of sphericity ($\varepsilon = .92$). The results show that there was significant differences in teachers level of knowledge of hardware across the items $F(1.84, 540.01) = 163.21$, p = 0.00.

Summary of teachers' knowledge of hardware: It seems obvious that teachers' responses were different across the types of hardware. When it comes to the comparison, the results showed that the teachers' knowledge of the use of computers/laptop was better than their knowledge of the use of tablets/handheld devices and graphing calculators. Overall, the result showed that teachers perceived their knowledge of hardware slightly above average (Mean =3.14). Therefore, it can be concluded that teachers have sufficient knowledge of operating hardware.

6.2.1.2 General software

Question 13 of the questionnaire (see Appendix B.1) dealt with teachers' knowledge of general software. This scale consisted of seven items. Distributions of the responses are presented as follows.

Percentage of Frequency Distribution

Figure 6-11 presents the percentage of distribution of participants' responses to the items about their knowledge of general software.

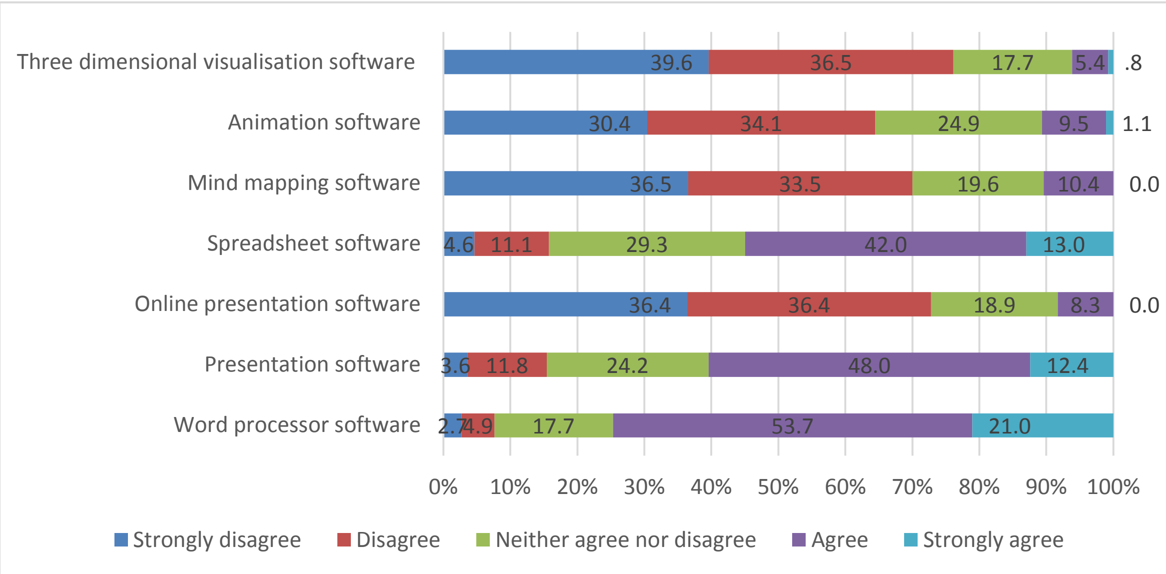

Figure 6-11: Distribution of the participants' answers to items regarding knowledge of general software

For the first item, the majority of the participants had positive responses. They agreed (53.7%) and strongly agreed (21%) with statement "I know how to use word processor software (e.g. Ms Word)". On the other hand, a very small number of the participants (2.7%) strongly disagreed and (4.9%) of the participants disagreed with the statement. In addition, 17.7% of the participants were unsure about the item.

Regarding knowledge of presentation software, the majority of the participants had positive responses. A large number of the participants (48%) agreed and 12.4% of the participants strongly agreed with the statement “I know how to use presentation software (e.g., Ms PowerPoint)”. In contrast, only 3.6% strongly disagreed and 11.8% disagreed with the statement. In addition, 17.7% of the participants remained unsure about their responses.

In the third item, “I know how to use online presentation software (e.g., Prezi)”, the responses were slightly different to the first two items. The majority of participants had negative responses to the statement. A large number of the participants (36.4%) strongly disagreed and the same number (36.4%) disagreed with the statement. Moreover, 18.9% of the participants neither agreed nor disagreed. On the other hand, there was no participant strongly agreed and only 8.3% agreed with the statement.

The fourth item talked about knowledge of Spreadsheet software. The majority of the participants had positive responses to the item. Figure 6-12 shows that majority of the participants (42%) agreed and 13% strongly agreed with the statement. On the other hand, a small number of the participants (4.6%) strongly disagreed and 11.1% of the participants disagreed. In addition, a moderately large number of the participants (29.3%) neither agreed nor disagreed with the statement.

In the fifth item, “I know how to use mind-mapping software (e.g., Inspiration)”, the responses were slightly similar to the third item. The majority of participants had negative responses to the statement that were 36.5% strongly disagreed and 33.5% disagreed. Nevertheless, there was no participant strongly agreed and only 10.4% agreed with the statement. In addition, 19.6% of the participants were neutral in responding the item.

It was similar to the fifth item that the majority of participants had negative responses to the sixth item “I know how to use animation software (e.g., Macromedia Flash)”, that were 30.4% strongly disagreed and 36.5% disagreed. On the other hand, a very small number of the participants had positive responses to the item, consisting of 1.1% strongly agreed and 9.5% agreed. In addition, nearly a quarter of the participants (24.9%) neither agreed nor disagreed with the statement.

The last item “I know how to use three-dimensional visualisation software (e.g., Sketch Up)” also received negative responses from the majority of participants that were 39.6% strongly disagreed and 36.5% agreed. Moreover, 17.7% of the participants had neutral responses to the item. In contrasts, only 0.8% of the participants strongly agreed and 5.4% of the participants agreed with the statement.

Mean and Standard Deviation

The averages of participants’ responses are provided to determine in which category participants’ knowledge fall into. Table 6-2 shows the mean score of knowledge of general software across the items.

Table 6-2: Mean scores of participants' responses to items regarding knowledge of general software

Knowledge of general software	Mean	Std. Deviation
a. Word processor software(e.g., Ms Word)	3.85	0.90
b. Presentation software (e.g., Ms PowerPoint)	3.54	0.98
c. Online presentation software (e.g., Prezi)	1.99	0.94
d. Spreadsheet software (e.g., Ms Excel)	3.48	1.01
e. Mind mapping software (e.g., Inspiration)	2.04	0.99
f. Animation software (e.g., Macromedia Flash)	2.17	1.00
g. Three dimensional visualisation software (e.g., Sketch Up)	1.91	0.92
Mean	2.71	

Across the items, the participants’ knowledge of word processor software was the highest one (Mean = 3.85), indicating most of the participants have moderately high knowledge of this software. Moreover, the participants also perceived their knowledge of presentation software (e.g., Ms Power Point) moderately high (Mean = 3.54). The third highest mean score was knowledge of spreadsheet software which falls into the category of slightly above average (Mean = 3.48). On the other hand, knowledge of using three-dimensional visualisation software (Mean = 1.91) and online presentation software (Mean = 1.99) were low.

A repeated measures ANOVA was run to determine if there was statisticaly significant difference in teacher knowledge of general software across the items. Mauchly’s test indicated that the assumption of sphericity had been violated,

$x^2(20) = 516.59,\ p = 0.00$, therefore degree of freedom were corrected using Greenhouse-Geisser estimate of sphericity ($\varepsilon = .48$). The results show that there was significant differences in teachers level of knowledge of general software across the items *F*(2.86, 686.55) = 461.36, p = .00.

Finally, the results showed that the participants' knowledge of general software was below average (Mean =2.71). Therefore, I can be concluded that teachers had insufficient knowledge of ICT.

6.2.1.3 Mathematical Software

Question 14 of the questionnaire dealt with the participants' knowledge of mathematical software. This question consisted of ten items. The distributions of participants' responses are presented as follows.

Percentage of Frequency Distribution

Figure 6-12 summarises the percentage of participants' responses to each item about their knowledge of mathematical software. In the first item, "I know how to use Maple software", the majority of the participants had negative responses to the item. Thirty-three percent of the participants strongly disagreed and 36.2% of the participants disagreed with the statement. On the other hand, a very small number of the participants (1.4%) strongly agreed and 8.3% of the participants agreed with the statement. In addition, a moderately high number (21.3%) of the participants neither agreed nor disagreed with the statement.

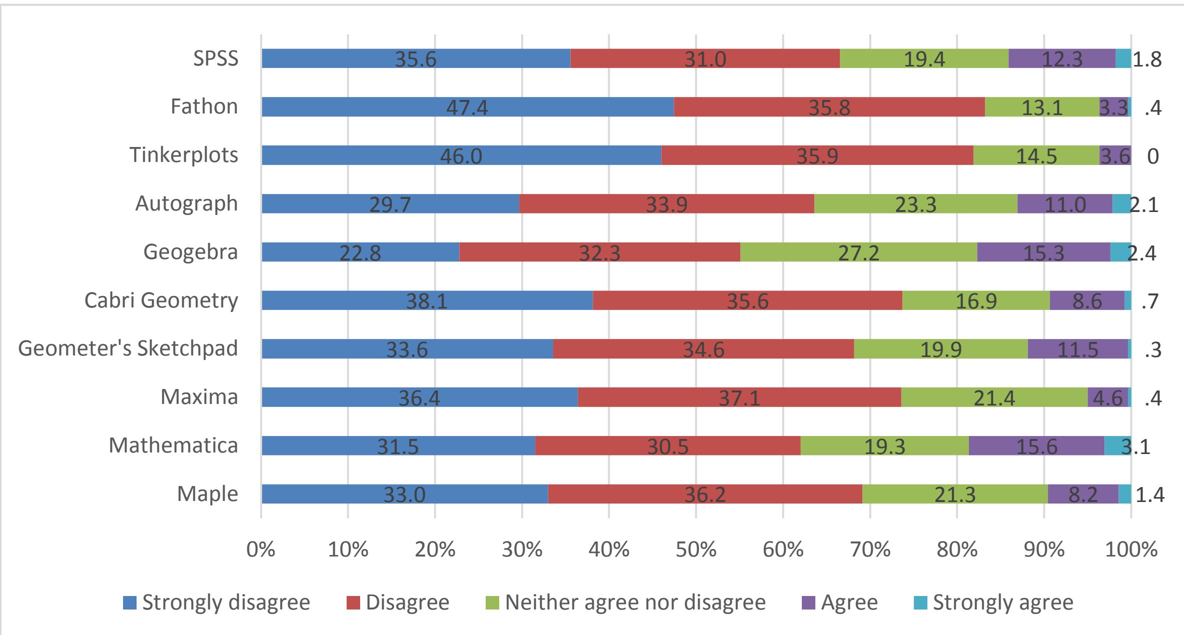

Figure 6-12: Distribution of the participants' answers to items regarding knowledge of mathematical software

Similarly, responses to the second item "I know how to use Mathematica software" were consistent with the first item. The majority of the participants had negative responses to the item, involving 31.5% of the participants strongly disagreed and 30.5% of the participants disagreed with the statement. Oppositely, a very small number of participants had positive responses that were 3.1% of the participants strongly agreed and 15.6% of the participants agreed with the statement. Additionally, 19.3% of the participants neither agreed nor disagreed with the statement.

The third item talked about teachers' knowledge of Maxima software. The majority of the participants also had negative responses to the item, involving 36.4% of the participants strongly disagreed and 37.1% disagreed with the statement. Moreover, a moderately large number (21.4%) of the participants were unsure about the item. In contrast, a very small number of the participants had positive responses to the item, comprising 0.4% of the participants strongly agreed and 4.6% of the participants agreed with the statement.

Negative responses still dominated the fourth item "I know how to use Geometer's Sketchpad". A large number of the participants (34.6%) disagreed and (33.6%) strongly disagreed with the statement. Moreover, 19.9% of the participants neither agreed nor disagreed with the statement. On the other hand, a very small number of the participants (0.3%) strongly agreed while only 8.6% of the participants agreed with the statement.

It was slightly similar to the fourth item, the majority of participants had negative responses to the fifth item "I know how to use Cabri Geometry", involving 38.1% of the participants strongly disagreed and 35.6% of the participants disagreed with the statement. On the other hand, only 0.7% of the participants strongly agreed and 8.6% agreed with the statement. In addition, 16.9% of the participants neither agreed nor disagreed with the statement.

However, participants' responses to the sixth item "I know how to to use GeoGebra", were slightly different to their responses to the other first five items. There were 22.8% of the participants who strongly disagreed and 32.3% of the participants disagreed with the statement. Furthermore, more than a quarter of the participants (27.2%) had neutral responses about their ability to use GeoGebra software. On the other hand, a slightly high number (15.3%) of the participants agreed and 2.4% of the participants strongly agreed with the statement.

The majority of the participants had negative responses to the seventh item "I know how to use Autograph software", comprising 29.7% of the participants strongly disagreed and 33.9% of the participants disagreed with the statement. Moreover, a moderately large (23.3%) of the participants were unsure about the statement. On the other hand, only 11% of the participants agreed and 2.1% of the participants strongly agreed with it.

The eighth item dealt with teacher knowledge of TinkerPlots software. This item received more negative responses compared to the other first-seven items did. There were 46% of the participants who strongly disagreed and 35.9% of the participants disagreed with the statement. Moreover, 14.5% of the participants neither agreed nor disagreed with the statement. In contrasts, there was no participant strongly agreed and only 3.6% of the participants agreed with the statement.

The ninth item "I know how to use Fathom software" had almost similar responses to the previous item. The majority of the participants had negative responses to the statement that were 47.4% of the participants strongly disagreed and 35.8% disagreed with the statement. Furthermore, 13.1% of the participants neither agreed nor disagreed with the statement. On the other hand, only a few of participants (0.4%) strongly agreed and 3.3% agreed with the statement.

The last item was about "I know how to use SPSS software". It is like other items, this item also received negative responses from the majority of the participants. 35.6% of the participants strongly disagreed and 31% of the participants disagreed with the statement. However, only 1.8% of participants strongly agreed and 12.3% of the participants agreed with the statement. In addition, 19.4% of the participants neither agreed nor disagreed with the statement.

Mean and Standard Deviation

Means of individual items that make up this theme were in a range of 1.73 to 2.42. This implies that all items of this theme fall into either moderately low or low category. Item GeoGebra had the highest score (Mean = 2.42) while Fathom was the lowest one (Mean= 1.73).

Table 6-3: Mean scores of participants' responses to items regarding knowledge of mathematical software

Knowledge of Mathematical software	Mean	Std. Deviation
a. Maple	2.09	0.97
b. Mathematica	2.28	1.15
c. Maxima	1.95	0.89
d. Geometer's Sketchpad	2.10	1.01
e. Cabri Geometry	1.98	0.98
f. GeoGebra	2.42	1.07
g. Autograph	2.22	1.06
h. Tinkerplots	1.76	0.83
i. Fathom	1.73	0.84
j. SPSS	2.14	1.09
Mean	2.07	

As discussed in the conceptual framework chapter, Mathematical software consists of three types of software that are Dynamic Mathematics Software, Dynamic Geometry Software, Computer Algebra System, and Statistical Software. The teachers' responses were presented based on types of software, and the results show that their knowledge of using Dynamic Mathematics Software (e.g., GeoGebra) was the highest one across all types of the software. Furthermore, the second highest one was teachers' knowledge in the use of Dynamic Geometry Software (e.g., Autograph). On the other hand, teachers' knowledge of Statistical Software (e.g., Tinkerplots and Fathom) was the lowest one.

A repeated measures ANOVA was carried out to determine if there was statisticaly significant difference in teachers' knowledge of mathematical software across the items. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(44) = 615.47,\ p = 0.00$, therefore degree of freedom were corrected using Greenhouse-Geisser estimate of sphericity ($\varepsilon = .69$). The results showed that there was significant differences in teachers level of knowledge of mathematical software across the items $F(6.38, 1665.11) = 35.48$, p = 0.00.

Overall, the results in Table 6-3 indicates that the participants' knowledge of specific mathematics software was moderately low (Mean=2.07). It can be concluded that teachers had insufficient knowledge of mathematical software.

6.2.1.4 Online Resources

Question 15 revealed about teachers' knowledge of online-learning resources and software learning management system. This question consisted of two items.

Percentage of Frequency Distribution

Figure 6-13 presents distributions of participants' responses to each item about teachers' knowledge of online resources.

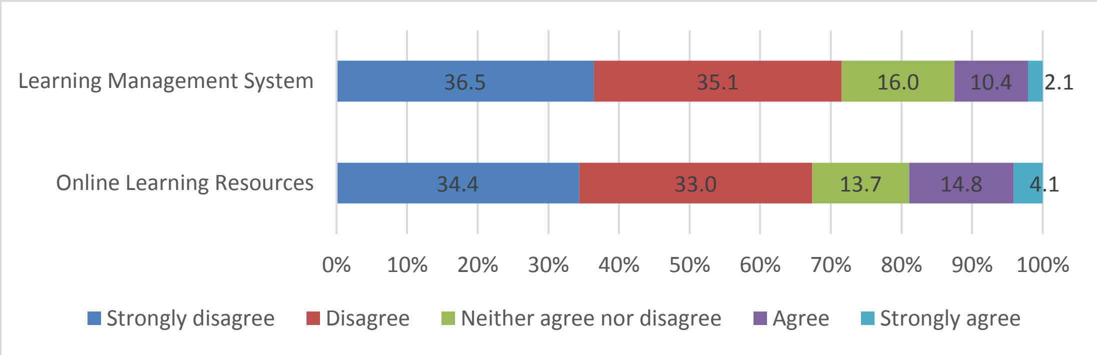

Figure 6-13: Distribution of the participants' answers to items regarding knowledge of online resources

In the first item, "I know how to use Web-based applications (e.g., rumah belajar, m-edukasi, Khanacademy, Youtube)", the majority of the participants had negative responses to the item that was 34.4% strongly disagreed and 33% disagreed. Moreover, 16% of the participants neither agreed nor disagreed with the statement. On the other hand, a small number (4.1%) of the participants strongly agreed and 14.8% of the participant agreed with the statement.

The participants had responded the second item "I know how to use Learning management system (e.g., Blackboard, Moodle)" was slightly similar to the first item. The majority of the participants (36.5%) strongly disagreed and 35.1% of the participants disagreed with the statement. In contrasts, a very small number of the participants (2.15%) strongly agreed and 10.4% of the participants agreed with the statement. In addition, 16% of the participants neither agreed nor disagreed with the statement.

Mean and Standard Deviation

The participants' average scores are presented below to determine which category participants' knowledge fall into.

Table 6-4 shows mean scores of teachers' knowledge of all items. The first item (Mean = 2.07) and the second item (Mean = 2.21) were moderately low. Moreover, the results also indicated that teachers' knowledge of online learning resource was better their knowledge of Learning Management System.

Table 6-4: Mean scores of participants' responses to items regarding knowledge of online tools

Knowledge of online tools	Mean	Std. Deviation
a. Online Learning Resources	2.21	1.18
b. Learning Management System	2.07	1.06
Mean Score	2.14	

A paired t-test was carried out to determine if there were statisticaly significant differences in teachers' knowledge of online resources across the items. The results showed that there was a significant difference in the score for teacher knowledge for online learning resources (M=2.21, SD =1.18) and learning management system (M 2.07, SD =1.06); t (287) =4.15, p= .00.

Overall, the result showed that teachers' knowledge of online tools was moderately low (Mean=2.14). It can be concluded that teachers have insufficient knowledge of online tools.

Summary of Teachers' Knowledge of ICT

This scale consisted of knowledge of hardware, knowledge of general software, knowledge of mathematical software, and knowledge of online resources. The mean score of knowledge of hardware was 3.14. The result indicated that participants' knowledge of hardware was slightly above average, and their knowledge of computer/laptop was higher than their knowledge of calculator and tablet/handheld device. Moreover, the mean score of knowledge of general software was 2.71, indicating that the participants' knowledge of general software was slightly below average. The result also showed that participants' knowledge of word processing software was higher than their knowledge of the other general software. In terms of mathematical software, overall, the results revealed that teachers' knowledge of mathematical software was moderately low (Mean=2.07). It showed that participants' knowledge of Dynamic Mathematics Software and Dynamic Geometry Software were higher than their knowledge of Computer Algebra System and Statistical Software. In addition, the results revealed that participant's knowledge of online resources was moderately low (Mean=2.14) in which their knowledge of online learning resources was higher than their knowledge of software of Learning management system. It can be concluded that teachers had insufficient knowledge of ICT.

6.2.2 Knowledge of ICT use in teaching

As discussed in the chapter of the conceptual framework, along with teachers' knowledge of ICT, this study also assessed teachers' knowledge of ICT use in teaching. This scale consisted of ICT-Content Knowledge, ICT-Pedagogical Knowledge, and ICT-Pedagogical Content Knowledge. The following sections present results of these aspects.

6.2.2.1 ICT-Content Knowledge

Question 16 was about teacher's ICT-Content Knowledge. This question consisted of four items. Distributions of participants' answers to each item of this question are presented as follows.

Percentage Frequency Distribution

Distributions of participants' answers to each item are presented in Figure 6-14.

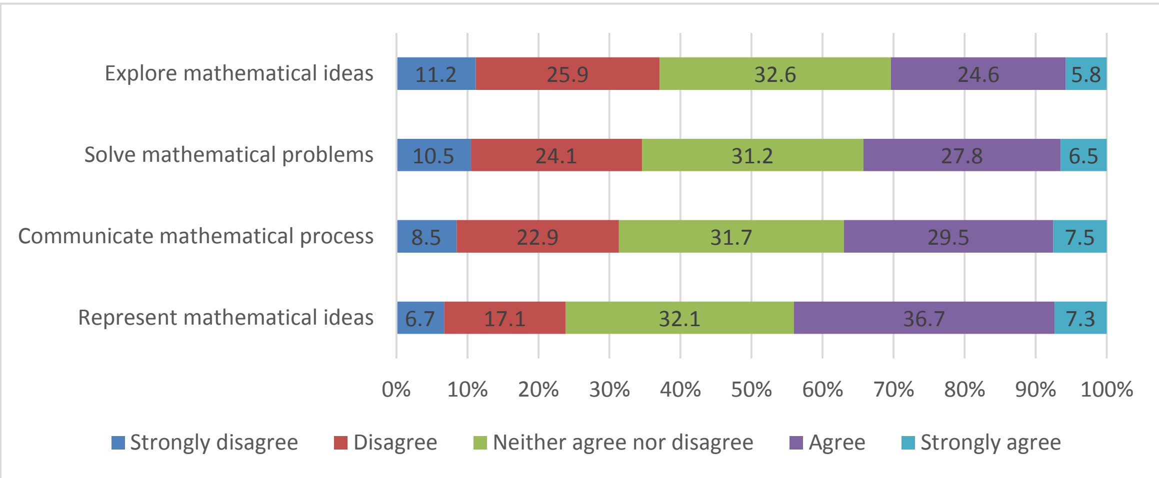

Figure 6-14: Distribution of the participants' answers to items regarding ICT-Content Knowledge

In the first item, (I can use ICT to represent mathematical ideas), the majority of the participants had positive responses, involving 36.7% of the participant agreed and 7.3% of the participants strongly agreed with the statement. On the other hand, a small number (6.7%) of the participants strongly disagreed and 17.1% of the participants disagreed with the statement. In addition, a moderately large number of the participants (32.1%) neither agreed nor disagreed with the statement that they can use ICT to represent mathematical ideas.

Participants' answers to the second item (I can use ICT to communicate mathematical processes) were slightly different compared to their responses to the first question. For the second item, the majority of the participants (31.7%) neither agreed nor disagreed with the statement. Moreover, a moderately high number of the participants (29.5%) agreed and 7.5% of the participants strongly agreed with the statement. On the contrary, only 8.5% of the participants strongly agreed and 22.95% of the participants disagreed with the statement.

Regarding the third item (I can use ICT to solve mathematical problems), the participants' answers were almost similar to their responses to the first item. The majority of the participants (31.2%) neither agreed nor disagreed with the statement. Furthermore, less than a quarter of the participants (24.1%) disagreed and 10.5% of the participants strongly disagreed with the statement. On the other hand, 27.8% of the participants agreed and 6.5% of the participants strongly agreed with the statement.

The last item was about "I can use ICT to explore mathematical ideas". It was almost similar to the last two items that the majority of the participants (32.6%) neither agreed nor disagreed with the statement. Moreover, more than a quarter of the participants (25.9%) disagreed and 11.2% of the participants strongly disagreed with the statement. In contrast, only 5.8% of the participants strongly agreed and 24.6% of the participants agreed with the statement.

Mean and Standard Deviation

In order to determine which category the participants' answers belong to, mean scores are presented in Table 6-5. The participants perceived their knowledge of the use of ICT to represent mathematics ideas (Mean=3.10) and knowledge of the use of ICT to communicate mathematical processes (Mean = 3.02) were slightly above average. On the other hand, teachers perceived their knowledge of ICT use to solve mathematical problems (Mean=2.90) and to explore mathematical ideas (Mean=2.84) were slightly below average. The data shows that teacher perceived their knowledge of the use of ICT to represent mathematical idea was the highest one across all items. Overall, teachers' ICT content knowledge was slightly below average (Mean =2.96). Therefore, in can be concluded that teachers have insufficient ICT-content knowledge.

Table 6-5: Mean scores of participants' responses to items regarding ICT-content knowledge

ICT-Content Knowledge	Mean	Std. Deviation
a. Use ICT to represent mathematical ideas	3.10	1.03
b. Use ICT to communicate mathematical processes	3.02	1.08
c. Use ICT to solve mathematical problems	2.90	1.10
d. Use ICT to explore mathematical ideas	2.84	1.08
Mean	2.96	

A repeated measures ANOVA was carried out to see if there was statistically significant difference in teachers' ICT-Content Knowledge across the items. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(5) = 100.23,\ p = 0.00$, therefore degree of freedom were corrected using Huynh-Feldt estimate of sphericity ($\varepsilon = .82$). The results showed that there was significant differences in teachers level of ICT-Content Knowledge across the items $F(2.46, 766.98) = 45.82$, p = 0.00.

6.2.2.2 ICT-Pedagogical Knowledge

Another scale of teachers' knowledge in the use of ICT was assessed through question 17 of the questionnaire that was about teachers' ICT-Pedagogical Knowledge. This scale consisted of five items. Distributions of participants' answers are presented as follows.

Frequency Distribution

Figure 6-15 presents distributions of participants' responses for each item. The first item related to teacher-centred approaches while the others associated with student-centred approaches.

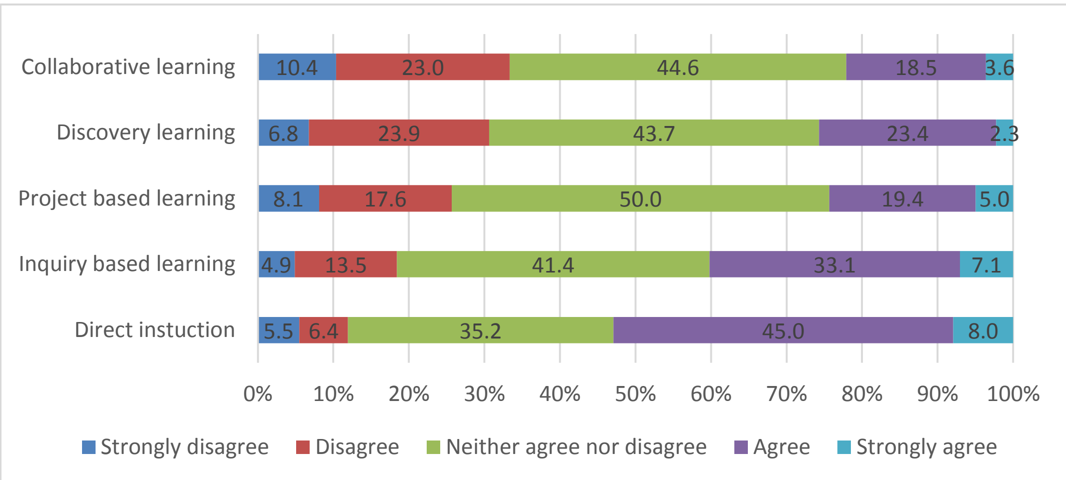

Figure 6-15: Distribution of the participants' answers to items regarding ICT-Pedagogical Knowledge

The results showed that the majority participants had positive responses to the first item "I can use ICT in teaching by employing direct instruction", involving 45% of the participants agreed and 8% of the participants strongly agreed with the statement. A moderately high number of the participants (35.2%) neither agreed nor disagreed with the statement. On the other hand, a very small number of the participants (5.5%) strongly disagreed and only 6.4% of the participants disagreed with the statement.

The second item "I can use ICT in teaching by employing inquiry-based learning" received less positive responses compared to the first item. 33.1% of the participants agreed and 7.1% of the participants strongly agreed with the statement. In contrasts, only 4.9% of the participants strongly agreed and 13.5% of the participants disagreed with the statement. In addition, a large number of the participants (41.4%) had neutral responses on this item.

Regarding the third item, "I can use ICT in teaching by employing project-based learning", a half of the participants neither agreed nor disagreed with the statement. Furthermore, 19.4% of the participants agreed and 5% of the participants strongly agreed with the statement. On the other hand, 8.1% of the participants strongly disagreed and 17.6% of the participants agreed with the statement.

The majority of the participants (43.7%) neither agreed nor disagreed with statement "I can use ICT in teaching by employing discovery learning". Moreover, a moderately large number of the participants (23.9%) disagreed and only 6.8% of the participants strongly disagreed with the statement. In contrast, a very small number of the participants (2.3%) strongly agreed and 23.4% of the participants agreed with the statement.

In relation to the last item "I can use ICT in teaching by employing collaborative learning", a small number of the participants responded positively to the statement that was 18.5% of the participants agreed and 3.6% of the participants strongly agreed. On the other hand, 10.4% of the participants strongly disagreed and 23% of the participant disagreed with the statement. However, the majority (44.6%) of the participants were unsure about the statement.

Mean and Standard Deviation

Table 6-6 presents mean score across all items on teacher ICT pedagogical knowledge. The results revealed that scores of participants' knowledge of ICT use for direct instruction (Mean=3.33) and inquiry-based learning (Mean=3.14) were slightly above average. On the other hand, participants' knowledge of ICT use for project-based learning (mean=2.85) discovery learning (mean=2.81) and collaborative learning (mean=2.72) were slightly below average.

Table 6-6: Mean scores of participants' responses to items regarding ICT pedagogical knowledge

ICT-Pedagogical Knowledge	Mean	Std. Deviation
a. Use ICT in teaching by employing direct instruction	3.33	0.93
b. Use ICT in teaching by employing inquiry-based learning	3.14	0.94
c. Use ICT in teaching by employing project-based learning	2.85	0.95
d. Use ICT in teaching by employing discovery learning	2.81	0.91
e. Use ICT in teaching by employing collaborative learning	2.72	0.97
Mean	2.97	

A repeated measures ANOVA was carried out to determine if there was statistically significant difference in teachers' ICT-Pedagogical Knowledge across the items. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(9) = 215.00,\ p = 0.00$, therefore degree of freedom were corrected using Greenhouse-Geisser estimate of sphericity (ε = .66). The results show that there was significant differences in teachers level of ICT-Pedagogical Knowledge across the items $F(2.63, 563.26) = 24.57$, p = 0.00.

The results showed that teachers' knowledge of ICT use for direct instruction was higher than their other knowledge of the use of ICT through employing other teaching approaches. Overall, teachers' ICT-pedagogical knowledge was slightly below average (Mean = 2.97). It can be concluded that teachers have insufficient ICT-pedagogical knowledge.

6.2.2.3 ICT-Pedagogical Content Knowledge

Question 18 of the questionnaire dealt with teachers' ICT Pedagogical Content Knowledge. This question consisted of five items. Distributions of participants' answers to each question are presented below.

__Percentage Distribution__

Participants' answers to all items are presented in Figure 6-16. Regarding the first item, most of the participants (40.1%) neither agreed nor disagreed with the statement. Furthermore, a large number of participants had positive responses to the item, comprising 37% of participants agreed and 3.7% of the participants strongly agreed. On the other hand, 4.9% of the participants strongly disagreed and 14.4% of the participants disagreed with the statement.

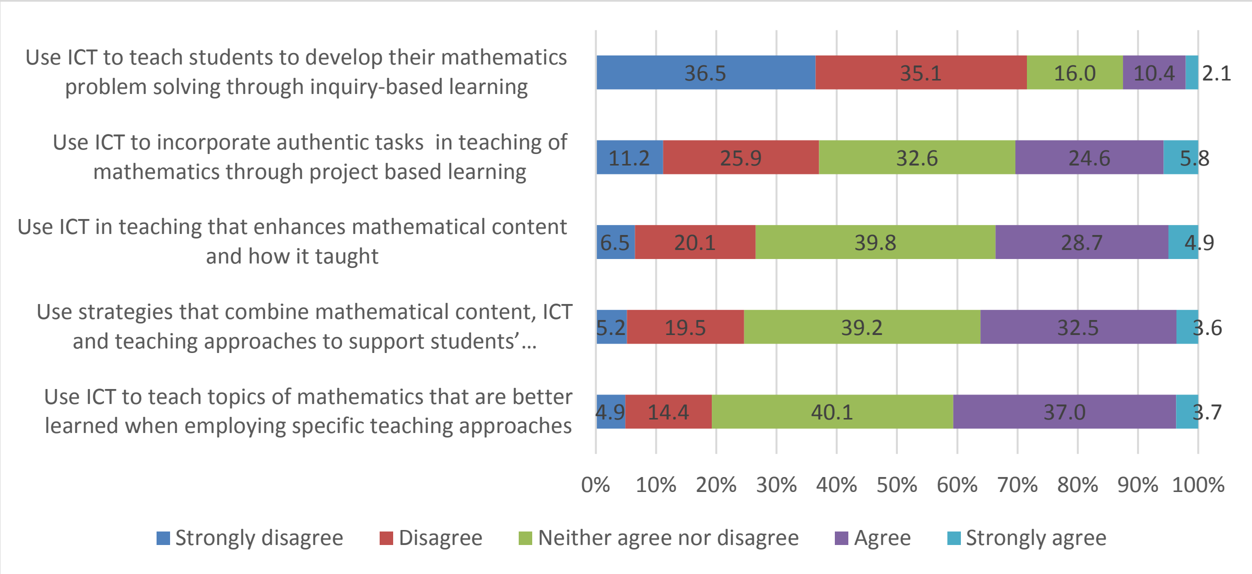

Figure 6-16: Distribution of the participants' answers to items regarding ICT Pedagogical Content Knowledge

In the second item, participants' responses were slightly different to their responses to the first item. Nevertheless, responses of neither agree nor disagree (39.2%) dominated the participants' responses. Moreover, a moderately large number of the participants (32.5%) agreed and 3.6% of the participants strongly agreed with the statement. On the other hand, 5.2% of the participants strongly disagreed and 19.5% of the participants disagreed with the statement.

Participants' answers to the third item were almost similar to their responses to the second item that the majority of the participants (39.8%) neither agreed nor disagreed with the statement. Furthermore, 28.7% of the participants agreed and 4.9% of the participants strongly agreed with the statement. On the other hand, 6.5% of the participants strongly disagreed and 20.1% of the participants disagreed with the statement.

For the fourth item, most of the participants had negative responses to this item that were 11.2% of the participants strongly disagreed and 25.9% of the participants disagreed with the statement. However, there were 24.6% of the participants who agreed and 5.8% of the participants who strongly agreed with the statement. In addition, 32.6% of the participants neither agreed nor disagreed with the statement.

Participants had different responses to the last item "I can use ICT to teach students to develop their mathematical problem solving through inquiry-based learning" compared to their responses to the other items. For this item, the majority of the participants (36.5%) strongly disagreed and 35.1% of the participants disagreed with the statement. In contrast, a very small number of the participants (2.1%) strongly agreed and 10.4% of the participants agreed with the statement. In addition, 16% of the participants neither agreed nor disagreed with the statement.

Mean and Standard Deviation

Items of this question had a large range of mean scores. Overall, the result showed that teachers ICT-pedagogical content knowledge (Mean = 2.87) was slightly below average. Therefore, it can be concluded that teachers had insufficient of ICT-pedagogical content knowledge.

Table 6-7: Mean scores of participants' responses to items regarding ICT Pedagogical Content Knowledge

ICT-Pedagogical Content Knowledge	Mean	Std. Deviation
a. Use ICT to teach topics of mathematics that are better learned when employing specific teaching approaches	3.20	0.90
b. Use strategies that combine mathematical content, ICT and teaching approaches to support students' understandings as they are learning mathematics	3.10	0.93
c. Use ICT in teaching that enhances mathematical content and how it taught	3.06	0.97
d. Use ICT to incorporate authentic tasks in teaching mathematics through project-based learning	2.88	1.08
e. Use ICT to teach students to develop their mathematics problem solving through inquiry-based learning	2.07	1.06
Mean	2.87	

A repeated measures ANOVA was carried out to determine if there was statistically significant difference of teacher's responses across the items of ICT-Pedagogical Content Knowledge. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(9) = 278.83,\ p = 0.00$, therefore degree of freedom were corrected using Greenhouse-Geisser estimate of sphericity (ε = .68). The results show that there was significant differences in teachers level of ICT-Pedagogical Content Knowledge across the items $F(2.74, 760.20) = 176.15$, p = 0.00.

Summary of teachers' knowledge of ICT use in teaching: This scale consisted of three themes, namely ICT-content knowledge, ICT-pedagogical knowledge, ICT-pedagogical content knowledge. The participants revealed that their ICT-content knowledge (Mean =2.96), ICT-pedagogical knowledge (Mean=2.97) and ICT-pedagogical content knowledge (Mean=2.87) were slightly below average. A repeated measures ANOVA was carried out to determine if there was statisticaly significant difference of teacher's responses across the category of knowledge of ICT use in teaching. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(2) = 97.98,\ p = 0.00$, therefore degree of freedom were corrected using Huynh-Feldt estimate of sphericity (ε = .80). The results showed that there was significant differences in teachers level of knowledge of ICT use in teaching across those three categories $F(1.59, 513.85) = 48.9$, p = .013. Finally, it can conclude that the teachers had insufficient knowledge of ICT use in teaching.

6.2.3 Summary of Results on Teachers' Knowledge

As mentioned earlier, this study investigated teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching. The descriptive statistical analyses showed that Indonesian secondary mathematics teachers had insufficient knowledge both of ICT and ICT use in teaching. Regarding knowledge of ICT, the results revealed that teachers' knowledge of computer was higher than their knowledge of other hardware. The results also showed that the level of teachers' knowledge of general software was higher than the level of their knowledge of mathematical software. In terms of knowledge of ICT use in teaching, teachers' ICT-Pedagogical Content Knowledge was lower than their ICT-Pedagogical Knowledge and ICT-Content Knowledge.

6.3 Descriptive Analysis of Teachers' Classroom Practices

In this section, I provide results of teachers' use of ICT. First, I present results about a general profile of the ICT use including distributions of teachers who had used and had not use ICT. Moreover, I present results of teachers' use of ICT regarding the type of ICT, functional activities and pedagogical activities.

6.3.1 General Profile of ICT Use

This section provides results of participants' answers to items regarding the general profile of teachers' ICT use. This includes the percentage of teachers who used ICT and the percentage of mathematics lessons taught with ICT.

Percentage of Teachers who used ICT in the classroom

Question 19 of the questionnaire was the first question in terms of teachers' use of ICT. If the participants responded "YES", they were required to go to the next question. However, if their answers were "NO", then they should go to question 31. There were 341 participants responded this question. Figure 6-17 presents distributions of participants' answers.

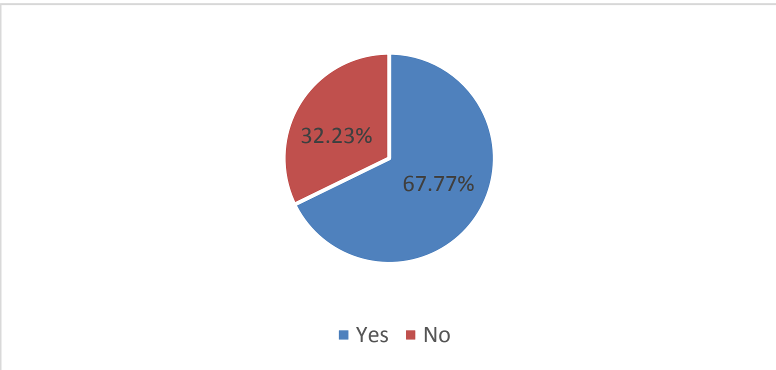

Figure 6-17: Percentage of the participants who used ICT

The figure shows that the number of participants who had used ICT at least once in their classrooms was bigger (67.77%) than one who had never used it (32.23%). This indicates that the government policy required teachers to integrate ICT in the classroom has been gradually implemented by the majority of mathematics teachers in Aceh province, Indonesia. However, a moderately large number of the teachers never used the digital tool.

Years of experience in the use of ICT

To gain detailed insight into the use of ICT, this study then looked at how long the participants had used ICT in the classroom. Question 20 of the questionnaire dealt with this issue (How many years have you been using ICT in teaching?). Only the participant who had chosen 'YES' in the question 19 responded this question. Therefore, numbers of participants of this question and the next following questions (from question 20 to 30) were 224 teachers. Therefore, they did not represent the total participants of this study.

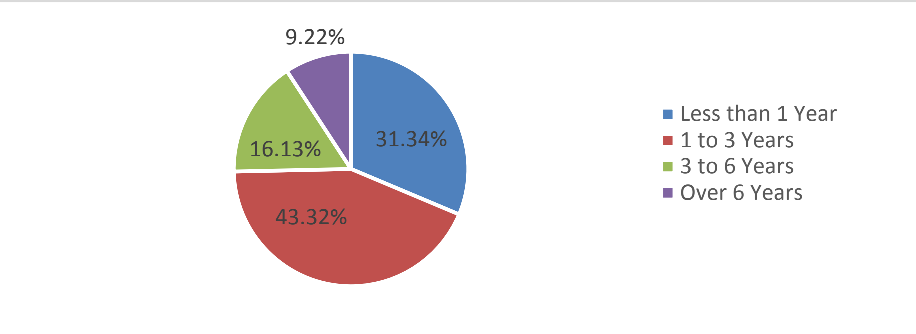

Figure 6-18: Years of experience in the use of ICT

Figure 6-18 shows that majority of the participants (43.32%) had been using ICT for only one to three years. On the other hand, a very small number of participants (9.22%) had been using ICT for over six years while 31.34% and 16.13% of the participants had been using ICT for less than one year and three to six years respectively.

__The number of mathematics lessons taught with ICT__

Question 21 was intended to collect information about percentages of mathematics lessons taught with ICT. Figure 6-19 shows that the majority of participants (23.90%) used ICT for 21% to 30% of mathematics lessons. The same number of the participants (23.90%) used the digital tool for 31% to 50% of the lessons. On the other hand, a very small number of participants (5.5%) used ICT in teaching for over 70% of the lessons. These results indicated that the integration of ICT was still in a limited number of mathematics lessons.

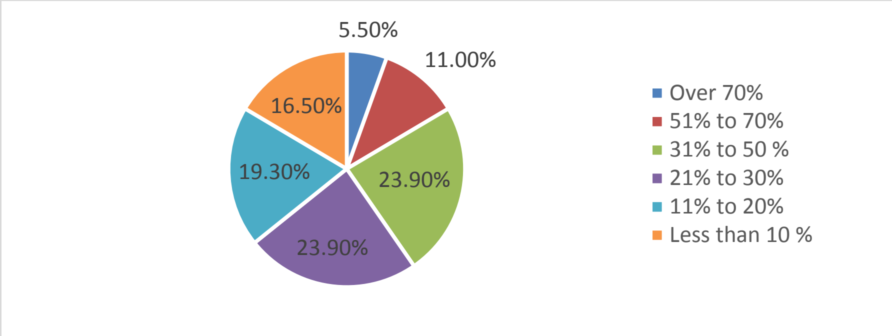

Figure 6-19: Percentage of mathematics lessons taught by using ICT

Summary of general profile of ICT use: The result showed that a large number of participants (32.23%) never used ICT in the classroom. Moreover, the integration of ICT in the classroom just emerged as the finding showed that the majority of the result showed the majority of participants had been using ICT for 1 to 3 years. In addition, the integration of ICT was in teaching a limited number of mathematics lessons.

6.3.2 The Use of Hardware, Software and Online Resources

After profiling teachers' use of ICT in the previous section, detailed insights on the frequency of teacher use of certain type of hardware and software in the classroom are provided in this subsection. The results of teachers' frequency use of hardware and software are presented as follows.

Frequency of Hardware Use

Question 22 of the questionnaire was about how often the teachers used Calculator, Computer/Laptop and Tablet/Handheld devices in their teaching of mathematics lessons. This question consisted of three items. Results of participants' answers to each item are presented below.

Percentage of Frequency Distribution

The results of participants' answers to each item are presented in Figure 6-20. In the first item, (I use a calculator (e.g., scientific and graphics calculator) in teaching), a small number of the participants (1.4%) always used ICT and 12.3% of the participants often used it. On the other hand, a significant number of the participants (20.10%) never used this tool in their classrooms. Moreover, 29.7% of the participants rarely used and 36.5% of the participants sometimes use the tool in their classrooms.

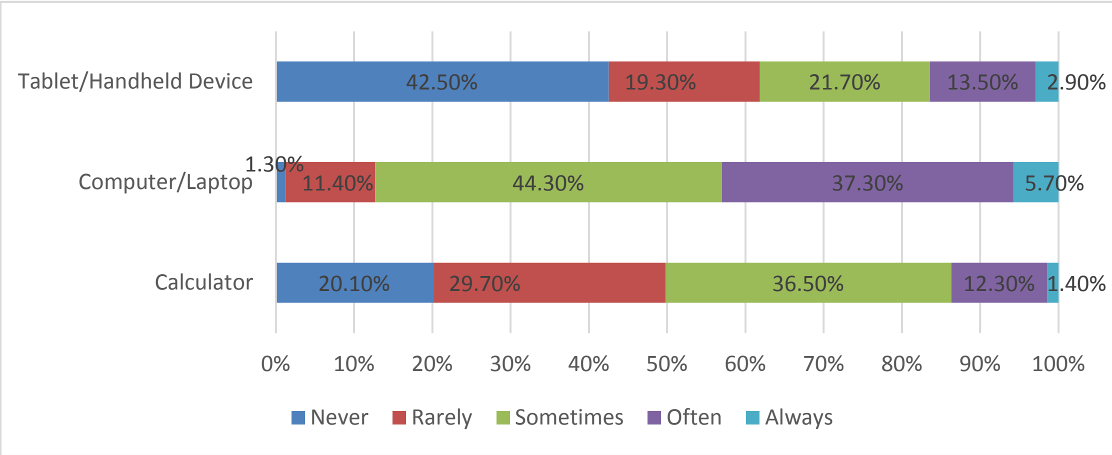

Figure 6-20: Distribution of participants' answers to items about frequency of hardware use

In terms of the use of computer/laptop, as seen in Figure 6-20, 5.7% of the participants always used this tool when they integrate ICT in the classroom, 37.3% of the participants often used it. On the other hand, only 1.3% never used this tool while 11.4% use the tool rarely. In addition, the majority of the participants (44.3%) sometimes used computer/laptop when they teach with ICT.

The last item dealt with teachers' use of tablet/handheld devices in teaching. The figure indicates that the majority of the participants (42.5%) never used a tablet/handheld device while 19.3% of the participants rarely used it. In contrast, a very small number of the participants (2.9%) always used it and 13.5% of the participants often used the tool for teaching mathematics. In addition, 21.7% of the participants sometimes used this hardware in the classroom.

__Mean and Standard Deviation__

To compare participants' responses across the items, mean scores of all item are presented in Table 6-8. It can be summarised that participants mainly used computer/laptop for teaching purpose (Mean = 3.35). Tablet/handheld device was the second most frequently used hardware (Mean = 2.45). On the other hand, the calculator was the least frequently used hardware in mathematics teaching (Mean = 2.15).

Table 6-8: Mean scores of participants’ responses to items regarding hardware use

Hardware	Mean	Std. Deviation
Tablet/Handheld Device	2.45	.99
Computer/Laptop	3.35	.81
Calculator	2.15	1.16

A repeated measures ANOVA was carried out to determine if there was statisticaly significant difference in teacher’s classroom practice in the use of hardware. Mauchly’s test indicated that the assumption of sphericity had not been violated, $x^2(2) = 3.18,\ p = .20$, therefore degree of freedom were corrected using Sphericity assumed. The results show that there was significant differences in teachers use of hardware $F(2, 408) = 132.89$, p = 0.00.

<u>Frequency Use of General Software</u>

This study also portrayed the frequency use of the general software. Question 23 of the questionnaire was intended to reveal this aspect. This question consisted of five items. Figure-21 informs distribution of participants’ responses to each item.

<u>Percentage of Frequency Distribution</u>

The first item dealt with teachers’ use of Word Processor software. The majority of the participants (37.7%) sometimes used the software, and 29.5% of the participants often used it. Furthermore, 8.6% of the participants always used the software when they teach with ICT. On the other hand, 10.5% of the participants never used the tool and 13.6% of the participants rarely used the software.

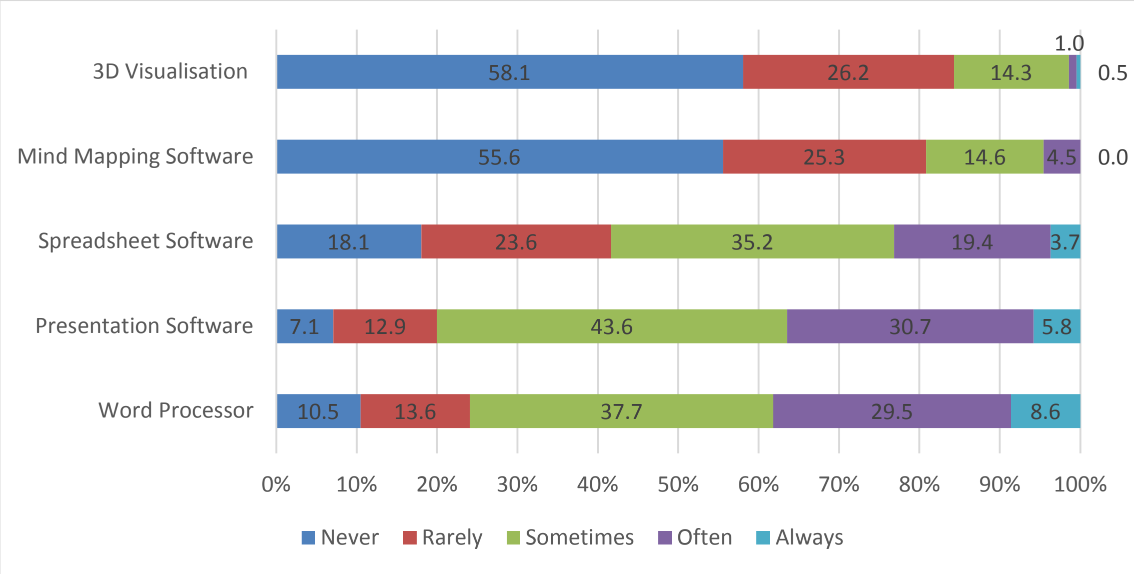

Figure 6-21: Distribution of the participants' answers to items regarding the use of general software

Another item of this question was about the use of presentation software (e.g., PowerPoint). The majority of the participants (43.6%) sometimes used the software and (30.7%) of the participants often used it. Moreover, small numbers (5.8%) of the participants always used the software. On the other hand, 7.1% of the participants never used presentation software, and 12.9% of the participants rarely used the software when the teachers integrate ICT into the classroom.

The third item explored the frequency of the use of Spreadsheet software (e.g., Ms Excel). The majority of the participants (35.2%) sometimes used the software and 23.6% of the participants rarely used it. Furthermore, 19.4% of the participants often used the software while slightly a small number of the participants (18.1%) never used it. Finally, only 3.7% of the participants always used the software when they taught with ICT.

Figure 6-21 also shows that the participants rarely used Mind Mapping Software (e.g., Inspiration). As shown in the figure, the majority of participants (55.6%) never used the software, and 25.3% of the participants rarely use it. On the other hand, there was no any participant who always used the software and only 4.5% of the participants often used it. In addition, 14.6% of the participants sometimes used the software in the mathematics classroom.

The last item exposed teachers' use of three-dimensional visualisation software (e.g., Sketchup). The results show that the majority of the participants (58.1%)

never used the software in mathematics teaching. Moreover, 26.2% of the participants rarely used it and 14.3% of the participants used it sometimes. On the other hand, a very small number of the participants (1%) often used the software and only 0.5% of the participants always used it when they integrated ICT in the classroom.

Mean and Standard Deviation

Table 6-9 : Mean scores of participants' responses to items regarding general software use

General Software	Mean	Std. Deviation
Word Processor (e.g., Ms Word)	3.12	1.09
Presentation (e.g., Ms PowerPoint)	3.15	.97
Spreadsheet (e.g., Ms Excel)	2.67	1.06
Mind Mapping (e.g., Inspiration)	1.68	.89
There-Dimensional Visualisation (e.g., Sketchup)	1.60	.80

To compare participants' responses across the items, mean scores of all item are presented in Table 6-9. The results show that presentation software (e.g., Ms Power Point) was the most commonly used of general software (Mean =3.15). Moreover, word processor software (e.g., Ms Word) was the second most commonly used general software in the classroom (Mean =3.12). On the other hand, three-dimensional visualisation software was the least frequently used in mathematics teaching (Mean= 1.60).

A repeated measures ANOVA was carried out to determine if there was statisticaly significant difference of teacher's classroom practice in the use of general software. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(9) = 81.36,\ p = 0.00$, therefore degree of freedom were corrected using Huynh-Feldt estimate of sphericity ($\varepsilon = .817$). The results show that there was significant differences in teacher use of general software across the items $F(3.33, 642.86) = 226.87$, $p = 0.00$.

Frequency of Mathematical Software Use

Along with the frequency of general software use, this study also investigated the frequency of mathematical software use. Question 24 of the questionnaire, which consisted of three items, was intended to reveal this issue.

Percentage of Frequency Distribution

Results of the participants' responses to each item are presented in Figure 6-22.

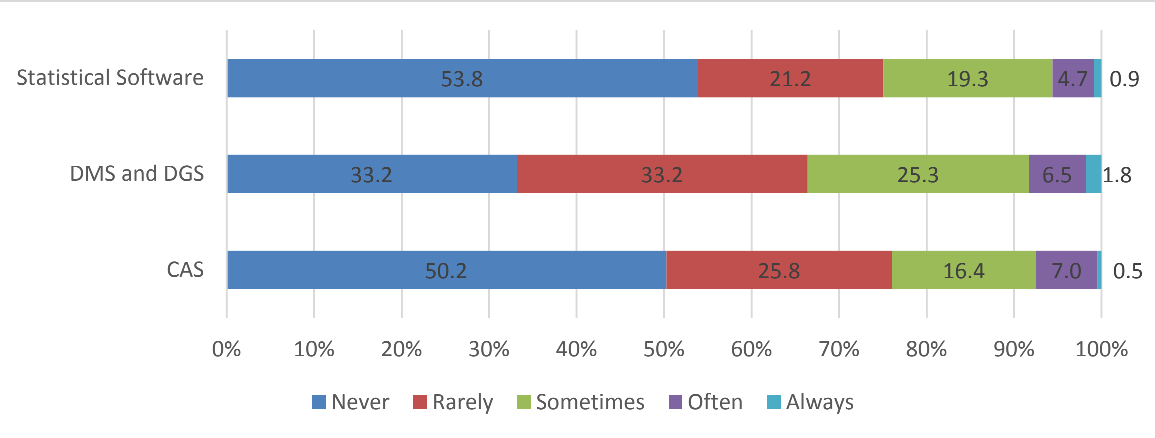

Figure 6-22: Distribution of the participants' answers to items regarding the use of mathematical software

The first item exposed the frequency use of software of Computer Algebra System (CAS) (e.g., Maple). The majority of the participants (50.2%) never used this software in their classroom, and 25.8% of the participants rarely used it. Moreover, 16.4 % of the participants sometimes used the software. In contrast, only 0.5% of the participants always used CAS software and 7% often used the software in mathematics teaching.

The second item was about the frequency of Dynamic Mathematics and Dynamic (DMS) and Dynamic Geometry Software (DGS) use (e.g., Geogebra, Autograph). A moderately large number of the participants (33.2%) never used the software, and the same numbers of the participants (33.2%) rarely use it. On the other hand, 1.8% of the participants always used the software and 6.5% of the participants often use it when they integrated ICT in the classroom. Moreover, more than a quarter of the participants (25.3%) used the software sometimes.

The last item of this question was about the frequency of the use of Statistical Software (e.g., Tinkerplots, Fathon). The majority of the participants (53.85) never used the software while a moderately significant number of the participants (21.2%) used it rarely. Moreover, 19.3% of the participants sometimes used Statistical Software. In contrast, only 4.7% of the participants often used it, and a very small numbers of the participants (0.9%) always used the software when they teach with ICT.

Mean and Standard Deviation

To compare participants' responses across the items, mean scores of each item are presented in Table 6-10.

Table 6-10: Mean scores of participants' responses to items regarding Mathematical software use

Mathematical Software	Mean	Std. Deviation
Computer Algebra System	1.82	.98
Dynamic Mathematics and Dynamic Geometry Software	2.11	1.00
Statistical Software	1.78	.98

In short, the results show that Dynamic Mathematics and Dynamic Geometry Software were two most frequently used the mathematical software. The mean score for this item was 2.11. CAS was the second most frequently used mathematics software (Mean=1.82). In addition, Statistical Software was the least frequently used mathematical software in the classroom (Mean=1.78).

A repeated measures ANOVA was carried out to determine if there was statisticaly significant difference of teacher's classroom practice in the use of mathematical software. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(2) = 21.31,\ p = 0.00$, therefore degree of freedom were corrected using Huynh-Feldt estimate of sphericity (ε = .92). The results show that there was significant differences in teachers use of mathematical software $F(1.84, 388.05) = 17.85$, p = 0.00.

The Frequency of Online Resources Use

Question 25 was about the frequency of use of online resources. This question consisted of two items. This first item was about the frequency of use of web-based applications (e.g., m-edukasi, Hotmath, SMILE, Youtube and KhanAcademy). Moreover, the second item was about the frequency Learning Management System use (e.g., Blackboard and Moodle). Figure 6-23 presents distributions of participants' responses to each item.

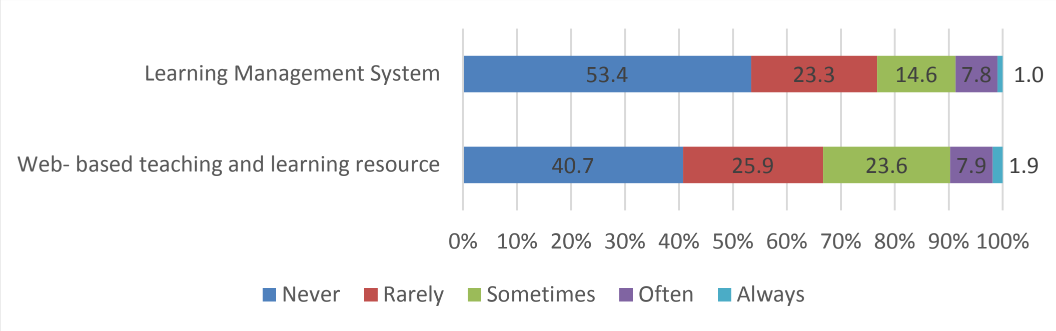

Figure 6-23: Distribution of the participants' answers to items regarding the use of online resources

Regarding the use of web-based teaching and learning resources, Figure 6-23 reveals that majority of the participants (40.7%) never used this tool, and 25.9% of the participants rarely used it. Contrary, a very small number of participants (1.9%) always used the resources and only 7.9% of the participants often used this online tool in mathematics teaching. Furthermore, 23.6% of the participants sometimes used the resource.

In terms of participants' responses to the frequency of use of learning management system, Figure 6-24 shows that majority of the participants (53.4%) never used the tool while 23.3% of the participants used it rarely. In contrast, only 1.9% of the participants always used the resource and 7.9% of the participants often used it. In addition, a moderately large number (23.6%) of the participants sometimes used web-based applications in mathematics teaching.

Mean and Standard Deviation

To compare participant's responses across the items, mean scores of each item are presented in Table 6-11. The use of web-based application received mean score 2.04 while the mean score of Learning Management System was only 1.80.

Table 6-11: Mean scores of participants' responses to items regarding the use of online resource

Online Resource	Mean	Std. Deviation
Web-based teaching and learning resources	2.04	1.06
Learning management system	1.80	1.02

A paired t-test was carried out to determine if there was statisticaly significant difference of teacher's responses across the items of knowledge of online tools. There was a significant difference in the score for teacher knowledge for web-based teaching and learning resources (M=2.04, SD =1.06) and learning management system (M 1.80, SD =1.02); $t\ (205) = 4.27$, $p= .00$. In summary, it can conclude that teachers more frequently used web-based teaching and learning resources than software for learning management system.

6.3.3 Functional Activity

As previously discussed in the conceptual framework chapter, this study also looked at functional and pedagogical activities with ICT. Question 29 of the questionnaire which consisted of six items was intended to investigate the frequency of ICT use for conducting the functional activities.

Percentage of Frequency Distribution

In the first item, "I use ICT to do arithmetic", Figure 6-24 shows that 14.4% of the participants never used ICT to do arithmetic, and 25.5% of the participants rarely used ICT to do the activity. Moreover, the majority of the participants (32.9%) sometimes used ICT to do this activity. In addition, about one-fifth of the participants (21.8%) often did arithmetic with ICT while a very small number of the participants (5.6%) always use ICT to do this activity.

The second item was about the frequency of ICT use to draw graphs. The results show that 15.8% of participants never used ICT to draw graphs, while almost a quarter of the participants (24.3%) rarely used ICT do it. Moreover, the majority of the participants (34.2%) sometimes used ICT to conduct this activity. On the other hand, only 5% of the participants always used ICT to draw graphs and 20.7% of the participants often used ICT to do this task.

Distributions of the participants' responses to each item are presented in Figure 6-24.

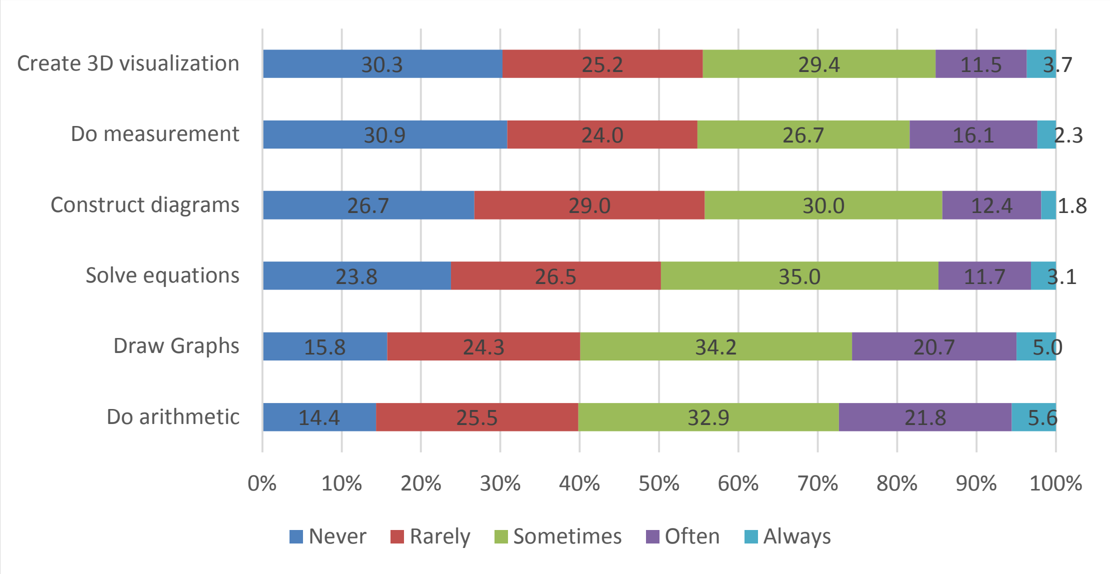

Figure 6-24: Distributions of participants' answers to items regarding the use of ICT for doing functional activities

Another item of this question was about the frequency of use of ICT to solve equations. Figure 6-24 shows that moderately large numbers of the participants (23.8%) never used ICT to solve mathematical equations and 26.5% of the participants rarely use the tool to this task. Moreover, the majority of the participants (35%) sometimes used ICT to solve equations while 11.7% often used the digital tool to do the task. In addition, a very small number of participants (3.1%) always used ICT to solve mathematical equations.

Regarding the fourth item “I use ICT to construct diagrams”, the results show that 26.7% of the participants never used ICT for construction diagrams while a moderately large number of the participants (29%) rarely used ICT for this purpose. On the other hand, only a few of participants (1.8%) always used and 12.4% of the participants often used this digital tool to construct diagrams. In addition, 30% of the participants sometimes used ICT to construct diagrams.

Another important functional ICT in mathematics is measurement. Regarding this feature, the Figure shows that the majority of the participants (30.9%) never used the digital tool to do measurements. Moreover, 24% rarely used and 26.7% and sometimes used ICT for the measurement. On the other hand, only a small number of the participants (2.3%) always used and 16.1% of the participants often used ICT to do measurements in mathematics teaching.

Participants' responses to the last item "I use ICT to create visualisations of three-dimensional objects" showed that the majority of the participants (30.3%) never used and 25.5% of the participants rarely used ICT to create the visualisation. Furthermore, 29.4% of the participants sometimes used the digital tools to conduct this activity. Moreover, a small number of the participants (3.7%) never used ICT and 11.5% often used the tool to create three-dimensional visualisations.

Mean and Standard Deviation

Mean scores of each item about teachers' use of ICT for conducting functional activities are presented in Table 6.12.

Table 6-12: Mean scores of participants' responses to items regarding functional activities

Functional Activities	Mean	Std. Deviation
Do arithmetic	3.12	.91
Draw graphs	3.01	1.03
Solve equations	2.85	1.16
Construct diagrams	2.96	1.23
Do measurements	2.82	1.16
Create three-dimensional visualisations	2.74	1.22

The results showed that the teachers most frequently used ICT for doing arithmetic (Mean = 3.12). The second most frequent use of ICT was for drawing graphs (Mean =3.01). On the other hand, the use of ICT for creating three-dimensional visualisations was the least frequent activity conducted by the teachers (Mean = 2.74).

A repeated measures ANOVA was carried out to determine if there was statisticaly significant difference of teacher's fuctional use of ICT. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(14) = 214.07,\ p = 0.00$, therefore degree of freedom were corrected using Greenhouse-Geisser estimate of sphericity ($\varepsilon = .67$). The results show that there was significant differences in teachers use of ICT for various functional activities *F*(3.35, 713.55.05) = 12.82, p = 0.00.

6.3.4 Pedagogical Activity

As previously discussed in the conceptual framework chapter, there were three levels investigated in terms of the pedagogical activity that are classroom level, subject level and task level. Question 26, 27, 28 and 30 of the questionnaire were intended to investigate this aspect. Participants' responses to this issue are presented in the following sections.

Classroom Level

Question 26 and 27 of the questionnaire aimed to disclose classroom activities and teaching approaches by the teachers when they used ICT. Participants' responses to these two questions are presented below.

Classroom Activity

The Question 27 of the questionnaire, which consisted of six items, sought information about what activity the teachers conducted when they integrated ICT.

Percentage of Frequency Distribution

Figure 6-25 presents percentage distributions of participants' responses to each item about their classroom activity with ICT. In the first item, (I use ICT to present content of mathematics), a small number of the participants (4.8%) never used ICT to present mathematics content in the classroom and 15.6% rarely used ICT to do this activity. Moreover, the majority of the participants (47.8%) sometimes used ICT to present mathematics contents. On the other hand, about a quarter of the participants (26.7%) often used ICT and 5.3% of the participants always used the tool to present content of mathematics in the classroom.

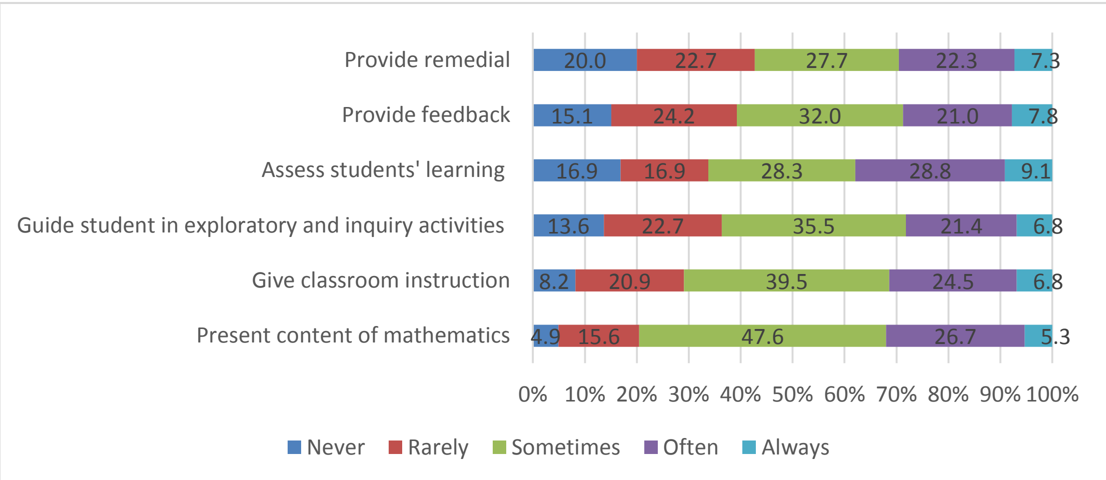

Figure 6-25: Distribution of the participants' answers to items regarding the use of ICT for different classroom activities

In terms of the frequency use of ICT to give classroom instruction, 8.2% of participants never used ICT to do this activity while 20.9% of the participants rarely used ICT to conduct this task. Moreover, the majority of the participants (39.5%) sometimes used ICT in this regard. In contrast, a moderately large number of the participants (24.5%) often used while a very small number of participants always used ICT (6.85%) for giving classroom instruction.

Results of the third item (I use ICT to guide students in exploratory and inquiry activities) showed that 13.6% of the participants never used ICT to conduct this activity while 22.7% rarely used ICT for this purpose. Moreover, the majority of the participants (35.5%) sometimes used ICT. On the other hand, only a small numbers of the participants (6.8%) always used and 21.4% of the participants often used ICT to guide students in exploratory and inquiries activity.

Regarding the use of ICT to assess students' learning, 16.9% of the participants never used it to conduct this activity, and the same number of participants (16.9%) rarely used it. Furthermore, 28.3 % of the participants sometimes used it while 28.8% of the participants often used it. In addition, only 9.1% of the participants always used ICT to assess students' learning in mathematics teaching.

Moreover, the fifth item was about the use of ICT to provide feedback to students. Figure 6-26 shows that 15.1% of participants never used ICT for providing feedback to students and 24.2% rarely used it. Moreover, the majority of the participants (32%) used it sometimes. Finally, a very small number of the participants (7.8%) always used and 21% often used ICT for providing feedback to the students.

The last item was about the use ICT to provide remedial for students. Figure 6-26 shows that 20% of the participants never done it and almost the same number of the participants (22.7%) rarely used it. Moreover, 27.7% of the participants sometimes used ICT for this purpose while 22.3% of the participants often used it. In addition, only 7.3% of the participants have always used ICT to provide remedial to the students.

Mean and Standard Deviation

The mean scores of all the items about the frequency of ICT use to conduct various classroom activities are presented in Table 6.13.

Table 6-13: Mean scores of participants' responses to items regarding classroom activities

Classroom Activities	Mean	Std. Deviation
Present content of mathematics	2.79	1.11
Give classroom instructions	2.75	1.10
Guide student in exploratory and inquiry activities	2.44	1.07
Assess students' learning	2.34	1.06
Provide feedback	2.35	1.15
Provide remedial	2.33	1.13

The most common use of ICT was for presenting contents of mathematics (Mean =2.79). Furthermore, the second most common use of ICT was for classroom instruction (Mean = 2.75). On the other hand, the least frequent use of ICT was for providing remedial (Mean =2.33).

A repeated measures ANOVA was carried out to determine if there was statisticaly significant difference of teacher's classroom activities. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(14) = 99.46,\ p = 0.00$, therefore degree of freedom were corrected using Huynh-Feldt estimate of sphericity (ε = .83). The results show that there was significant differences in teacher use of pedagogical activities across those categories $F(4.26, 890.19) = 25.98$, p = 0.00.

Teaching Approach

This issue was investigated through question 26, which consisted of two items. The first item was about a teacher-centred approach (e.g., direct instruction) while the second one was about a student-centred approach (e.g., inquiry-based learning).

Percentage of Frequency Distribution

Figure 6-26 presents the distribution of participants' responses to items about their teaching approaches when they integrated ICT in the classroom. For the first item, (I employ a teacher-centred approach (e.g. direct instruction) in teaching), Figure 6-27 shows that 8.1 % of the participants never used the approach while 17.0% of the participants rarely used it. Moreover, the majority of the participants (44.1%) sometimes used the approach. On the other hand, about a quarter of the participants (25.7%) often used teacher-centred approach while only 5.0% always used this approach.

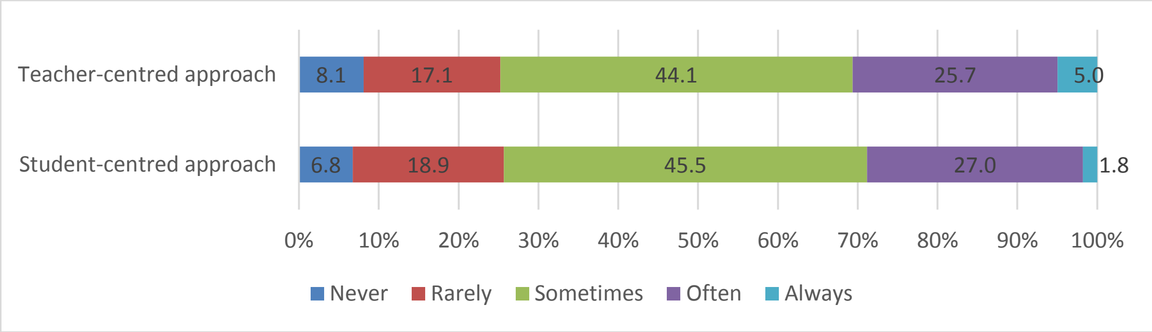

Figure 6-26: Distribution of the participants' answers to items regarding their teaching approaches with ICT

Moreover, regarding the participants' responses to the frequency of the use of a student-centred approach, the results show that 6.8% of the participants never used this approach and 18.9% rarely used it. Moreover, the majority of the participants (45.5%) sometimes used this approach. On the other hand, very small number of the participants (1.8%) always used while 27.0% often used this approach when they taught with ICT.

Mean and Standard Deviation

To compare participants' responses between the items, mean scores of each item about teachers' teaching approaches are presented in Table 6.14.

Table 6-14: Mean scores of participants' responses to items regarding teaching approaches

Teaching Approaches	Mean	Std. Deviation
Teacher-centred approach	3.02	.90
Students-centred approach	2.98	.98

In summary, the frequency use of a teacher-centred approach was slightly higher than a student-centred approach with mean scores were 3.02 and 2.98 respectively.

A paired t-test was carried out to determine if there was statisticaly significant difference of teacher's teaching approaches. The results showed that there was no significant difference in the use of ICT for teacher-centred approach (M=3.02, SD =.90) student-centred approach (M=2.98, SD =.98); t (220) =--.66, p= .51.

Subject Level

In order to attain a completed insight of teachers' practice in the use of ICT, the study also sought information about mathematics subject taught with ICT. This issue was investigated through question 28. As explained in the methodology chapter, this question consisted of five items.

Percentage of Frequency Distribution

Figure 6-27 shows distribution of the participants' responses to each item about topics taught with ICT

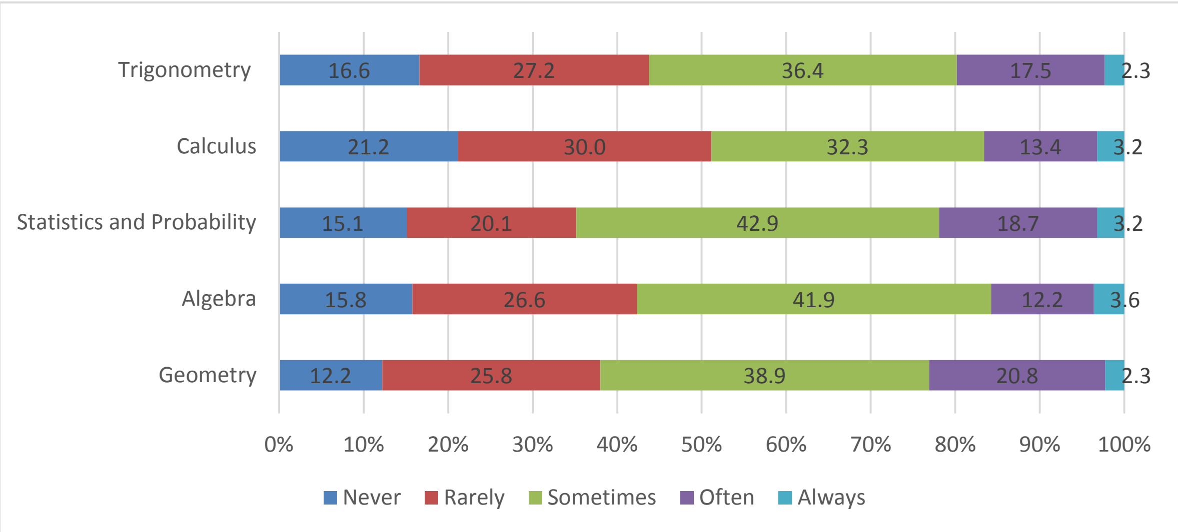

Figure-6-27: Distribution of the participants' answers to items regarding topics of mathematics taught with ICT

First, regarding the use of ICT in the teaching of Geometry, Figure 6-27 shows that 12.2% of the participants never used ICT to teach Geometry, and 25.8% of the participants rarely used the digital tool to teach this topic. Moreover, the majority of the participants (38.9%) sometimes used ICT. On the other hand, only 2.3% of the participants always used ICT and 20.8% of the participants often used ICT to teach this topic.

The second item was about the frequency of ICT use in the teaching of Algebra. Figure 6-27 shows that 15.8% of the participants never used ICT to teach while 26.6% of the participants rarely used the technology to teach this subject. On the other hand, a very small numbers of the participants (3.6%) always used ICT and 12.2% often used ICT in geometry teaching. In addition, the majority of the participants (41.9%) sometimes used ICT in teaching of the subject.

In the last item, (I use ICT to teach Statistics and Probability), the results show that 15.1% of the participants never used ICT to teach this topic. Moreover, a moderately large numbers of the participants (20.1%) rarely used and the majority of the participants (42.9%) sometimes used ICT in teaching of statistics and probability. On the other hand, only a few of the participants (3.2%) always used ICT while 18.7% often used ICT to teach this topic.

In terms of the frequency of use of ICT to teach calculus, the results show that 21.2% of the participants never used ICT to teach this topic. A relatively large numbers of the participants (30%) rarely used ICT in Calculus teaching. Moreover, the majority of the participants (32.3%) sometimes used it while 13.4 % of the participants often use ICT to teach this topic. In addition, only 3.2% of participants used ICT to teach Calculus.

The last item dealt with the frequency of ICT use to teach trigonometry. As shown in Figure 6-27, the results show that 16.5% of the participants never used ICT to teach trigonometry. Moreover, 27.2% of the participants rarely used ICT to teach this subject. The majority of the participants (36.4%) sometimes used it while 17.5% often used ICT to teach the subject. Additionally, a very small number of the participants (2.3%) used ICT to teach trigonometry.

Mean and Standard Deviation

To compare participants' responses between the items, mean scores of each item are presented in Table 6.15. In summary, the results show that the most frequent use of ICT was for the teaching of Geometry as well as Statistics and Probability in which both items received 2.75 of mean scores. On the other hand, the least frequently used of ICT in Calculus teaching that has 2.47 of mean scores.

Table 6-15: Mean scores of participants' responses to items regarding topics taught with ICT

Topics of Mathematics	Mean	Std. Deviation
Geometry	2.75	.99
Algebra	2.61	1.01
Statistics and Probability	2.75	1.03
Calculus	2.47	1.07
Trigonometry	2.62	1.03

A repeated measures ANOVA was carried out to determine if there was statisticaly significant difference of topics of mathematics taught with ICT. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(9) = 25.69,\ p = 0.00$, therefore degree of freedom were corrected using Huynh-Feldt estimate of sphericity ($\varepsilon = .96$). The results show that there was significant differences in the use of ICT across topics of mathematics *F*(3.86, 817.75) = 9.07, p = 0.00.

Task Level

Question 30 of the questionnaire was the last question about teachers' practice in the use of ICT. This question, which consisted of five items, explored types of tasks set for students when teachers used ICT in the classroom.

Percentage Distribution

Results of participants' answer to each item regarding types of tasks set for their students are presented in Figure 6-28.

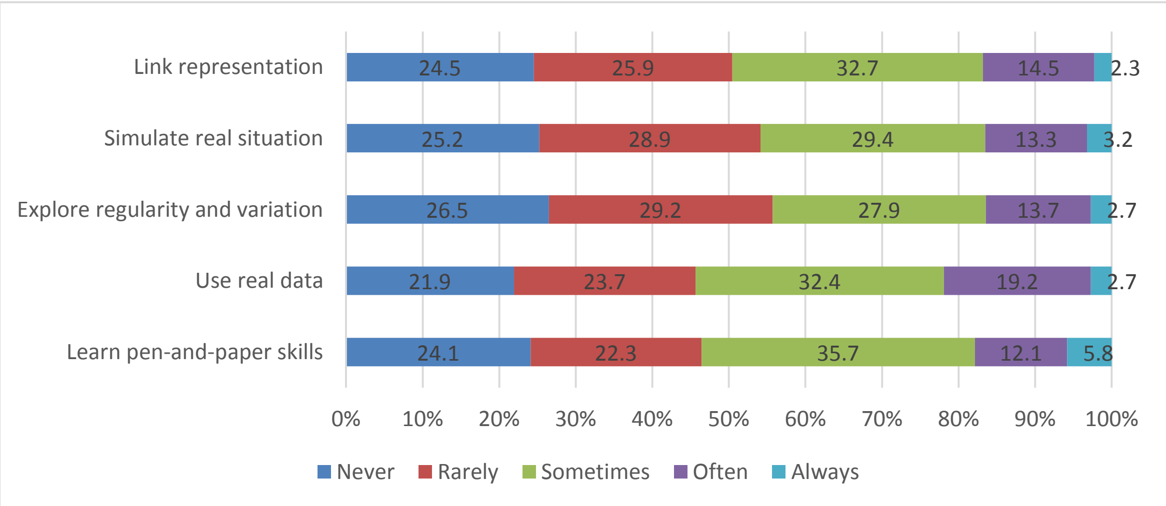

Figure 6-28: Distribution of the participants' answers to items regarding types of tasks set for the students

The first item revealed the frequency of "Learn pen-and-paper skills" tasks set by the participants when they integrated ICT in the classroom. Nearly a quarter of the participants (24.1%) never created this type of tasks while 22.3% of the participants rarely provided the tasks for their students. Furthermore, the majority of the participants (35.7%) sometimes set this type of tasks. On the other hand, only 5.8% of the participants always set "Learn pen-and-paper skills" tasks and 12.1% of participants often set the tasks.

Another item was about the frequency of 'use real data' tasks set by the teachers. Figure 6-28 shows that 21.9% never set this task, while 23.7% of participants rarely do it. Moreover, the majority of the participants (32.4%) sometimes set this type of tasks and only 12.1% of the participants often created the tasks. In addition, only a few of the participants (2.7%) always set tasks of 'use real data' in the classroom.

The 'explore regularity and variation' was another type of tasks that may set by teachers when they integrate ICT in the mathematics classroom. Regarding this, the results show that more than a quarter of the participants (26.5%) never set this type of tasks while 29.2% of participants rarely provided the task. Moreover, 27.9% of participants sometimes designed these tasks and only 13.7% of the participants often created the task. In addition, a small number of the participants always provided tasks of exploring regularity and practice when they integrated ICT in the classroom.

The fourth item was about the frequency of the simulating real situation task set by the teachers. Figure 6-28 shows that a quarter of the participants (25.2%) never created this type of task, while a slightly large number of the participants (28.9%) rarely set the tasks. Moreover, 29.4% of the participants sometimes created this type of task and only 13.3% of the participants often set when they used ICT in the classroom. Finally, only a few number of the participants (3.2%) always set simulate a real situation when they used ICT in mathematics teaching.

The last item dealt with the frequency of use of task of 'link representation' by the teachers. The results show that the majority of the participants (32.7%) sometimes set the tasks. Moreover, 24.5% of the participants never designed this task, and about a quarter of the participants (25.9%) rarely set this type of task when they used ICT in the classroom. In contrast, a very small number of the participants (2.3%) always provided this task to their students and only 14.5% of the participants often set this type of tasks for their students.

Mean and Standard Deviation

Mean scores of participants' response to each item about the task types set for the students are presented in Table 6.16. The results show that "Learn pen-and-paper skills" and "use real data" were the two most frequently use of tasks when teachers integrate ICT in the classroom. On the other hand, "explore regularity and variation" was the least frequently used task in the teaching with 2.40 of mean score.

Table 6-16: Mean scores of participants' responses to items regarding the tasks set for students

Type of tasks	Mean	Std. Deviation
Learn pen-and-paper skills	2.53	1.15
Use real data	2.57	1.11
Explore regularity and variation	2.37	1.10
Simulate real situation	2.40	1.10
Link representation	2.44	1.08

A repeated measures ANOVA was carried out to determine if there was statisticaly significant difference of topics of mathematics taught with ICT .Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(9) = 35.94,\ p = 0.00$, therefore degree of freedom were corrected using Huynh-Feldt estimate of sphericity ($\varepsilon = .94$). The results show that there was significant differences in the use of ICT across tasks $F(3.76, 812.99) = 5.20$, p = 0.01.

6.3.5 Summary of Results on Teachers' Classroom Practices

More than half of the participants (67.7%) had used ICT in their teaching of mathematics at least once. However, a large number of the participants (43.32%) used it for only 1 to 3 years, and significant numbers of participants (47.8%) integrated ICT in 21% to 50% of their mathematics lessons.

In terms of the use of hardware, the participants mostly used computers/laptops presentation software (e.g., Ms PowerPoint) in secondary mathematics classrooms. This indicates that the use of the general software was more frequent than the use of mathematical software. Moreover, Dynamic Mathematics Software and Dynamic Geometry Software were two most frequently used the mathematical software.In addition, regarding online resources; teachers more frequently used web-based applications than they used software of the learning management system.

Moreover, the participants commonly use ICT for doing arithmetic and drawing graphs as well as presenting contents of mathematics and giving classroom. There was no significant difference in the use a teacher-centred approach and a student-centred approach. The survey results also suggested that Geometry was the most commonly taught topics by using ICT. Finally, regarding task set for the students, “drill and practice” and “use real data” were two most frequently task set for the students.

6.4 Descriptive Analysis of Barriers to the Use of ICT in the Classroom

As previously discussed in the methodology chapter, there were three questions (Q31, Q32, Q33) of the questionnaire dealt with barriers to the use of ICT in the classroom. The first question was about teacher-level barriers while the second one explored school-level barriers. In addition, the last question aimed to investigate curriculum-level barriers. Results of those questions are presented in the following sections.

6.4.1 Teacher-Level Barriers

Question 31 of the questionnaire was about teacher-level barriers to the use of ICT in the classroom. This question consisted of three items and was measured on a 5-point Likert type scale from “strongly disagree” to “strongly agree”. Distributions of participants’ answers to each item are presented below.

Percentage of Frequency Distribution

Figure 6-29 presents distributions of the participants’ responses to each item about teachers-level barriers to integrate ICT.

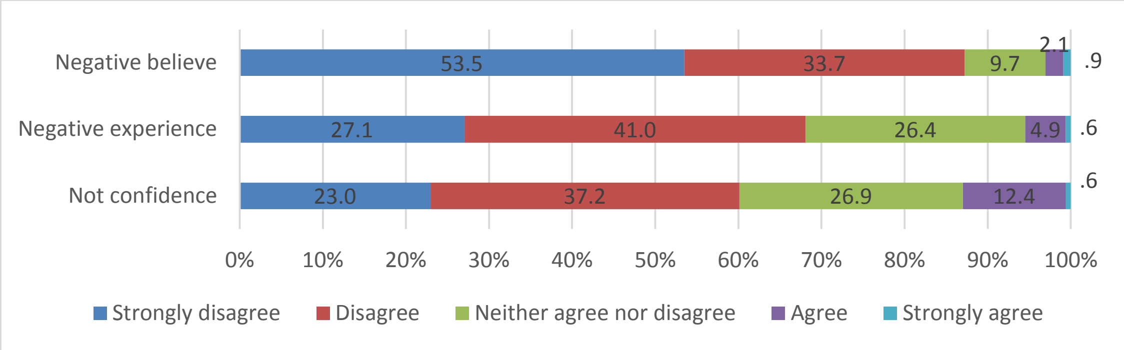

Figure 6-29: Distribution of the participants' answers to items regarding the teacher-level barrier

The first item was that “I am not confident to use ICT in the classroom”. The majority of the participants (37.2%) disagreed, and 23% of the participants strongly disagreed with the statement. On the other hand, a few of the participants (0.6%) strongly agreed, and 12.4% of the participants agreed with the statement. However, a relatively large number of the participants (26.9%) neither agreed nor disagreed with the statement.

Overall, the majority of the participants (41%) did not agree with the statement that “I had negative experiences with ICT in the past”. A moderately large number of the participants (27.1%) strongly disagreed with the statement. On the other hand, a very small number of participants (0.6%) agreed and 4.9% of the participants strongly agreed with the statement. Moreover, more than a quarter of the participants (26.4%) were not sure about the statements.

The last item dealt with teachers’ belief in the use of ICT in the classroom. The majority of the participants (53.5%) strongly disagreed, and a moderately large number of the participants (33.7%) disagreed with the statement. Moreover, 9.7% of the participants were unsure about this statement. In contrast, a very small number of the participants (0.9%) strongly agree and 2.1% agreed with the statement.

Mean and Standard Deviation

To compare responses across all items, mean scores of participants’ responses to each item about teacher-level barriers are presented in Table 6-17.

Table 6-17: Mean scores of participants' responses to items regarding the teacher-level barrier

Teacher-Level Barrier	Mean	Std. Deviation
I am not confident to use ICT in the classroom	2.31	.98
I had negative experience with ICT in the past	2.11	.88
I believe that ICT does not enhance learning	1.63	.82
Mean	2.01	

The table shows that "I am not confident" (Mean=2.31) was the highest mean score of teacher-level barriers. This indicates that teachers' confidence in the use of ICT in the classroom was the main barrier of the teacher level. On the other hand, "I believe that ICT does not enhance learning" (Mean=1.63) was the lowest mean score of this category. This indicates that teachers had fewer problems with their belief about the use of ICT in the classroom.

A repeated measure ANOVA was carried out to determine if there was statisticaly significant difference of teacher barriers at the teacher-level barrier. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(2) = 9.37$, $p = 0.01$, therefore degree of freedom were corrected using Huynh-Feldt estimate of sphericity ($\varepsilon = .98$). The results show that there was significant differences in teacher barriers to use of ICT across items of teacher level barrier $F(1.96, 639.72) = 60.42$, p = 0.00.

6.4.2 School-Level Barriers

Question 32 was about school-level barriers to the use of ICT in the classroom. This question consisted of six items and was measured on a 5-point Likert type scale from "strongly disagree" to "strongly agree. Distributions of participants' answers to each item are presented below.

Percentage of Frequency Distribution

Figure 6-30 presents distributions of participants' responses to each item regarding teacher-level barriers. The first item of this scale was "I do not have access to hardware at my school". The majority of the participants (41%) disagreed and more than a quarter of the participants (27.4%) strongly disagreed with this statement. Moreover, 18.2% of the participants were not sure with the statement. On the other hand, 10% of the participants agreed and only 3.3% of the participants strongly agreed with the statement.

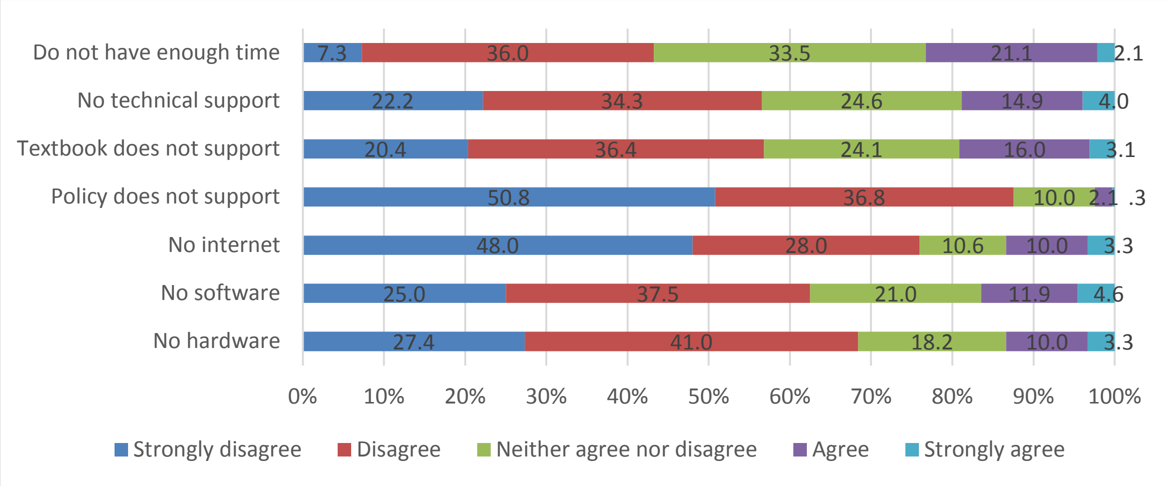

Figure 6-30: Distribution of the participants' answers to items regarding the school-level barriers

The next item focused on access to software in schools. The highest number of the participants (37.5%) agreed with the statement. Furthermore, a quarter of the participants (25%) strongly disagreed while 21% of the participants were unsure of the statement. In contrast, only 11.9% of the participants agreed and a few of the participants (4.6%) strongly disagreed with the statement.

Regarding the third item (my school does not have the internet connection), the majority of the participants (48%) strongly disagreed and 28% of the participants disagreed with the statement. Moreover, there were 10.6% of the participants who were unsure about the statement. However, a very small number of the participants (3.3%) strongly agreed and 10% agreed with the statement.

The fourth item dealt with school policy on the use of ICT. The majority of the participants (50.8%) strongly agreed with this statement. Moreover, a moderately large number of the participants (36.8%) disagreed and 10% of the participants were unsure of the statement. In contrast, a very small number of the participants (0.3%) strongly disagreed and 2.1% agreed with the statement.

Another item of this scale was (textbooks do not incorporate information about the use of ICT). The results show that majority of the participants disagreed (36.4%) and 20.4% strongly disagreed with the statement. Furthermore, nearly a quarter of the participants (24.1%) were unsure with this statement. However, 3.1% of participants strongly disagreed while 16% of the participants agreed with the statement.

The next item was a statement about technical support (my school does not provide technical support). The majority of the participants (34.3%) disagreed while 22.2% of the participants strongly disagreed with the statement. Moreover, 24.6% of the participants were unsure with the statement. On the other hand, only 4% of the participants strongly agreed and 14.9% of the participants agreed with the statement.

In the last item, (i do not have enough time to prepare ICT-based lessons), the results show that majority of the participants (36%) disagreed and 7.3% of the participants strongly disagreed with the statement. On the other hand, only 2.1% of the participants strongly agreed and 21.1% of the participants agreed with the statement. In addition, a moderately large number of the participants (33.5%) neither agreed nor disagreed with the statement.

Mean and Standard Deviation

To compare participants' responses across the items, mean scores of each item regarding school-level barriers are presented in Table 6-18. Results show that mean score of the last item (I do not have enough time to prepare ICT-based lessons) was the highest one (2.75), indicating teachers' lack of time was the main barrier at the school level. This barrier then was followed by textbooks do not incorporate information about ICT use (Mean=2.45), Lack of technical support from school (Mean=2.44), Lack of software (Mean = 2.34) and lack of hardware (Mean=2.21). In short, the results suggest that teachers do not have enough time to prepare ICT-based lessons was the main barrier at the school level.

Table 6-18: Mean scores of participants' responses to items regarding the school-level barrier

School-Level Barriers	Mean	Std. Deviation
I do not have access to hardware at school	2.21	1.06
I do not have access to software at school	2.34	1.11
My school does not have internet connection	1.93	1.13
My school's policy does not support the use of ICT	1.64	.77
Textbooks do not incorporate information about the use of ICT	2.45	1.08
My school does not provide technical support	2.44	1.11
I do not have enough time to prepare ICT-based lessons	2.74	1.01
Mean	2.25	

A repeated measure ANOVA was carried out to determine if there was statisticaly significant difference in teacher barriers at the school-level barrier. *Mauchly's test indicated that the assumption of sphericity had been violated,* $x^2(14) = 194.59,\ p = 0.00$, therefore degree of freedom were corrected using Huynh-Feldt estimate of sphericity ($\varepsilon = .83$). The results show that there was significant differences in teacher barriers to use of ICT across items of school level barrier $F(4.17, 1316.98) = 49.82$, p = 0.00.

6.4.3 Curriculum-Level Barriers

Question 32 of the questionnaire was about curriculum-level barriers to the use of ICT. This scale consisted of two items and was measured on a 5-point Likert type scale.

Percentage of Frequency Distribution

Figure 6-31 presents distributions of participants' responses to items about curriculum-level barriers.

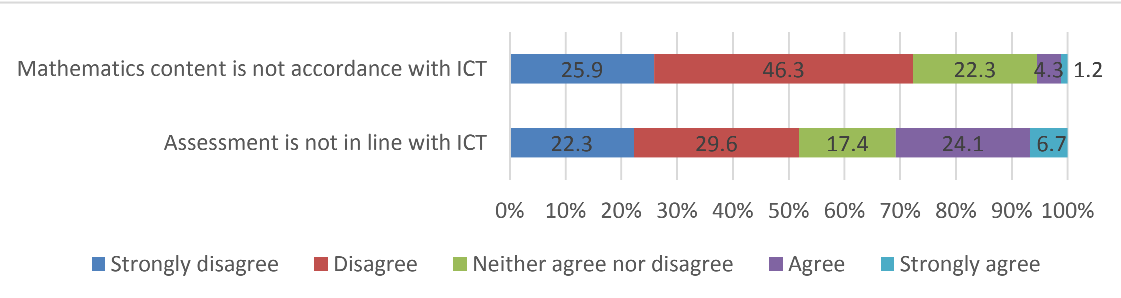

Figure 6-31: Distribution of the participants' answers to items regarding the curriculum level-barrier

The first item of this scale was (in my school, student's assessment is not in line with the use of ICT). The majority of the participants (29.6%) disagreed and 22.3% of the participants strongly disagreed with the statement. Furthermore, 7.4% of the participants neither agreed nor disagreed with the statement. However, nearly a quarter of the participants (24.1%) agreed while only 6.7% of the participants strongly agreed with the statement.

Regarding the second item (Structure of Mathematics' content that I teach is not in line with the use of ICT), the results show that the majority of the participants (46.3%) disagreed and a quarter of the participants (25.9%) strongly disagreed with the statement. Furthermore, 22.3% of the participants neither agreed nor disagreed with the statement. In contrast, only 4.3% of the participants agreed and 1.2% of the participants disagreed with the statement.

Mean and Standard Deviation

To compare the responses, mean scores of each item are presented in Table 6-20. As shown in Table 6-19, mean score of participants' responses to the barrier of students' assessment (Mean = 2.63) was higher than mean score of the responses about the barrier of the structure of mathematics contents was (Mean = 2.09). The results suggested that students' assessment is not in line with the use of ICT as a main barrier of the curriculum level.

Table 6-19: Mean scores of participants' responses to items regarding the curriculum-level barrier

Barriers at Curriculum Level	Mean	Std. Deviation
Student's assessment is not in line with the use of ICT	2.63	1.25
Structure of Mathematics' content is not in line with the use of ICT	2.09	.87
Mean	2.36	

A paired t-test was carried out to determine if there was statisticaly significant difference of teacher barriers at the curriculum-level barrier. The results show that there was significant difference in barrier at the curriculum level for student assesment (M=2.63, SD =1.25) and structure of mathematics content (M=2.09, SD =.87); t (325) =7.85, p= .00.

6.4.4 Summary of Results on Teachers' barriers

The results suggested that teachers' lack of confidence in the use of ICT in the classroom as the main barrier at the teacher level. Furthermore, the results also revealed that teachers' lack of time to prepare ICT based-lessons as the main barrier regarding the school level. In addition, regarding curriculum-level barriers, the participants perceived that students' assessment did not support ICT integration as the main barrier of the curriculum level.

6.5 Inferential Statistical Analysis

Inferential statistic tests were administered to explore research question #3 and research question #5. The third research question was intended to examine the relationship between teachers' knowledge and their classroom practices in the use of ICT in the classroom. Moreover, the fifth research question aimed to explore the differences in teachers' knowledge and classroom practices by the participants' demographic background. Results of data analysis regarding those aspects are presented in the next sections.

6.5.1 Relationship between Teachers' Knowledge and Classroom Practice

As mentioned in section 5.7, to examine the relationship between teacher knowledge and classroom practice, Spearman's correlation was employed in this study. In the section, it was also mentioned that there are three assumptions needed to satisfy in order to be eligible to use this test. According to Sheskin (2004), those assumptions are as follows:

- Assumption #1: Two variables that are measured on a continuous and/or ordinal scale; that is, it can be : (a) two continuous variables; (b) two ordinal variables
- Assumption #2: Two variables represent paired observations
- Assumption #3: It needs to be a monotonic relationship between the two variables

It is clear that the data met the first two assumptions. Teachers' use of ICT was measured on the ordinal scale ranging from 'Never' (1) to 'Always' (5). Moreover, teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching were also measured in a five-point ordinal scale ranging from 'Strongly Agree' (5) to 'Strongly Disagree' (1).

Furthermore, the third assumption, which needs to be a monotonic relationship between the two variables, is presented below.

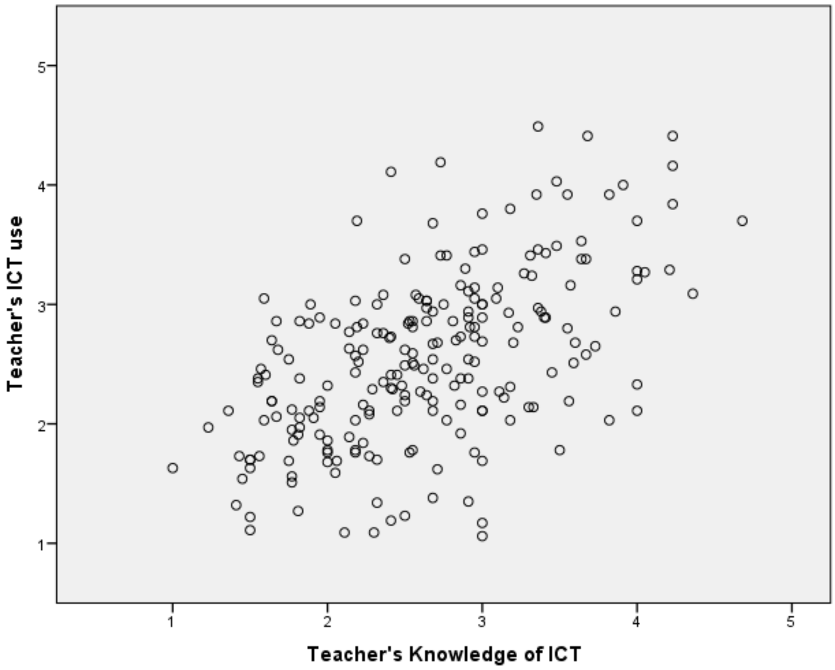

Figure 6-32: Scatterplot of teachers' knowledge of ICT and their use of ICT

From visual inspection of Figure 6-32, there is a monotonic relationship between teachers' knowledge of ICT and their use of ICT in the classroom. In addition, from the inspection of this scatterplot, it can be concluded that there are no significant outliers in this data set.

Figure 6-33 presents the relationship between teachers' knowledge of ICT use in teaching and the use of ICT in the classroom.

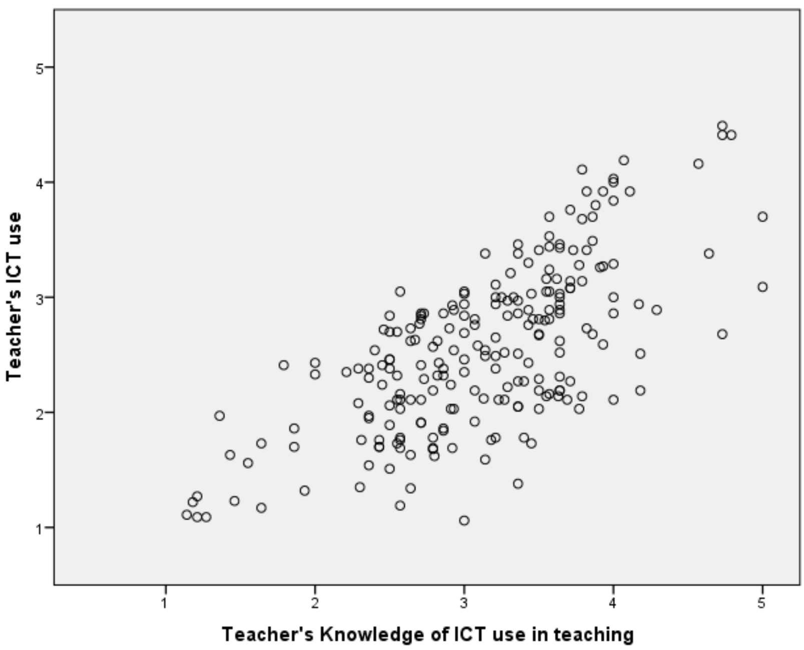

Figure 6-33: Scatterplot of teachers' knowledge of ICT use in teaching and their use of ICT

From visual inspection of the scatterplot above, there is a monotonic relationship between teachers' knowledge of ICT use in teaching and the use of ICT. Moreover, it can also be concluded that there are no significant outliers in this data set. Finally, it can conclude that the data set of teachers' classroom practices and their knowledge satisfy all assumptions. Therefore, Spearman's correlation employed for the statistical test would produce valid results.

Relationship between teachers' knowledge and classroom practices

Table 6-20: Summary of correlation matrix

Variable	ICT use in teaching	Knowledge of ICT	Knowledge of ICT use in teaching
Classroom Practices	1.00		
Knowledge of ICT	.524**	1.00	
Knowledge of ICT use in teaching	.645**	.666**	1.00

**. Correlation is significant at the 0.01 level (2-tailed).

As discussed in the chapter of the conceptual framework, this study distinguishes knowledge of ICT and knowledge of ICT use in teaching. Table 6-20 summarises results of Spearman's correlation regarding teachers' knowledge and their use of ICT in the classroom.

Cohen (1992) proposed these guidelines for the interpretation of a correlation coefficient:

Table 6-21: Guidelines for the interpretation of a correlation coefficient

Strength of Association	Correlation coefficient value	
	Negative	Positive
Weak	-.3 to -.1	.1 to .3
Moderate	-.5 to -.3	.3 to .5
Strong	-.9 to -.5	.5 to .9
Very Strong	-1 to -.9	.9 to 1.0

Sources: adopted from (Cohen, 1992)

As shown in Table 6-21, there was a strong positive correlation between teachers' knowledge of ICT use in teaching and their use of ICT (r_s = .645). Further analysis showed a strong positive correlation between teachers' knowledge of ICT and their use of ICT (r_s = .524). Moreover, the results suggest that the relationship between teachers' knowledge of ICT use in teaching and teachers' use of ICT was stronger than the relationship between teachers' knowledge of ICT and their use of ICT in the classroom.

In conclusion, a Spearman's correlation was employed to assess the relationship between teachers' knowledge of ICT and their use of ICT and the relationship between teachers' knowledge of ICT use in teaching and their use of ICT. Preliminary analysis showed the relationship to be monotonic, as assessed by visual inspection of a scatterplot. Moreover, there were strong positive correlations for both knowledge, and the correlation between teachers' knowledge of ICT use in teaching and teachers' use of ICT was stronger than the correlation between teachers' knowledge of ICT and their use of ICT in teaching.

6.5.2 Differences in Teachers' Knowledge and Teachers' Use of ICT according to their Demographic Background

To assess the differences among participants different background (Gender, Level of Education, Teacher Certification, Teaching Experience, and Type of School) on the scale of "teachers' knowledge" and "teachers' use of ICT ". As previously described in the Chapter of Research Methodology, the following statistic tests were performed to test those variables.

Assumption

Mann-Whitney Test: As mentioned earlier, according to Sheskin (2004)**,** there are four assumptions needed to satisfy to employ Mann-Whitney Test. The assumptions are:

- Assumption #1: One dependent variable that is measured at the continuous or ordinal level.
- Assumption #2: One independent variable that consists of two categorical, independent groups (i.e., a dichotomous variable).
- Assumption #3: There is no relationship between the observations in each group of the independent variable.
- Assumption #4: Determine the distribution of score have the same shape or a different shape.

It seems that the data meet the first three assumptions. First, teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching was measured on five-point ordinal scales ranging from 'Strongly Agree' (5) to 'Strongly Disagree' (1). Moreover, teachers' use of ICT was also measured in ordinal scales ranging from 'Never' (1) to 'Always' (5). Second, independent variables that consist of two categorical independent groups are Gender, Teacher Certification, and Type of School. Third, it is clear that there is no relationship between data of both teachers' knowledge and teachers' use of ICT in each group of the independent variables.

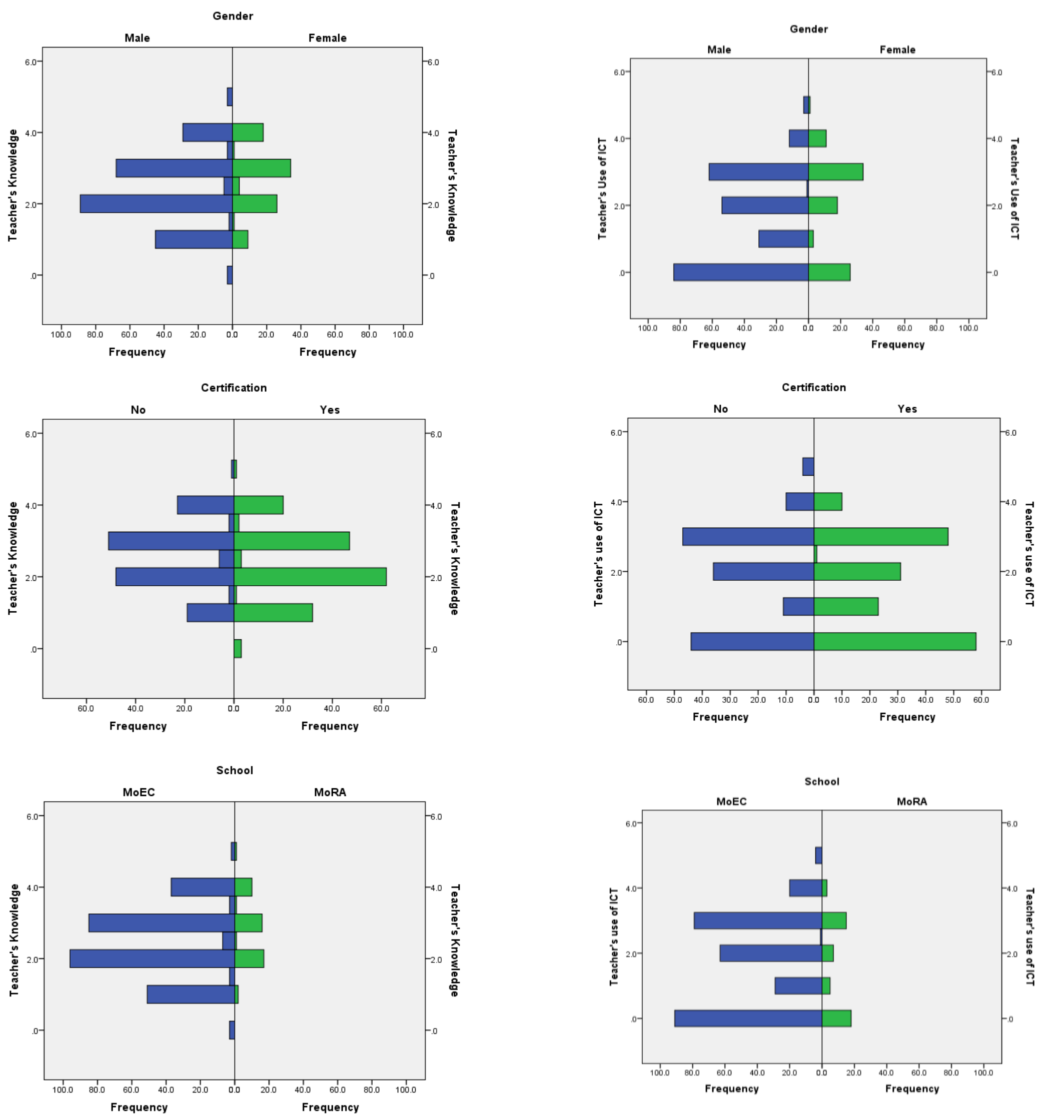

Figure 6-34: Distribution of teachers' knowledge and classroom practices according to gender, certification and type of school.

Regarding the assumption #4, Figures 6-34 present distributions of teachers' knowledge and teachers' use of ICT by gender, teacher certification, and type of school. By visually inspecting the shapes of these distributions, it shows that the distributions look fairly similar so it can make judgments about differences in medians.

It can be concluded that that Mann-Whitney test is fitted to use for testing differences in teachers' knowledge and teachers' use of ICT according to their gender, teacher certification, and type of school.

Kruskal-Wallis Test: As mentioned previously, according to Sheskin (2004), there are four assumptions needed to produce a valid result of Kruskal-Wallis test. The assumptions are:

- Assumption #1: One dependent variable that is measured at the continuous or ordinal level
- Assumption #2: One independent variable that consists of two or more categorical, independent groups.
- Assumption #3: There is no relationship between the observations in each group of the independent variable.
- Assumption #4: Determine whether the distributions of scores for each group of independent variables have the same shape or a different shape.

Looking Figure 6-35, by visually inspecting the shapes of the distributions, it shows that there are some similarity and differences in distribution. With respect to the distributions of teachers' knowledge and teachers' use of ICT by teaching experience, the distributions of scores were fairly similar for all groups. Thus, it can investigate the differences in medians.

On the other hand, with regard to teachers' level of education, the distribution of scores of teachers' knowledge and teachers' use of ICT were dissimilar. Therefore, I still can use Kruskal-Wallis H test, but the inference I can make will be different. Since the distributions were not similar, I would not be able to use median to understand the differences across the groups of the highest level of education. Therefore, in the interpretation, I can only say whether one or more groups' scores were higher or lower than the other groups based on mean ranks.

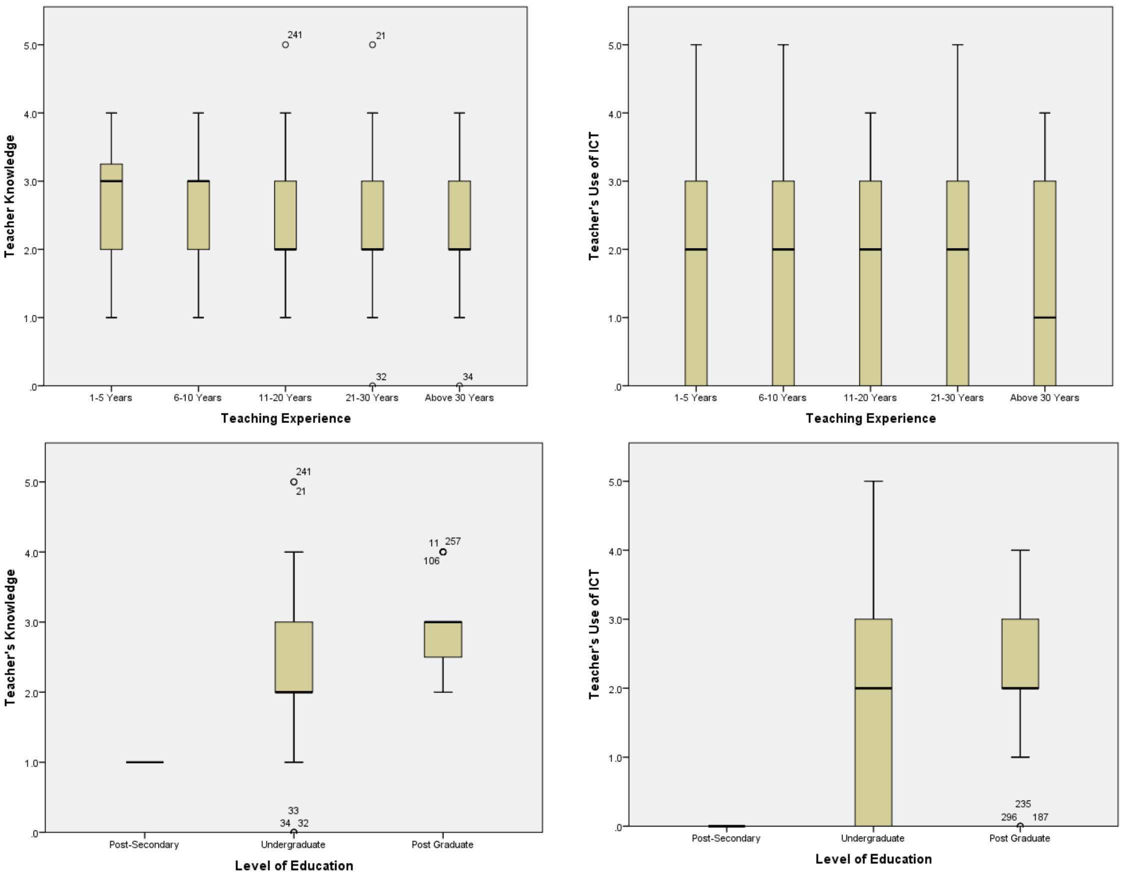

Figure 6-35: Distribution of teachers' knowledge and teachers' classroom practice according to years of teaching experience and level of education

Regarding those assumptions, the dependent variable of the highest level of education and teaching experience satisfy those assumptions; therefore, Kruskal-Wallis test was employed to determine differences in teachers' knowledge and teachers' use of ICT by those independent variables.

Result of Mann-Whitney Test

Gender: This study also looked at differences in teachers' knowledge and classroom practices. The results of Mann-Whitney test are presented in Table 6-22.

Table 6-22: Results of Mann Whitney test on gender

Domain	Median	ρ
Teachers' knowledge	Male= 2.0 ; Female= 3.0	.004
Teachers' Use of ICT	Male = 2.0 ; Female = 3.0	.006

*the significant level is .05

A mann-Whitney U test was run to determine if there were differences in scores of teachers' knowledge and classroom practice between male and female teachers. In terms of teachers' knowledge, as assessed by visual inspection, the distributions of knowledge scores for males and females were different. The median score of knowledge was statistically higher in females (3.0) than males (2.0), p = .004.and the median scores of teacher' use of ICT in female (3.0) was higher than male (2.0) with p= .006.

Teacher Certification: As previously mentioned in Session 2.3, the Indonesian government has attempted to implement teacher reform through several programmes. One of them was the teacher certification programme that has been implemented for about ten years. However, the results (see section 6.1.5) show that a significant number of the participants have not been awarded the teaching certificate.

A Mann-Whitney U test was also run to determine if there were differences in scores of teacher knowledge and classroom practice between certificated and non-certificated teachers. Table 6-23 shows that a median score of knowledge was statistically significantly higher in non-certificated teachers (3.0) than in certificated teachers (2.0), p = 0.030. In contrast, Median scores of ICT use in non-certificated teachers (2.0) and certificated teachers (2.0) were not statistically significantly different, p = 0.108.

Table 6-23: Results of Mann-Whitney test on teacher certification

Domain	Median	ρ
Teachers' knowledge	No: 3.0 ; Yes: 2.0	.030
Teachers' use of ICT	No: 2.0 ; Yes: 2.0	.108

*the significant level is .05

Type of School: As discussed in Section 2.2, Indonesian schools are administered by the Ministry of Education and Culture (MoEC) or the Ministry of Religious Affairs (MoRA). A Mann-Whitney U test was employed to determine if there were differences in scores of teachers' knowledge and teachers' use of ICT between MoRA teachers and MoEC teachers. Table 6-24 shows that a median score of knowledge was statistically higher in MORA teachers (3.0) that MoEC teachers (2.0), p = 0.010. However, median scores of ICT use for MoRA teachers (2.0) and MoEC teachers (2.0) was not statistically significantly different, p = 0.606.

Table 6-24: Results of Mann-Whitney test on type of school

Domain	Median		ρ
Teachers' knowledge	MoRA: 3.0	; MoEC: 2.0	.010
Teachers' use of ICT	MoRA: 2.0	; MoEC: 2.0	.606

*the significant level is .05

Results of Kruskal-Wallis Tests

As mentioned earlier, Kruskal-Wallis tests were administered to examine differences in teacher's knowledge and teachers' use of ICT according to their level of education and the numbers of years of teaching experiences. Results of the test are presented below.

Level of Education: The education level of Indonesian teachers varies from a post-secondary to a post-graduate degree. As mentioned in Section 2.3, the Indonesian teacher requires all teachers to hold at least a four-year university degree. This study attempts to examine differences in teachers' knowledge and classroom practices according to their level of education.

Table 6-25: Results of Kruskal-Wallis test on level of education

Variable	Value
Teachers' knowledge	H-Value = 15.716; Degree of Freedom = 2; Sig. = .000 Mean Rank = Post-Secondary (30.00); Undergraduate (164.03); and Post-Graduate (225.07)
Teachers' use of ICT	H-Value = 7.102; Degree of Freedom = 2; Sig. = .029 Mean Rank = Post-Secondary (53.50); Undergraduate (165.99); and Post-Graduate (202.83)

A Kruskal-Wallis test was run to determine if there were differences in teachers' knowledge and teachers' use of ICT scores across the three groups of participants with a different highest level of education: post-secondary, undergraduate, and postgraduate groups. As assessed by visual inspections of boxplots (see Figure 6-35), distribution of teachers' knowledge score and teachers' use of ICT scores were not similar for all groups.

In terms of teacher knowledge, as shown in Table 6-25, a Kruskal-Wallis test provided very strong evidence of a difference in teacher knowledge ($p = 0.00$) between the mean ranks of at least one pair of groups. Dunn's pairwise tests were carried out for the three pairs of groups. There was very strong evidence ($p=.013$, adjusted using Bonferroni correction) of a difference between the group of the teachers who had post-secondary degree and post-graduate degree. The mean rank of knowledge for post-secondary group was 30.00 compared to 225.07 in the group of post-graduate. Moreover, There was also very strong evidence (p=.002 adjusted using Bonferroni correction) of a difference between the group of the teachers who had undergraduate degree and post-graduate degree. The mean rank of knowledge for undergraduate degree group was 164.03 compared to 225.07 in the group of post-graduate. On the other hand, there was no evidence of a difference between another pair.

Regarding teacher classroom practice, a Kruskal-Wallis test also provided an evidence of a difference in teacher classroom practices (p = .029) between the mean ranks of at least one pair of groups. Dunn's pairwise tests were carried out for the three pairs of groups. There was very strong evidence (p=.030, adjusted using Bonferroni correction) of a difference between the group of the teachers who had post-secondary degree and post-graduate degree. The mean rank of classroom practice for post-secondary group was 53.50 compared to 202.83 in the group of post-graduate. On the other hand, there was no evidence of a difference between the other pairs.

Teaching Experience: This study attempts to determine differences in teachers' knowledge and classroom practices according to their teaching experiences.

Table 6-26: Results of Kruskal-Wallis test on years of teaching experience

Variable	Value
Teachers' knowledge	H-Value = 15.789; Degree of Freedom = 4; Sig. = .012 Median= 1-5 Years (3.0); 6-10 Years (3.0); 11-20 Years (2.0); 21-30 Years (2.0); Over 30 Years (2.0).
Teachers' use of ICT	H-Value = 3.032; Degree of Freedom = 4; Sig. = .553 Median = 1-5 Years (2.0); 6-10 Years (2.0); 11-20 Years (2.0); 21-30 Years (2.0); Over 30 Years (1.0)

A Kruskal-Wallis H test was run to determine if there were differences in teachers' knowledge and teachers' ICT use across five groups of participants with different the number of years of teaching experiences, namely 1 to 5 years, 6-10 years, 11 to 20 years, 21 to 30 years, and over 30 years. As assessed by visual inspection of boxplots (see Figure 6-35), distributions of teachers' knowledge and teachers' ICT use scores were fairly similar for all groups.

In terms of teacher knowledge, a Kruskal-Wallis test provided very strong evidence of a difference in teacher knowledge (p = 0.012) between the mean ranks of at least one pair of groups. Dunn's pairwise tests were carried out for the three pairs of groups. There was very strong evidence (p=.014, adjusted using Bonferroni correction) of a difference between the group of the teachers who had 21-30 years of teaching experience and 6-10 years of teaching experience. The median score of knowledge for 21-30 years group was 2.0 compared to 3.0 in the group of 6-10 years of teaching experience. Moreover, There was also very strong evidence (p=.047 adjusted using Bonferroni correction) of a difference between the group of the teachers who had 10-20 years and 6-10 years of teaching experience. The median of knowledge for 10-20 years group was 2.0 compared to 3.0 in the group of 6-10 years of teaching experience. On the other hand, there was no evidence of a difference between the other pair.

However, regarding teacher classroom practices, the results show that median scores of teachers' ICT use were not statistically significantly different across the groups $\chi2$ (4) =1.561, p= 0.816.

Summary of differences in teachers' knowledge and teachers' use of ICT

Table 6-27 summarise statistical test results on differences in teachers' knowledge and classroom practices according to their background. The results suggest that teachers' knowledge were not statistically significantly different across groups for all the demographic background while teachers' classroom practices were statistically significantly different only across groups for education level and gender.

Table 6-27: Summary of the results of Mann-Whitney and Kruskal-Wallis tests.

Variables	Gender	Type of School	T. Certification	Level of Ed.	T. Experience
Knowledge	Significant	Significant	Significant	Significant	Significant
Practices	Significant	Not Significant	Not Significant	Significant	Not Significant

Table 6-28 highlights the independent and dependent variables that produced statistically significantly different results and shows the directions of the differences.

To large extent, the results suggested that teacher knowledge were statistically significantly different across groups for all background categories (gender, level of education, teacher certification, and teaching experience). Female teachers had the stronger knowledge than male teachers. Moreover, teachers with a post-graduate degree had higher stronger knowledge than teachers who hold an undergraduate degree and post-secondary education. In addition, non-certificated teachers had stronger knowledge that certificated teachers. Teachers with teaching experience of 6 to 10 years had higher knowledge than the other teachers. Finally, MoRA teachers had higher scores of knowledge than MoEC teachers. In relation to teachers' use of ICT, however, median scores were statistically significantly different only across groups according to the level of education and gender.

Table 6-28: Results of inferential statistic tests showing statistically significant difference

Variables	Directions of the differences
Knowledge	Gender (Female>Male); Type of school (MoRA > MoEC); Teacher certification (No>Yes); Level of education (Post-graduate > Undergraduate and Post-secondary); Teaching experience (6-10 years > 1-5 years, 11-20 years, 21-30 years & Over 30 years)
Practices	Level of education (Post-graduate > Undergraduate & Post-Secondary); Gender (Female > Male)

Overall, the results suggest that teachers with post-graduate more frequently used ICT that teachers with an undergraduate degree and teachers with a post-secondary degree. In addition, female teachers more frequently used ICT than male teachers.

6.6 Summary

The results suggested that Indonesian secondary mathematics teachers had insufficient knowledge of both ICT and ICT use in teaching. Furthermore, Mann-Whitney and Kruskal-Wallis tests reported that levels of teacher knowledge were statistically significantly different across groups for all background categories (Gender, Teacher certification, Level of education, Teaching experience, and Type of schools).

In relation to teachers' use of ICT, the results revealed that more than half of the participants had used ICT in the classroom at least once. However, they used it for a teaching limited number of the mathematics lessons. Computers/laptops and presentation software were the most frequently used hardware and software in mathematics classrooms. Regarding functional activities, the participants mostly used ICT for doing arithmetic and drawing a graph as well as presenting contents of mathematics. Moreover, there was no significant difference in the frequency of teacher use a teacher-centred approach and a student-centred approach. Geometry was the most frequently taught subject with ICT, and ‘Learn pen-and-paper skills’ and ‘use real data’ were two most common tasks set for students. In addition, Mann-Whitney and Kruskal-Wallis tests reported teachers’ use of ICT statistically significantly different only across groups for gender and level of education.

Spearman correlation tests suggested that there were strong positive correlations between teachers’ knowledge and teachers’ use of ICT. It is important to note that the correlation between teachers’ knowledge of ICT use in teaching and teachers’ use of ICT was stronger than the correlation between teachers’ knowledge of ICT and their use of ICT in teaching.

Furthermore, along with insufficient knowledge, the results indicated that teachers still dealt with various challenges to integrate ICT in secondary mathematics classrooms. Lack time to prepare ICT-based lesson was the main barrier at the school level. Moreover, lack of confidence was the main barrier at the teacher level, and student assessment was the main curriculum at the curriculum level.

In this chapter, I have presented the results of the quantitative phase. In the next chapter, I explore the findings of the qualitative phase.

Chapter 7 Qualitative Findings

The qualitative data were collected through classroom observations and semi-structured interviews with ten participants. This chapter elaborates the qualitative data consisting of descriptions of teachers' classroom practices and the relationship between teachers' knowledge and their classroom practices in the use of ICT in the classroom. The first section of this chapter presents teachers' classroom practices. In this section, I first present classroom observation data which is then followed by the triangulation of classroom observation and interview data. In the second section, I explore patterns of the relationship between teachers' knowledge and their classroom practices. This section consists of two sections dealing with the relationship between teachers' knowledge of ICT and their classroom practices and the relationship between teachers' knowledge of ICT use in teaching and their classroom practices.

7.1 Teachers' Classroom Practices in the Use of ICT

As discussed earlier, teachers' classroom practices in the use of ICT in the classroom was investigated quantitatively and qualitatively. Qualitative data were collected through classroom observations and semi-structured interviews. This section provides finding from classroom observation and semi-structured interview in which the first section describes each participant's classroom practices based on the classroom observation data by using the pedagogical map for MAS. Furthermore, the second section triangulates classroom observation data and interviews data and summarises teachers' classroom practices.

7.1.1 Descriptions of Teachers' Classroom Practices

In this section, I provide descriptions that allow the reader a closer look at teachers' use of ICT in the classroom. The descriptions are mainly drawn from classroom observation data. Regarding the structures of these descriptions, I first introduce profiles of the teachers by providing information about their schools, teaching experiences, educational backgrounds and ICT training as well as their views regarding the aim of the use of ICT in the classroom. I then illustrate the observed classes and highlight classroom activities. Finally, I describe teachers' classroom practices by using Pierce and Stacey's Pedagogical Map of MAS (2010).

It is important to note that not all the themes were easily noticed across observed lessons. Thus, I focus on the themes with strong evidence across the teachers.

7.1.1.1 Rina

Rina was a novice teacher who had been teaching for one year at the secondary school. She held a bachelor degree in mathematics education and had just started her master study in mathematics education as well. As a novice teacher, Rina did not yet have a teaching certificate. Rina's school, which was located in the capital of Aceh province, was a private school that enrolled less than eighty students every year. In terms ICT facility, this school was equipped with a computer room and a permanent digital projector in every classroom.

Rina stated that she had never participated in any professional development relating to the use of ICT since she worked at the school. However, she had learned about how to use ICT in teaching during her undergraduate study. For instance, she took a module about ICT that offered contents such as Autograph software and design of e-Learning. At the end of this course, Rina was assigned to design ICT-based lessons, and taught the lesson to a peer group. Rina hoped that she would have an opportunity to learn about the use of other software such as GeoGebra: "I want to learn about other software, now I only know about how to use Autograph."

Rina's classroom practice. Rina was observed once in which she taught at a Year-11 class where there were 22 students. In the class, where students' desks were clustered into small groups, Rina used a laptop and a digital projector while the students used one laptop for a group of three to four students. Rina and her students used Dynamic Geometry Software (Autograph). In the class, she taught Transformation Geometry, emphasising on Translation.

The teacher started the lesson by introducing the topic by providing several examples of the transformation in a real-life situation, and she took a few minutes to show students how to use the software. When the students were familiar with the software, the teacher distributed worksheets and assigned the students to complete the following tasks.

First, they were given a triangle (ABC) which was translated by the translation$T = (\frac{-2}{1})$, then, by using Autograph software, students worked in groups and they made the translation of the triangle. The students were assigned to move the triangle to several different positions and write down the coordinates of the vertices of the original triangles and the images. Students were asked to drag the triangle to as many different positions as possible, and they were assigned to draw a conclusion about the translation of a triangle by the translation $T = (\frac{-2}{1})$.

Second, they were given a trapezium of TPQS was translated by the translation $T = (\frac{15}{2})$ then it continued by the translation$T = (\frac{2}{-8})$. The second task was similar to the first task in which the teacher also assigned the students to use Autograph software and worked in groups. The students were assigned to drag the trapezium to as many different positions as possible, and then they wrote down the coordinates of the vertices of the original trapeziums and the images. Finally, the students drew a conclusion about the translation of trapezium TPQS by the translation $T = (\frac{15}{2})$ then continued by the translation$T = (\frac{2}{-8})$.

After working on the first and the second task, students presented their workings in front of the class. Finally, the teacher and students together drew a conclusion about the translation. In the final activity of this lesson, students were assigned to complete two questions about the translation by using pen and paper.

In the interview, Rina explained why she used ICT in the way she used it in the observed class. She believed that ICT facilitates student to learn through an enquiry-based approach. She stated that

> … I hoped students would learn mathematics through enquiry and reinvention of the concepts of mathematics, so, through using ICT, they can do and experience this process.

Moreover, Rina believed that her teaching approach would increase students' motivation and they could experience the process of mathematics learning. In addition, the teacher believed that the digital technology helps students draw graphs quickly. Finally, according to Rina, ICT is helpful as it offers good visualisation and users can make it accurately.

Rina's teaching is mapped in Figure 7-1. She took the introduction of DGS (Autograph) as an opportunity to introduce her new approach to teaching mathematics. With the help of DGS, Rina could deliver the lesson with an interesting activity by having students to develop their understanding of the concept of translation. The teacher had more time to spend on concepts when she used ICT in the classroom. In this teacher's classroom, classroom social interaction became more active whereby students were expected to do discoveries and make a general statement. They were also encouraged to share their workings with the class. The teacher set tasks of exploration regularity variation and link representations (e.g., the student dragged the figure to as many different positions as possible and were assigned to draw a conclusion). Consequently, students were empowered to take greater control over their learning.

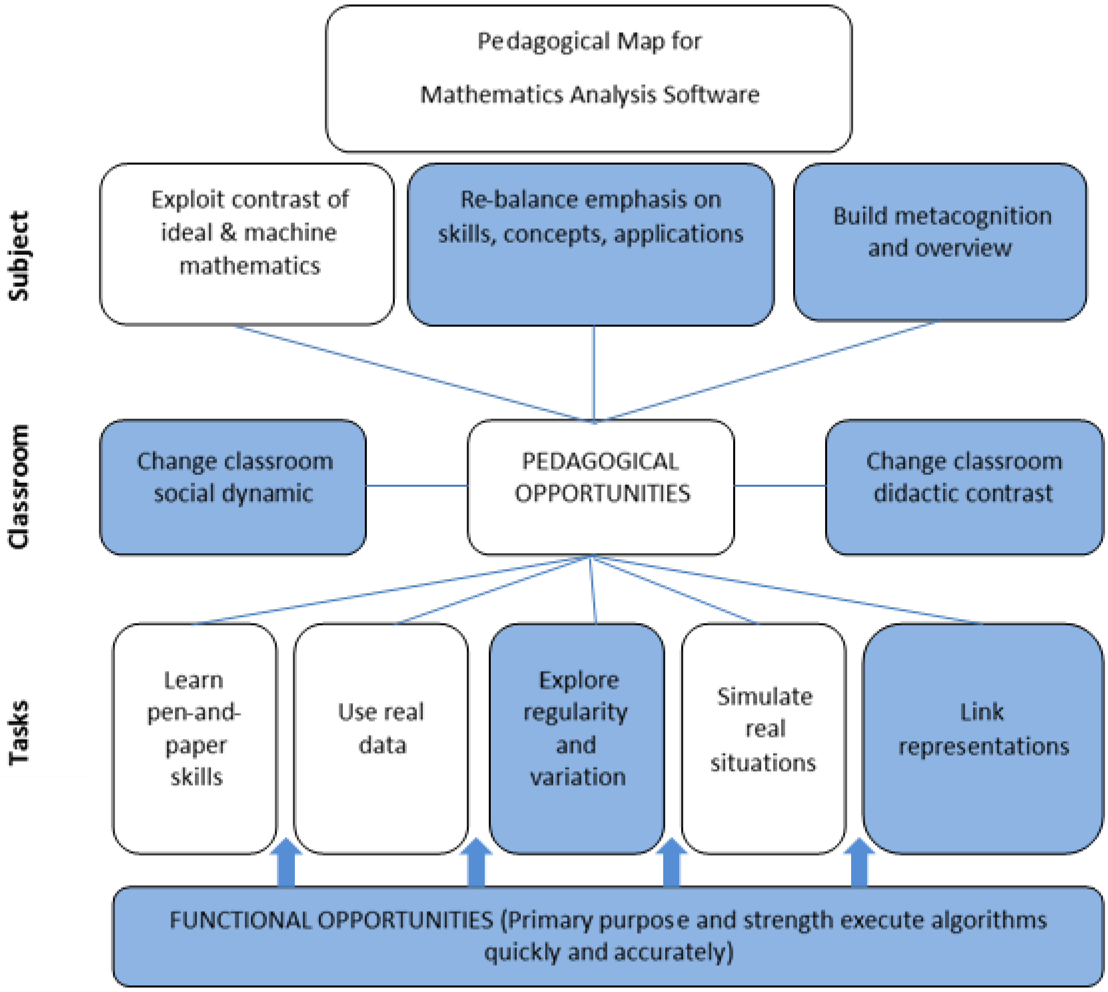

Figure 7-1: Rina's use of Autograph to assist students in learning of Translation

7.1.1.2 Mir

Mir was a novice teacher who had been teaching mathematics for two years at the secondary school. She earned a bachelor degree in mathematics education. However, as a new teacher, Mir did not have a teaching certificate. Mir's school was located in the capital of Aceh province and it was managed by the Ministry of Education and Culture.

Since working as a secondary school teacher, Rina had never had any chance to attend professional development in the use of ICT in mathematics teaching. Consequently, she did autodidactic learning through watching YouTube video to develop her knowledge in ICT. Moreover, she also learned how to use ICT in teaching when she did her undergraduate study. She added that she needed training in teaching methods for teaching with ICT. She stated:

> …because the characteristics of mathematical topics are different, some topics focusing on mathematical concepts while the other emphasise on the application of mathematical concepts, so I need training on teaching methods for teaching with ICT. So, the use of ICT depends on subjects being taught and the teaching method, I need such training (Mir).

Mir's classroom practices. The observed class was Year 11 where 24 students attended the class. The teacher set small groups of student desks' configuration. Moreover, she used a digital projector and a laptop while students were allocated one laptop for two students. During the lesson, Mir and her students used DGS (Autograph).

In the observed class, the teacher taught Transformation Geometry, particularly the concept of reflection. According to her lesson plan, the aims of the lesson were that students would be able to determine the characteristics of reflection, 'reinvent' a concept of the reflection and apply the concept of the reflection in problem solving.

Mir started the lesson by introducing the topic of transformation geometry. Then, she asked students to provide several examples of transformation in real-life settings. The teacher formed groups of two students, and then she led a discussion about characteristics of the reflection. Furthermore, Mir assigned students to complete a worksheet, which consisted of the following tasks. First, given a figure PQRST with coordinates P (6, -5), Q (9, 3), R (6,5), S (1,3) and T (2,3) was reflected in Y-axis, they had to determine the image of the figure by using GeoGebra software. The students were assigned to move the image to several different positions and determined the general formula of the reflection. Finally, the students were asked to draw a conclusion about the reflection. The other five tasks were similar to the first task. For these tasks, students were assigned to reflect the figure in X-axis, line y = x, line y = -x, line x = 4, and line y = 3. Furthermore, the teacher assigned students to draw a conclusion about the reflection and to present their works in front of the class. At the end of the lesson, Mir presented a conclusion about the concept of reflection, and then she finished the lesson.

In the interview, Mir explained that the use of ICT would increase students' interest in learning of mathematics. Moreover, by this integration, she stated that students would be able to apply mathematical concepts. Moreover, ICT also contributes to saving her and the students' time during teaching and learning process.

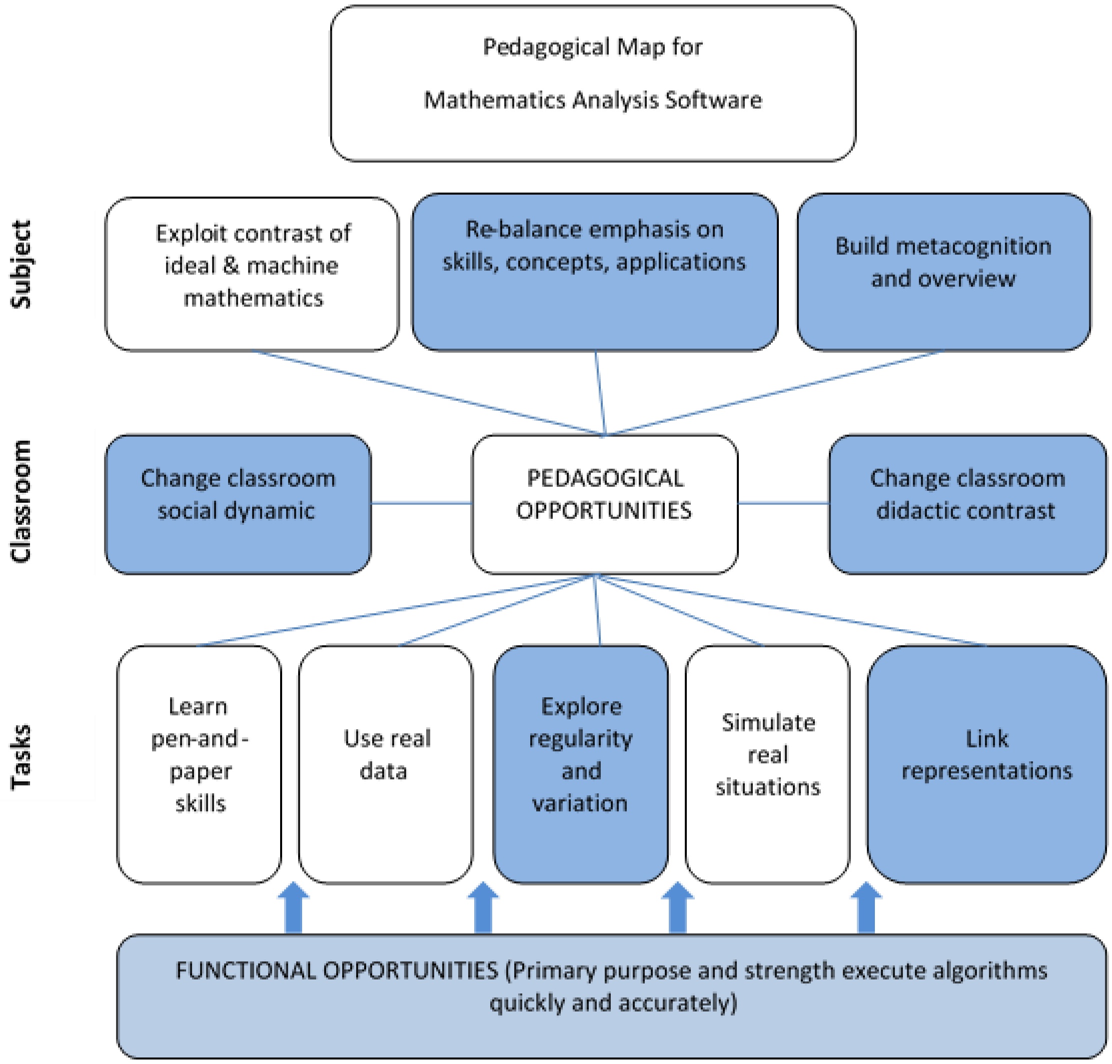

Figure 7-2: Mir's use of Autograph to assist students in learning of Transformation Geometry

In the observed class, as is shown in Figure 7-3, Mir employed different activities in the teaching and learning process, such as discussion, question and answer as well as presentation. In the classroom, the teacher spent less time on a routine skill, such as calculation, and more time on concepts and increased emphasis on mathematical thinking. With regards to classroom interaction, it was shown that students were encouraged to do group works and to discuss and share their works with the class. Moreover, students were also expected to make their own generalisations rather than relying on the teacher to teach them such information. Furthermore, the main type of task they teacher set for her students was to explore regularity and variation (e.g., the teacher assigned students to move the figure to several different positions, and they wrote down the vertexes and images of the vertexes).

7.1.1.3 Anton

Anton was a senior secondary mathematics teacher who had been teaching for 12 years. He holds a bachelor degree and a master's degree both in Mathematics Education, and had been awarded a teaching certificate. Anton's school was in a remote area, which was located about 150 miles away from the capital city of Aceh province and managed by the Ministry of Education and Culture.

In the last three years, Anton had participated two times in ICT training courses both of which the courses were facilitated by Aceh Provincial Office of Education. In the training, the teacher learned about the use of Autograph software, GeoGebra software and the graphing calculator. Anton revealed that the most important topic of both training courses was about the use of GeoGebra software. Moreover, the teacher said that, in the future, he needs a training course focusing on the use of ICT for teaching specific contents of mathematics.

> I need a training that focuses on specific-mathematic software, it is better to be related to the content of mathematics, for instance how to use ICT to teach specific mathematics topics, for example how to teach trigonometry by using ICT.

Furthermore, the participant went on to explain that he also needed to learn about lesson plan designs regarding the integration of ICT in the classroom.

> It is necessary to learn about a lesson plan, the tools of teaching, and teaching approach. I think it will make it easier to implement it in the classroom; I do not need to adjust it.

Anton's Classroom Practice. The observed class was Year 10 where 20 students were involved in the class. Anton set u-shaped layout of the students' desks. Moreover, the teacher used a digital projector and a laptop while the students used one laptop for a group of three students. In addition, both the teacher and the students used Autograph software.

In the observed class, Anton taught Trigonometry, particularly the graphics of trigonometric functions. The aim of the lesson was that students would be able to draw and analyse graphs of trigonometric functions. He started the by presenting the objective of the lesson. The teacher then introduced several features of the Autograph software that they were going to use and taught them how to draw a graph by using the software. Anton assigned students to use Autograph software and work in a group of three students to do the following tasks:

- First, students were assigned to draw graphs of the following trigonometric functions: Y = Sin x; Y= 2 Sin x; Y= -3 Sin x; Y= 3 Sin x; Y = Cos X. Given a trigonometric function Y= A sin X, then students were assigned to draw a conclusion about the variable A
- Second, students were assigned to draw graphs of the following trigonometric functions: Y = sin X; Y= Sin 2X; Y= Sin$\frac{1}{2}x$. Given a trigonometric function of Y = Sin BX, then students were assigned to draw a conclusion about the variable B
- Third, students were assigned to draw graphs of the following trigonometric functions: Y= Sin X + 1; Y = Sin X – 1; Y= Sin X + 2; Y= Sin X – 2. Given a trigonometric function Y = Sin X + C, students were assigned to draw a conclusion about the variable C
- Fourth, students were assigned to draw graphs of the following trigonometric functions by using pen and paper: Y = -5 Sin 2X + 1; Y = 2 Cos 2X – 2.
- Finally, students presented their works in front of the class, and then the teacher drew a conclusion about the lesson.

In the interview, the participant disclosed that he used ICT in the class because it saved his time for classroom instruction as well as encouraged students to learn mathematics. When the teacher was questioned why he used ICT in his class, he responded:

> Time, I spent too much time to draw manually. Then, the students also enjoy using it; by using the software, students become more interested in learning mathematics.

In addition, he believed that ICT helps him to visualise mathematical figures, and he considered hand drawing to be not as good as drawing by using the software.

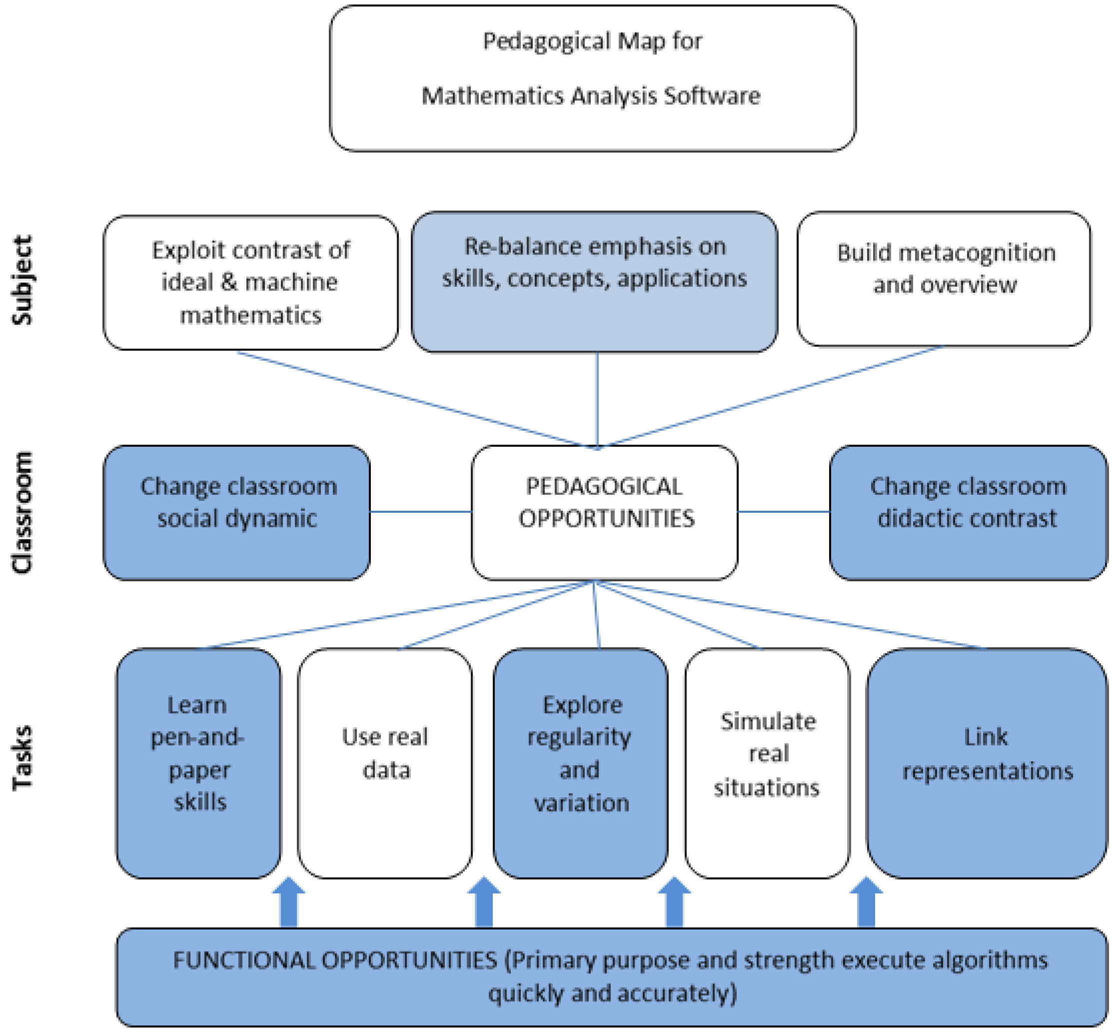

Figure 7-3: Anton's use of Autograph to assist students in learning of graphs of trigonometric functions

In the observed class, as it is presented in Figure 7-3, the teacher utilised various activities, such as discussion, question and answer, and tasks. In this teacher's classroom, both didactic contract and social dynamic changed whereby students were expected to provide their own explanations and make their own generalisations and discoveries rather than relying on the teacher to provide such information. Students shared their findings, this including students' presenting their work for the rest of the class to see and publicly explaining their graphs and their reasons for the conclusion. Moreover, regarding tasks, this teacher employed three types of tasks, namely 'learn pen-and-paper skill', 'explore regularity and variation' and 'link representation'.

7.1.1.4 Hari

Hari was a senior teacher who had been teaching mathematics in secondary schools for more than 20 years. He had a bachelor and master's degree, both in Mathematics Education, and held a teaching certificate. Hari's school was located about 150 miles away from the capital of Aceh province, and it was under the direct affiliation of the Ministry of Education and Culture.

In the last three years, Hari had participated in two training courses provided by the government in the use of ICT. However, he claimed that he learned about how to use mathematical software such as Autograph and GeoGebra when he did his master's study. The teacher emphasised that he needed training on the use of *Smartboard* and the integration of the tool with mathematical software.

Hari's classroom practice. The observed class was Year 11 with 32 students in the class. In terms of the classroom setting, Hari arranged students' desks in several small groups. The teacher used a digital projector and a laptop and allocated one laptop for four to five students. Moreover, the teacher and the students used DGS (Autograph) during the teaching and learning process.

Hari taught Transformation Geometry focusing on the topic of the reflection. He started the class by introducing the meaning of transformation in the real-life. Moreover, the teacher briefly introduced the Autograph software and assigned students to work in a group of four to five students and complete the following tasks. First, students were assigned to randomly select pictures of nature, such as a flower, butterfly, kite, etc. Then, he asked students to insert the selected pictures into Autograph software to determine whether the object was symmetric or not. Then, the teacher connected the concept of symmetry and the reflection. Second, students were assigned to randomly plot six points and create a figure by connecting these points. The figure was then was translated in the X-axis. Moreover, the students were asked to move the figure into different positions and write down all the vertexes and images of the vertexes. At the end of the class, students were asked to share their work with the class, which was then followed by the teacher and the students drawing a conclusion about the reflection just before the teacher ended the lesson.

In the interview, Hari stated that he believed ICT helps an enquiry teaching approach become more effective:

> I mostly used enquiry teaching approach, because, by using this method, students are able to reinvent the concepts of mathematics…The use of ICT made the teaching approach become more effective in terms of time and student’s understanding.

Hari’s teaching is mapped in Figure 7-4. With the help of dynamic geometry software (Autograph), Hari introduced his new approach to the topic of reflection. He started the lesson by presenting the concept of reflection in real-life by inserting pictures of nature into the software. In addition, with the help of ICT, Hari had more time to emphasise on the application of concepts of reflection in the real-life. In terms of classroom level, it showed that students were encouraged to work in groups and present their works in front of the class. In addition, students were also expected to make their own conclusion about concepts of reflection. Regarding task set for the students, two types of task were set for the students, namely ‘explored regularity and variation’ and ‘link representation’.

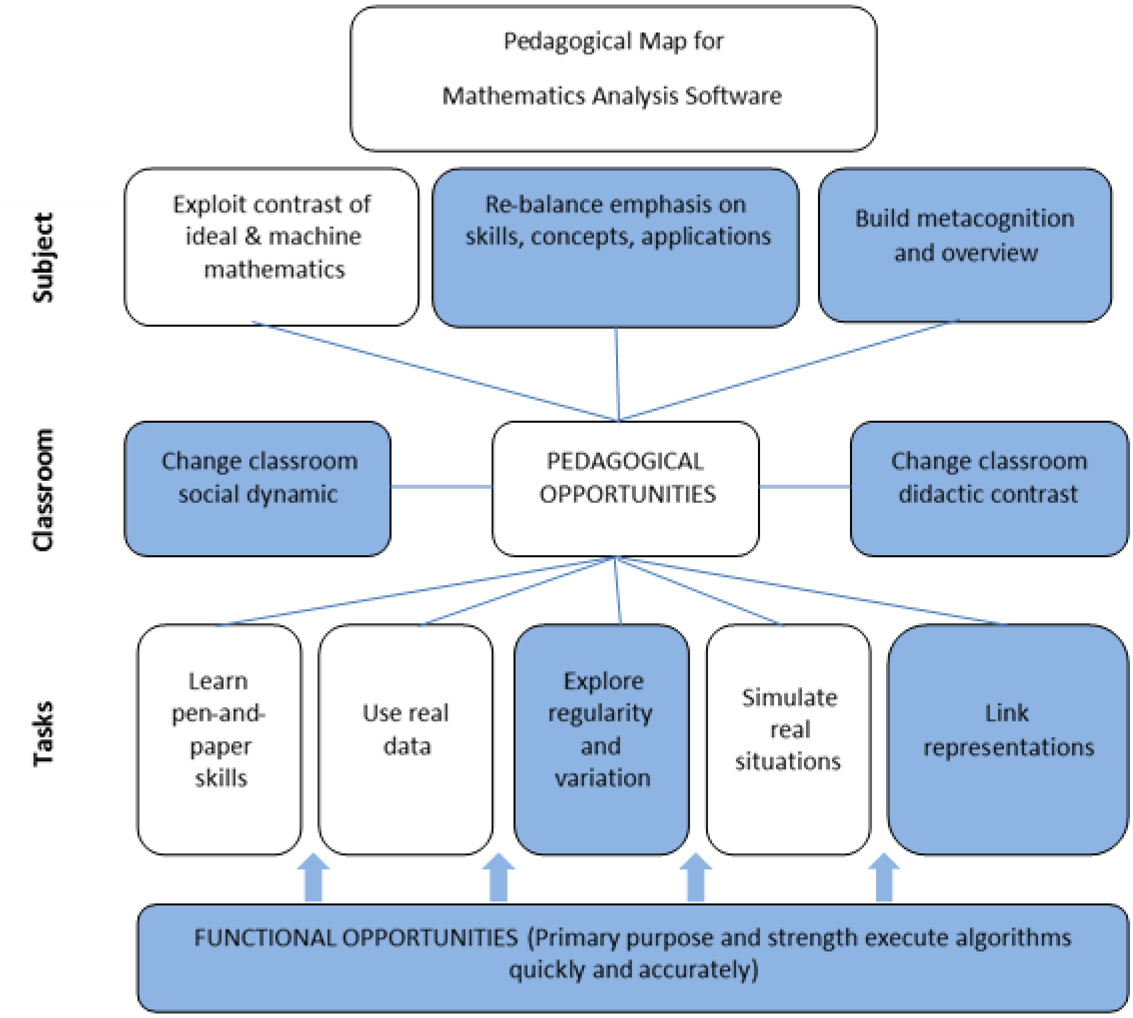

Figure 7-4: Hari's use of Autograph to assist students in learning Transformation Geometry (Reflection)

7.1.1.5 Bute

Bute is a junior teacher who had been teaching Mathematics for six years. As a junior teacher, Bute did not have a teaching certificate, buth she had earned both a bachelor and a master's degree in mathematics education. Bute's school was about 20 miles from the capital of Aceh province and managed by the Ministry of Education and Culture.

Bute learnt how to use ICT in the classroom when she did her master's degree. In her teaching career, she had never participated in any professional development in the use of ICT. She asserted that:

> .... I just tried when I was studying at one of the universities in the US. So, we always, I mean our professor was always asking me to use ICT, so we just learned autodidactedly, so I just learned and I used some tools like

> core math tools and GeoGebra, but I think why I use GeoGebra here is that it is familiar and easy to use. I never had special training.

Therefore, she stated that she really needed a training course in the use of specific mathematics software for mathematics teaching, saying "*I really need training in the use of technology, like a tool, I mean a math tool*". Furthermore, she emphasised that she needed to learn how to use free software.

> Because it is free software I can download it to my students' computers, and then they can practise it at home, something like that. I need a training course on using free software, and how this technology can be used to teach all subjects. Not just only one subject, like statistics, I think it can be used in all of the mathematics subjects at the senior secondary school.

Bute's classroom practice. The observed class was Year 11 and there were 15 students in the class. Bute used a computer room for teaching and learning mathematics equipped with a digital projector, and the students used a computer for two to three students. Bute and her students used GeoGebra software during the teaching and learning process. Furthermore, in terms of students' desks layout, Bute's class was set to row configuration.

In the observed class, Bute taught the topic of Inverse Functions. She started the lesson by reviewing the previous lesson. Moreover, in teaching the concept of Inverse Function, she showed them several examples of how to solve problems of the functions. She then showed the students how to check the answer by using GeoGebra software. Furthermore, the teacher assigned the students to work in a group to do the following tasks. First, students were asked to check the answers of their previous homework by using GeoGebra. One of the problems was: find the inverse function of y= $\frac{(5x-2)}{(x+2)}$. Second, the teacher assigned students to work in groups to complete four problems by pen-and-paper, one of the problems was: find the inverse functions of $y = (2x + 10\,)^{1/2}$. Third, students were asked to check their answer by using GeoGebra software, and then they presented their answers to the teacher when they found their answers were correct. Finally, the teacher ended the lesson by asking students their opinion about the lesson and briefly presented the next topic.

In the interview, Bute revealed her objective of the use of ICT in the classroom, was to help the students to apply the concepts of mathematics. She stated that:

> Yeah, I think, let's say when we are talking about mostly about geometry, it more like, okay I see. When we present it by using ICT, students can related to what they find it daily life, and this tool will help them to combine it.

Bute's classroom practice is mapped in Figure 7-3. From the observation, Bute used DGS (GeoGebra) for supporting pen-and-paper skill (e.g., by checking pen-and-paper work when students were learning the Inverse Function). Her teaching approach slightly changed as the students checked their answers and they used it as feedback for the learning process. This quick feedback led to students' discussion of their answers, as the teacher assigned them to keep doing the tasks until they found the correct answer.

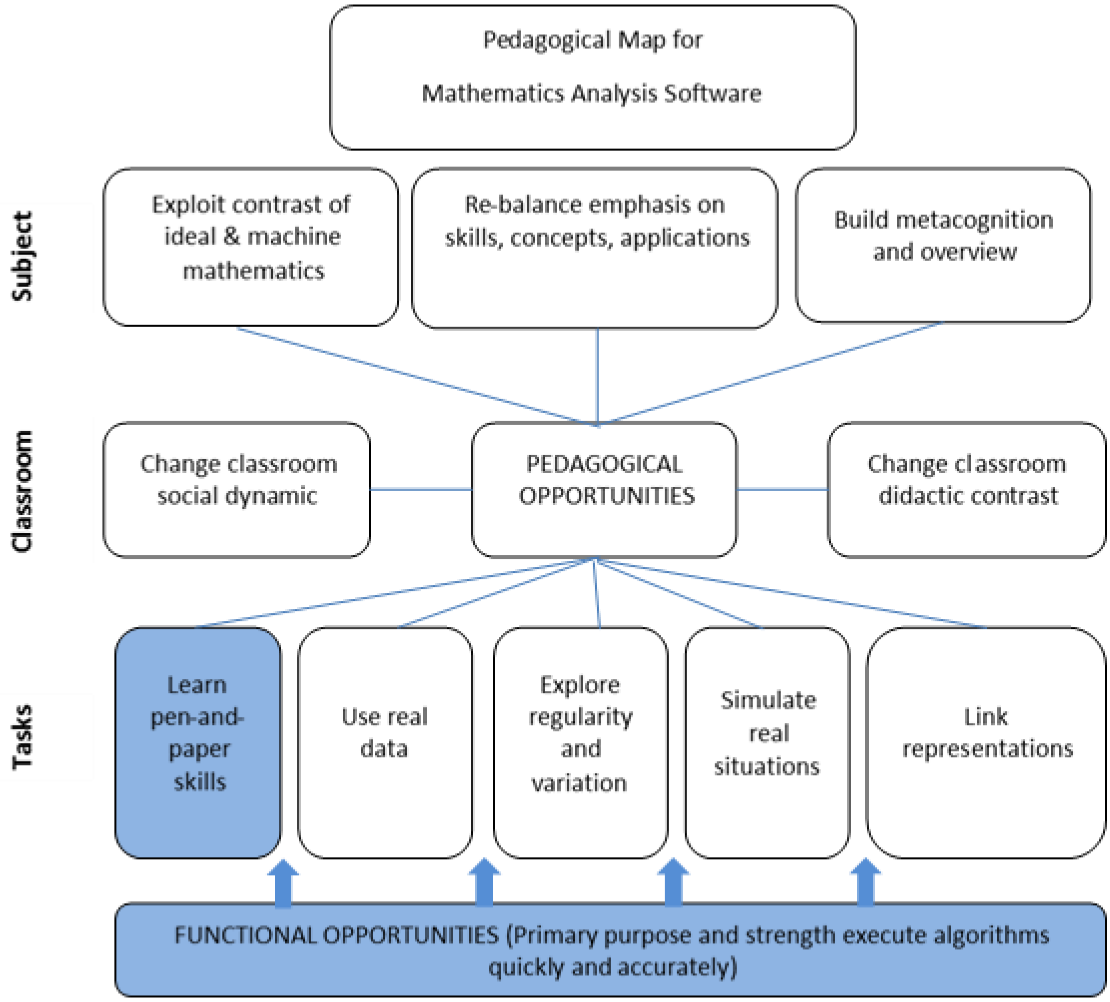

Figure 7-5: Bute's use of GeoGebra to assist students in learning of inverse functions

7.1.1.6 Muti

Muti had taught mathematics in several secondary schools for 17 years. In the current school, which was managed by Ministry of religious affairs and situated in the city of Banda Aceh, she had been teaching for six years. The teacher holds a bachelor degree in mathematics education and was completing her master's study in the same field. In addition, she was awarded a teaching certificate five years ago.

In the last three years, Muti had participated in several training courses on ICT and its use in mathematics teaching. One of the trainings courses was an online training on the use of GeoGebra Software which was provided by *P4TK-Pusat Pengembangan Pembelajaran Matematika* (the Centre of Mathematics Teaching Development). The training course was open to all teachers as long as they committed to participate once they had registered for the training. Moreover, according to the teacher, such online training is more effective. She said, *"... online training is easier. Only teachers who have high motivation are willing to participate. Only self-motivated learners will survive."*

Muti's classroom practice. The observed class was Year 11 and there were 21 students in the class. The teacher used a digital projector and a laptop while the students used one laptop for two students. Moreover, she used general software (PowerPoint) and dynamic geometry software (GeoGebra) while the students only used GeoGebra software. In terms of student's desk arrangement, the teacher set the row configuration (also known as the columns configuration).

In the observed class, the teacher taught Transformation Geometry focused on Translation. The classroom activity began with the teacher presented and explained the concept of translation in the context of mathematics. The teacher assigned students to use pen and paper to solve the following problems: Translate Point A (6,-1) by the vector$(\frac{-2}{-5})$; Translate 2x-3y= 4 by the vector$(\frac{2}{3})$; Translate 5x = 3y – 20 = 0 by the vector$(\frac{1}{-7})$; Translate $x^2 + y^2 = 25$ by the vector$(\frac{2}{-3})$. After they had finished working on those tasks, students presented their answers in front of the class and the teacher assigned the other students to use GeoGebra software to check the answers. Finally, the teacher ended the lesson and asked students for their opinions about the lesson.

In the interview, Muti revealed that she believed that, by the integration of the software in the classroom, students are able to analyse and imagine of mathematics concepts. Furthermore, she hoped that by using ICT she could show students that mathematics is not always an abstract concept. Moreover, *"through ICT, students can check a correct answer when they come up with different solutions of a problem"*. Therefore, she believed that students' confidence in learning mathematics would increase.

Muti's use of ICT is mapped in Figure 7-6. She valued the pedagogical use of dynamic geometry software (GeoGebra) for supporting pen-and-paper skill (e.g., by checking pen-and-paper works). This teacher remained the source of knowledge authority in the classroom. Her teaching remained fundamentally unchanged as she taught pen-and-paper first and then later assigned students to use GeoGebra to check their answers. The teacher utilised classroom activity that demonstrated only one of the pedagogical uses of dynamic geometry software.

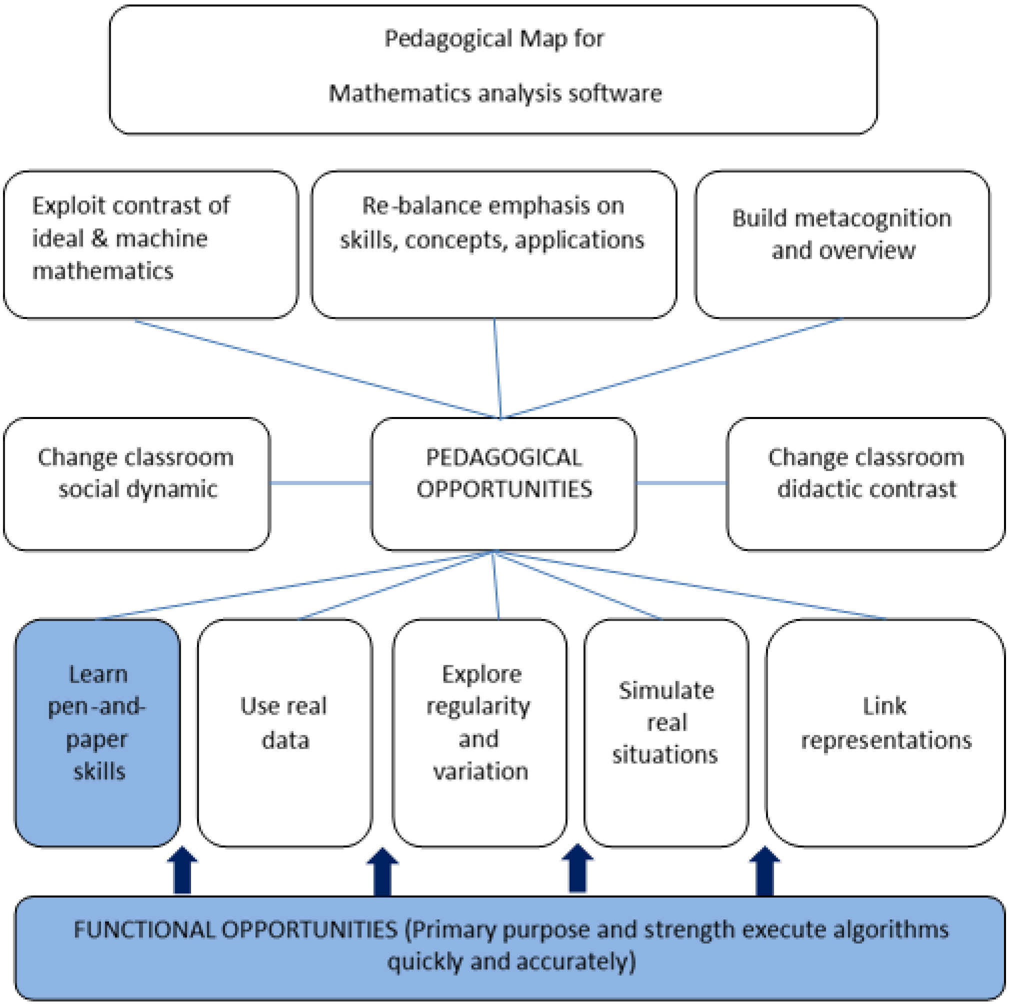

Figure 7-6: Muti's use of GeoGebra to assist students in learning of Transformation Geometry

7.1.1.7 Alfin

Alfin had been teaching mathematics at Years 10 and 11 in the secondary school for 10 years. He had earned a bachelor degree in mathematics education and was completing his master's study in the same field. However, Alfin had not yet been awarded a teaching certificate. His school was in West Aceh District located 150 miles away from the capital of Aceh province, and the school was operated by the Ministry of Education and Culture.

Alfin had participated in several training courses on the use of ICT. One of them was a course on the use of ICT for mathematics teaching conducted by Southeast Asian Ministers of Education Organization-Regional Open Learning Centre

(SEAMOLEC). This training course took 20 days and provided participants with a chance to learn about virtual mathematics, e-learning in mathematics teaching, and the use of GeoGebra. According to Alfin, this course focused on the use of open source software for mathematics teaching. Furthermore, it not only offered participants not only the way to use hardware and software, but also the idea to integrate that technology in mathematics teaching. Even though Alfin had participated in such a training course, he stated that he still need training on the use of ICT, particularly on designing ICT-based lessons, including ICT-based assessment.

Alfin's classroom practice. The observed class was Year 10 and there were 17 students in the class. The teacher used a laptop and digital projector while each student had one laptop. Furthermore, both the teacher and the students used dynamic geometry software (GeoGebra). Moreover, the teacher set the desk setting in a row configuration.

In the observed class, Alfin taught Geometry focused on three-dimensional geometry. However, during this lesson, Alfin only introduced the basic concepts of geometry related to three-dimensional geometry, such as the distance between two points, the distance between a point and a line segment. A highlight of classroom activities is described below.

The teacher started the class by presenting learning objectives and linked it to the previous topic. The teacher distributed printed hand-outs to the students and asked them to run GeoGebra software.

Alfin guided students to draw *two points* in the Cartesian coordinate by using GeoGebra and then asked students to find the distance between the points. By using GeoGebra, the teacher showed students that: "Any two distinct points are on exactly one line. Every line contains at least two points." He then asked students to do the same activity by using GeoGebra.

Moreover, by using the software, the teacher showed students that: "An unlimited number of lines can be drawn passing through a given point A ." He asked students to do the same activity by using GeoGebra. Furthermore, the teacher showed students that "perpendicular distance from a point to a line is the shortest distance from a fixed point to any point on a fixed line." The teacher also showed students an axiom that "The distance from a point to a line is the shortest distance between the point and any point on the line." He assigned students to repeat the same activity individually. Finally, he finished the lesson and briefly mentioned the mathematics topic for the next lesson.

In the interview, Alfin's objective of the use of ICT was to introduce concepts of mathematics to his students. He believed that ICT is very helpful in this introduction as students can do more practice and ICT encourages students to become more active in learning.

> Okay, I hoped students would understand the concepts of mathematics, for instance, concept of point, line, etc., so I wanted to introduce such concepts. ICT is very helpful to introduce such concepts, students can practise by themselves, and I even found students become more active when they use the software.

Alfin's classroom practice is mapped in Figure 7-7. From the observation, this teacher used GeoGebra for supporting pen-and-paper skill (e.g., by providing visualisation of distance between a point and a line segment, and doing the measurement of the distance between two points). Moreover, this teacher also used ICT to explore regularity and variation (e.g., the teacher showed the students how different straight-lines pass through a fixed point to any point on a fixed line, and showed them the shortest distance is the one which perpendicular to the fixed line). In terms of the classroom environment, his pattern of teaching tended to be a more teacher-centred approach while he remained the main source of knowledge authority in the classroom.

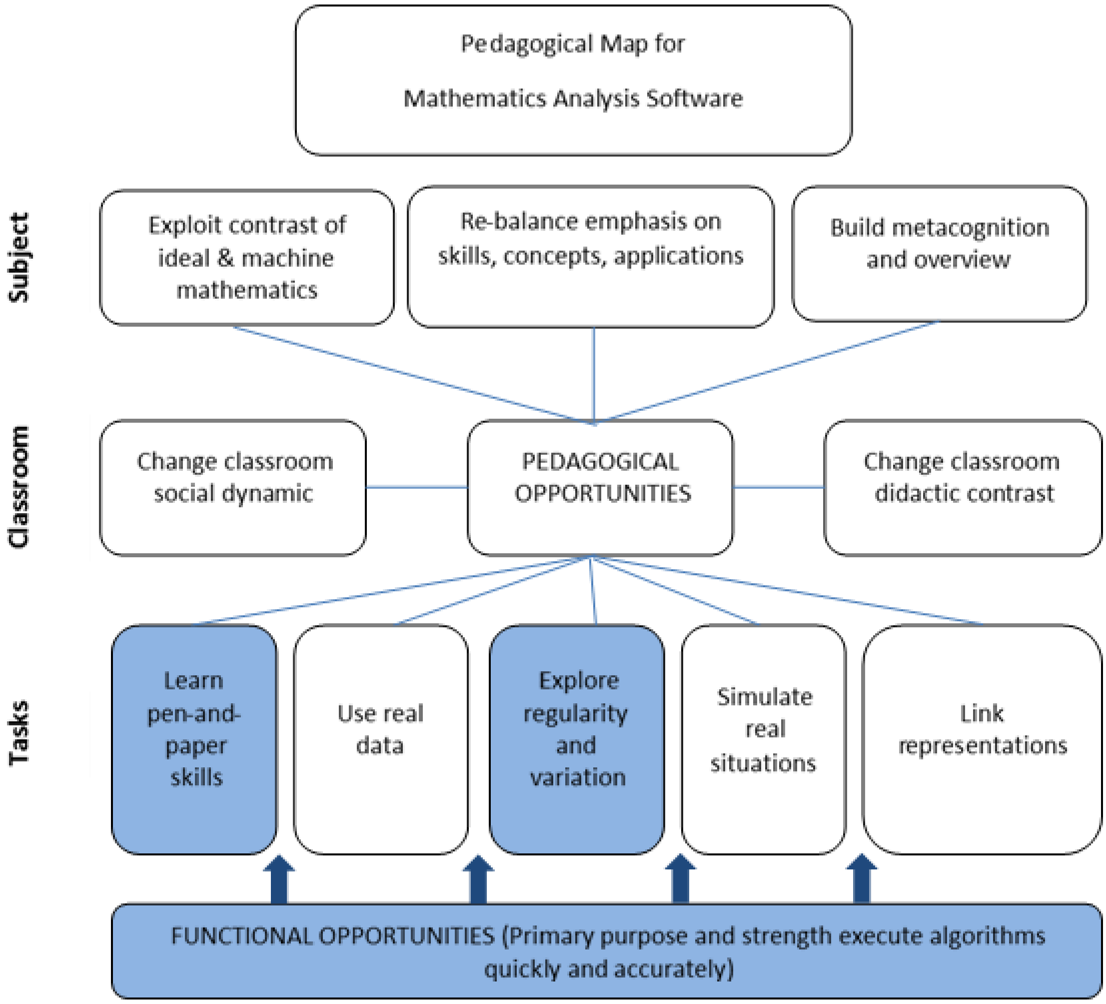

Figure 7-7: Alfin's use of dynamic mathematics software (GeoGebra) to assist students in learning of Geometry

7.1.1.8 Abu

Abu had been teaching mathematics at the school for 12 years. He earned both a bachelor and a master’s degree in mathematics education. Moreover, Abu also held a teaching certificate. His school was in a remote area located about 250 miles away from the capital of Aceh province and managed by the Ministry of Education and Culture.

Abu asserted that he had participated only once in a training course on the use of ICT provided by the government. Yet, he improved his knowledge by autodidactic learning and learned from his colleagues.

Abu’s classroom practice. The observed class was Year 10 where there were 13 students in the class with small groups of the arrangement of students’ desks. Abu used a digital projector and laptop, and students used one laptop for three to four students. Regarding software, both the teacher and the students used Autograph and MathExpert software.

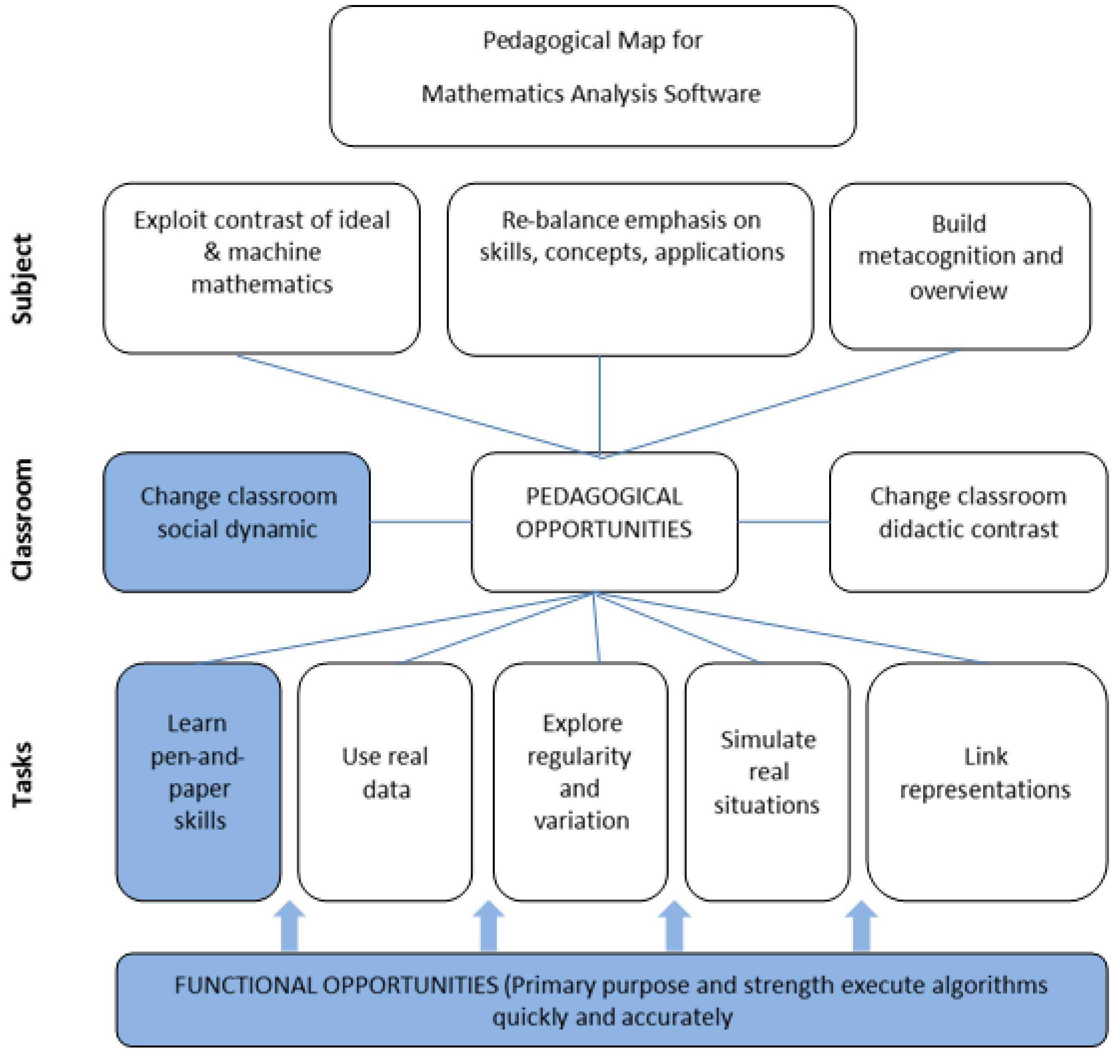

Figure 7-8: Abu's use of GeoGebra and Math Expert to assist students in learning of Differential Calculus

In the observed class, the teacher taught Differential Calculus, particularly about differentiation using the chain rule. Abu started the lesson by introducing the chain rule in Diferential Calculus. He then assigned students to find the differential of the following functions: $y = (5x+ 2)^2$;$y = (4t- 3)^{-8}$;$y = \sqrt[3]{2x-1}$;$y = 4x^3 - 5x^2 + 10x$. Moreover, the teacher asked students to use Math Expert software to check their answers. Then, Abu assigned each group to select one answer and present it in front of the class. Finally, the teacher provided five questions and asked students to choose one and complete it as a quiz for this lesson.

In the interview, the teacher revealed that he integrated ICT in the classroom to help his students visualise mathematics concepts. Moreover, he hoped his students were able to learn mathematics by using ICT on their own. He believed that ICT helps students to learn mathematics outside the classroom. He argued that, for instance, by using MathExpert, when students solve a mathematics problem they can check the answer and learn the solution step-by-step from the software.

Figure 7-8 shows that Abu valued the pedagogical use of DGS (GeoGebra) and CAS (Math Expert) for scaffolding pen-and-paper skills (e.g., by checking pen-and-paper work) and allowing easy interchange between graphical and symbolic representations. His classroom social dynamic had changed as he assigned students to work in groups and present their works in front of the class. However, this teacher remained the sources of knowledge authority in the classroom. His approach to mathematics topics remained unchanged, as he taught pen-and-paper and suggested students to practise first pen-and-paper first, and then later they used DGS and CAS to check their pen-and-paper work.

7.1.1.9 Laila

Laila had been teaching mathematics in secondary schools for 13 years. She earned a bachelor degree in mathematics education and was completing her master's degree in the same field. Moreover, Laila obtained a teaching certificate three years ago. Laila's school was located about 75 miles away from the capital of Aceh province and operated by the Ministry of Education and Culture.

Laila had participated in several teacher professional developments in the use of ICT. One of them was an overseas training in Malaysia. At the training course, she learned about how to use GeoGebra for the teaching of mathematics. According to the teacher, the training was designed to provide participants with a chance to learn from a workshop and classroom observations through observing experienced teachers use ICT in their classroom. In addition, she also learned about how to use ICT during her master's study.

Laila's classroom practice. The observed class was Year 11 where there were 19 students in the class and row configurations of the students' desks. Laila used a digital projector and a laptop while students used one laptop in a group of three to four students. Regarding the software, the teacher used PowerPoint and GeoGebra while the students only used GeoGebra.

In the observed class, Laila took 90 minutes to teach taught Transformation Geometry focusing on the topic of reflection. The teacher started the class by presenting an outline of the lesson by using PowerPoint. The following is the outline of the lesson regarding types of the reflection: Reflection in the origin; Reflection in x-axis; Reflection in y-axis; Reflection in y=x; and Reflection in y=-x. Furthermore, the teacher used GeoGebra to explore and teach students about all types of the reflection mentioned above, and she then assigned students to work in a group of three to four students to solve several problems, one of which was to find the reflection of $x^2 + y^2 - 4x + 2y - 4 = 0$ in y = x. Then, each group was assigned to select one problem and present it in front of the class while other groups were assigned to check the answer by using GeoGebra. Finally, the teacher drew conclusions about the lesson and ended the class.

In the interview, Laila revealed that she used ICT to help students to visualise geometric figures. According to the teacher, "*students are struggling to visualise geometric figures*." Moreover, by integrating of ICT, she also wanted the students to understand mathematics in depth. Therefore, they would not only memorise the mathematical concepts, but also understand them. She hoped students became involved in the process of 'enquiry' of mathematical concepts.

It the observed class, this teachers' use of ICT exhibited only two of the pedagogical uses of DGS. Figure 7-9 shows two blue boxes of pedagogical opportunities exposed in the classroom. Laila's classroom social dynamic had changed when students worked in groups and presented their work in front of the class. However, Laila remained the main source of knowledge authority. She valued the pedagogical use of GeoGebra for checking pen-and-paper works.

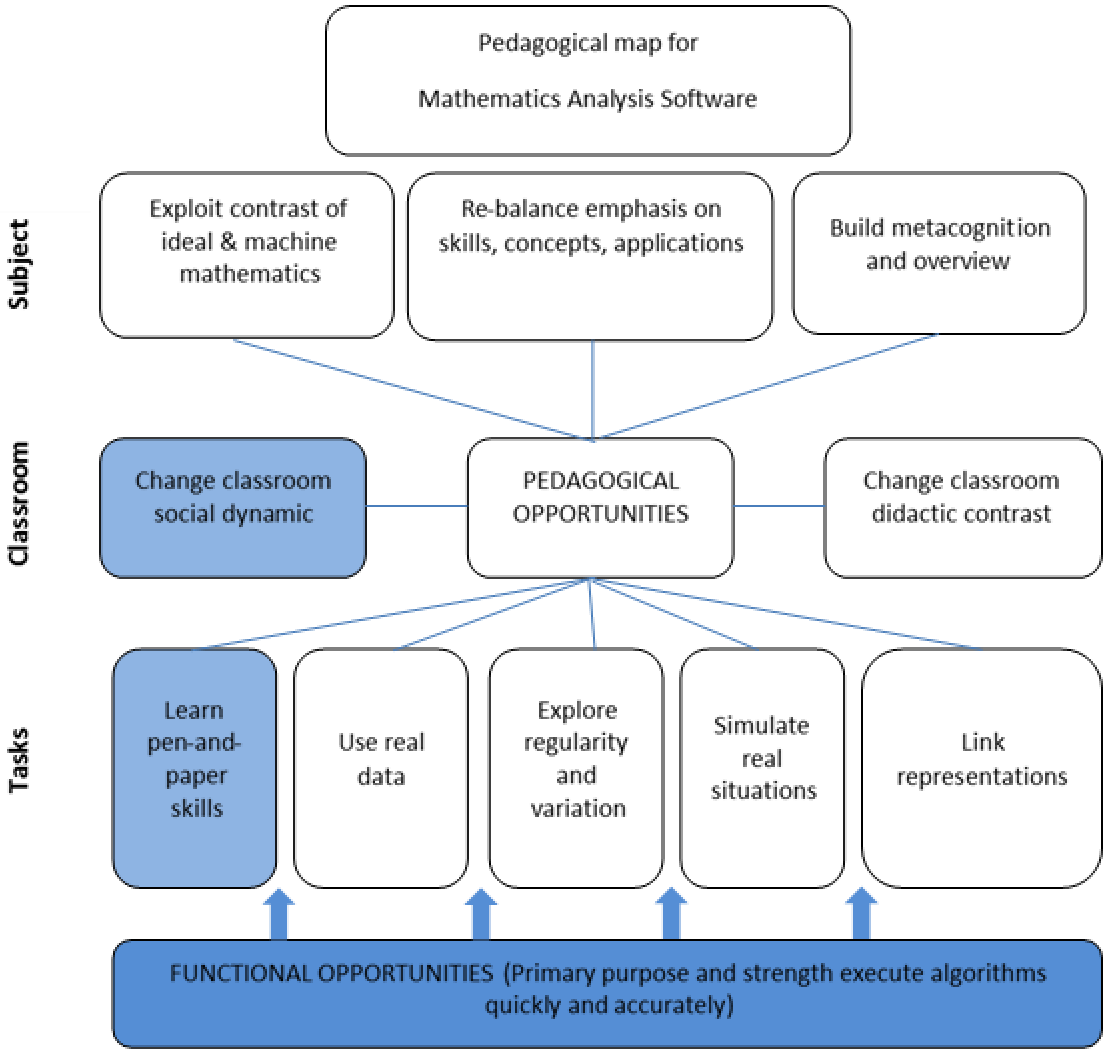

Figure 7-9: Laila's use of Power Point and GeoGebra to assist students in learning of Transformation Geometry

7.1.1.10 Din

Din was a senior teacher who had been teaching mathematics for 20 years in the secondary school. He earned a bachelor degree in mathematics education and as well as a teaching certificate. Din's school was managed by the Ministry of Education and Culture and located in the capital of Aceh province.

Din had participated in several teacher professional developments in the use of ICT provided by the government. One of them was a teacher-training programme in Malaysia focusing on mathematics teaching, including the use of ICT in teaching. Moreover, he admitted that he needed a training focusing on software for mathematics teaching. He stated: *"I need to learn functional software such as GeoGebra."*

Din's classroom practices. The observed class was Year 10 where there were 30 students in the class and with row configurations of students' desks. Din used a computer room equipped with a digital projector and computer for the teacher and students. He allocated one computer for each student. The teacher and his students both used GeoGebra software in the observed class.

During the observation, Din taught the topic of Geometry focusing on concepts of the Circle. The aims of this lesson were that students would be able to determine circle equations and to define the relationship between the circle equations and the centres as well as the radius. A brief description of classroom activity is presented as follows.

The teacher started the class by presenting the aims of the lesson, and he then distributed worksheets to students. The students were assigned to work individually to complete the following tasks. Firstly, students were assigned to randomly plot two points (Point A and Point B) in the Cartesian coordinate by using GeoGebra software. Then students were assigned to plot a circle with the centre at Point A and through point B.

Secondly, students were asked to write down properties of a circle including the centred Point, the diameter, a point passing through, and the circle equation, and then the students dragged Point A and Point B and wrote down the other properties. They were asked to repeat this activity several times. After finishing the second activity, students were assigned to draw a conclusion about the relationship between the circle equation, the centre and the radius. Thirdly, students were assigned to plot three points (Point C, Point D and Point E) in the Cartesian coordinate by using GeoGebra software, which then was followed by drawing a circle with the centre C and through point E; they were also asked to write down the following properties: the coordinate of the centre, the radius, and the circle equation. Moreover, the students were assigned to move the centre of the circle to the origin, and then the students were asked to write down the following properties: the coordinate of the centre the radius. Finally, students were assigned to draw a conclusion about task 1 and task 2, and they were asked to determine a relationship between $x^2 + y^2 = r^2$ and$(x - a)^2 + (y - b)^2 = r^2$.

Before the teacher finished the lessons, he assigned students to complete the following tasks without using ICT. The first task was to find the equation of a circle with (a) the centre at (0,0) and the radius is 3; (b) the centre at (0,2) and the radius is 2; (c) the centre at (3,0) and radius is 4; and (d) the centre at (3,4) and the radius is 5. The second task was to find the centre and radius of the circle:$x^2 + (y-3)^2 = 4$;$(x+2)^2 + (y-1)^2 = 9$; and $x^2 + y^2 - 6x = 4y = 12$. Finally, the teacher ended the lesson by briefly presenting the topic for the next lesson.

In the interview, Din asserted that ICT offers several advantages. He said,

> In my opinion, the use of ICT has many advantages, and one of them is to motivate students; therefore, I would be motivated when I find my students are enthusiastic.

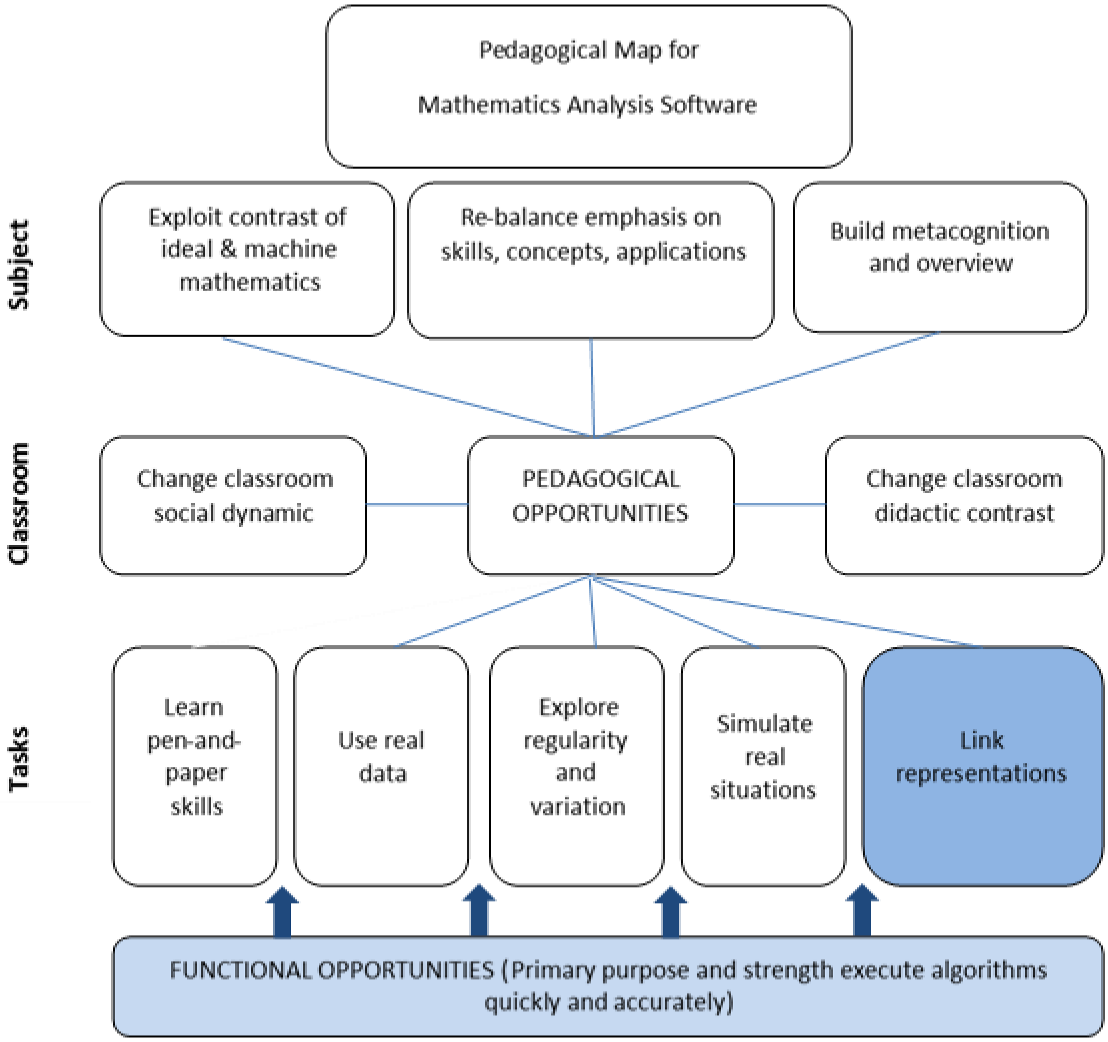

Figure 7-10: Din's use of GeoGebra to assist students in learning of Circle Equations

In the observed class, as it is shown in Figure 7-10, the use of ICT in the classroom did change the teacher’s approach to circle equation. Moreover, in the classroom, the classroom social dynamic and didactic contract did not change, as the teacher set tasks and guided students to complete the tasks individually. Moreover, the class interaction dominated students-to-teacher interaction instead of students-to-students interaction. In addition, students did not share their answer and explanation in front of the class. Regarding the task, the teacher set tasks of link representation (e.g., the teacher assigned students to use GeoGebra software to plot and move a circle and find the relationship between the circle properties, such as centre and radius and circle equations and graphs).

7.1.2 Triangulation of Classroom Observations and Semi-Structured Interview

As discussed in the previous section, the description of the teachers depicts how teachers use ICT in the classroom by providing data of classroom observations. In this section, I present teachers' classroom practices which emerged in both classroom observations and semi-structured interviews under the themes mentioned in the conceptual framework. As a reminder, I focus on teacher's classroom practices of the subject level, the classroom level and the task level. It is important to note that I present themes that were typically parts of teacher's practices based on classroom observations and interviews. Therefore, only activities that appeared in the observed classes and were revealed in the interviews were taken into account as teacher's classroom practices in the use of ICT.

7.1.2.1 Subject Level

In this section, using both classroom observation and interview data, I explore teachers' use of ICT at subject level. I first briefly present mathematics topics being taught with ICT. Furthermore, I present the subject level opportunities being exposed by the teachers in the classrooms.

The results of the classroom observations suggested that the majority of the participants taught Geometry in the observed classes. Five of them taught Transformation Geometry while two participants taught Plane Geometry. Moreover, two participants taught Algebra with different sub-topics, which were inverts of functions and quadratic equations. Only one of the participants taught Calculus with the topic of Differential. This finding was reinforced by the interviews in that the majority of the teachers confirmed that Geometry was the most frequently taught subject with ICT.

In terms of subject-level opportunities proposed in the pedagogical map, there are three opportunities: build metacognition and overview; rebalance emphasis on skills, concepts, and applications; and exploit contrast of ideal and machine mathematics.

Build metacognition and overview

In the classroom observations, it was revealed that there were three participants (Rina, Mir and Hari) who used ICT to build metacognition and overview of mathematics topics. For instance, the participants chose to approach topics through starting with an overview of the real world instead of starting with details of mathematics concepts. Hari, for example, inserted a picture of a butterfly into Autograph software and showed the students the 'reflection' of the butterfly.

In the interview, the three participants also indicated that ICT had changed their approach to mathematics topics. One of them was Mir who revealed that:

> By using ICT, it changed my approach to teaching. For example, in the classroom, I first gave students problems to be solved by using the tool, and then, through solving the problems students discovered the concepts of a topic in mathematics.

It appeared that Mir started with solving problems rather than at the end of the lesson, as set out in the textbook. The class would then revisit the detail of the concepts through the teacher's exposition.

However, the majority of the participants revealed that the use of MAS did not change their approaches to mathematics topics. The teachers did not take the opportunity to use the digital technology to support activities that encourage metacognition and an overview of mathematics topics. One of the teachers who indicated they did not take this opportunity was Bute. She revealed that:

> For this question, I say no..., this is because students do not have the same competence; there are students who only understand if they are taught through procedures starting from general formula and ending with examples. Yet, in the future, I hope there will be training about the use of ICT. And I never used a new way to approach mathematics topics when I

> used ICT, for example, I never guide students to do work on an application first before they have learned the mathematical formula. In the future, I want to try it.

Exploit contrast of ideal and machine mathematics

The second aspect of the subject-level opportunities is "exploit contrast of ideal & machine mathematics". Regarding this aspect, the teacher may deliberately capitalise on the constraints or limitation of ICT to provoke students' mathematical thinking. In the classroom observations, there was no participant who capitalised this opportunity in the classroom. This is in line with the interview finding that there was no participant who revealed they took this opportunity.

Rebalance on skills, concepts and applications.

Another pedagogical opportunity of Mathematics Analysis Software is "rebalance emphasis on skill, concepts, and applications". As mentioned in the pedagogical map, ICT may be used to alter the balance in teaching between skills, concepts and applications of mathematics. In the observed class, four participants (Rina, Mir, Anton and Hari) showed that they devoted a significant amount of time in the classroom presenting applications of mathematics concepts. For example, Rina spent about 20 minutes of her classroom activity for presenting applications and examples of translation in real-life.

The classroom observation's findings were reinforced by the interviews that a half of the participants (Rina, Mir, Anton, Hari and Laila) revealed they had taken opportunities to rebalance emphasis of concepts and application when they integrated ICT in the classroom. For instance, Laila stated:

> Applications of mathematics concepts should be emphasised when students use ICT in the classroom, it is not a trial and error activity but without understanding what students are doing. For example, when I taught the topic of Reflection, students used GeoGebra to reflect a picture of a cat in Y-axis, thus, students found that the result of the reflections was not changed, if they reflected a picture of a cat, the result was still a cat; therefore, students learned concepts of reflection, that reflection does not change the shape of an object.

Moreover, it is important to remind the reader that only classroom practices that were seen in both the classroom observation and the interview were taken into account as teachers' classroom practice in the use of ICT. Table 7-1 summarises the teachers' classroom practices at subject level.

Table 7-1: Summary of participants' use of ICT at the subject level

Parts.	Subject
Rina	Rebalance emphasis on skills, concepts and applications, and build metacognition and overview
Mir	Rebalance emphasis on skills, concepts and applications, and build metacognition and overview
Muti	-
Anton	Rebalance emphasis on skills, concepts, applications
Abu	-
Laila	-
Din	-
Hari	Rebalance emphasis on skills, concepts and applications, and build metacognition and overview
Alfin	-
Bute	-

7.1.2.2 Task Level

As mentioned in section 3.4, the pedagogical map offers five types of tasks that can be set by teachers when they use ICT in the classroom. The tasks are 'learn pen-and-paper skills', 'explore regularity and variation', 'link representation', 'simulate real situations' and 'use real data'.

As illustrated in the description of each participant's classroom practices, the participants had set different type of tasks for the students and some of them provided more than one type of tasks in one lesson. In the classroom observations, it is seen that five teachers (Rina, Mir, Anton, Hari and Alfin) set more than one type of task in one lesson. Four (Rina, Mir, Anton and Hari) out of the five teachers set the same tasks, which were 'Explore regularity and variation' and 'Link representation'. Anton, for instance, assigned students to use a slider to vary the parameter of 'A' for trigonometric functions Y = A sin X and Y = A Cos X to see what happens to graphs of the functions when the parameter is changed. He also assigned the same activity to the students to use slider of Autograph software to vary of the parameter of "A" and "B" for trigonometric function Y = Sin AX + B and Y = Cos AX + B. At the end of those activities, students were required to draw a conclusion about the parameters. It obviously appeared that the teacher set tasks that encouraged students to use dynamic geometry, explore regularity and variation and, then, make conjectures before proceeding to formal proof.

Moreover, at the same time, those tasks also allowed students to link between symbolic, numerical and graphical views of the functions.

Another teacher who employed more than one type of task was Alfin. He set 'learn pen–and- paper skill' and 'explore regularity and variation' tasks. The teacher asked students to "find the distance between two points." By using GeoGebra, the teacher showed students that: "Any two distinct points are on exactly one line. Every line contains at least two points." He then asked students to do the same activity by using GeoGebra. In the observation, this teacher used dynamic geometry software (GeoGebra) for supporting pen-and-paper skill (e.g., by providing visualisation of distance between a point and a line segment, and doing a measurement of the distance between two points). Moreover, this teacher also used ICT to explore regularity and variation (e.g., by showing students different straight lines pass through a fixed point to any point on a fixed line and showing them the shortest distance is the one which is perpendicular to the fixed line).

Moreover, five participants (Bute, Muti, Abu, Laila and Din) set only one type of task. It is interesting that four (Bute, Muti, Abu and Laila) out of the five participants employed the 'learn pen-and-paper skill' task. For instance, Muti assigned her students to check their pen-and-paper works on translations by using dynamic geometry software. The tasks that the teacher assigned students to use pen and paper were to solve the following problems: Translate Point A (6, -1) by the vector $\binom{-2}{-5}$ and Translate 2x-3y= 4 by the vector $\binom{2}{3}$. Students then checked their answer by using the software, which generates answers quickly, and the students looked at the correct results.

Another teacher who employed one type of tasks was Din. He only set a 'link representation' task, asking students to use dynamic geometry software to plot and move a circle and find the relationship between the circle properties, such as centre and radius, and circle equations and graphs. It appeared that the teacher created tasks of link representation.

In the observed class, the 'learn pen-and-paper skills' task was set by six teachers (Anton, Bute, Muti, Alfin, Abu and Laila). This was in line with the finding of the interviews that the majority of participants said that they mostly set 'Learn Pen-and-Paper Skills' tasks for their students when they integrated ICT in the classroom. For instance, Muti said:

> … In the teaching of circle properties, usually I assigned students to draw circles by using pens, then I asked them to check their answers by using GeoGebra software. Thus, GeoGebra was mostly used, not for enquiry but for getting instant answers, such as feedbacks.

Another teacher, Laila, claimed:

> … I set questions for the students and asked them to answer them, to prove their answers correct or not, I assigned them to check their answers by using GeoGebra software, and provided them a guideline to do it.

The data of classroom observations indicated that 'link representation' task was the second most frequently set task by the teachers, which was utilised by five of the participants (Rina, Mir, Anton, Hari and Din). This finding was strengthened by interviews in which those participants said they employed this type of task.

Another type of task that was used by a significant number of participants was 'explore regularity and variation'. In the observed classes, there four teachers (Rina, Mir, Anton and Hari) used this type of task. However, the interview findings indicated that five teachers set this type of task.

Table 7-2: Summary of participants' use of ICT at the task level

Parts.	Type of task used
Rina	Explore regularity and variation, and link representation
Mir	Explore regularity and variation, and link representation
Muti	Learn pen-and- paper skill
Anton	Explore regularity and variation, and link representation
Abu	Learn pen–and- paper skill
Laila	Learn pen–and- paper skill
Din	Link representation
Hari	Explore regularity and variation, and link representation
Alfin	Learn pen–and- paper skill, explore regularity and variation
Bute	Learn pen–and- paper skill

Table 7-2 summarises types of tasks set by each participant based on the classroom observations and interviews.

On the other hand, for the other types of tasks, 'simulate real situations' and 'use real data', there was no participant used these types of task in the observed class. In the interview, there was one participant, Abu, who mentioned that he often set tasks to simulate real situations.

> … For example, in the teaching of statistics, I assigned students to collect data, then this data were input to Excel, and they created bar chats.

7.1.2.3 Classroom Level

Classroom Didactic Contract

At the classroom level opportunities, as presented in Section 3.4, the focus was on change of classroom social dynamic and classroom didactic contract. Pierce and Stacey (2010) mentioned that the word 'change' in this context means things that contrast with a traditional classroom whereby the teacher is considered to be the only authority and students work mostly on their own. Thus, they separated these classroom changes into cognitive and social aspects, namely "change classroom didactic contract" and "change classroom social dynamics".

Based on the classroom observations, as illustrated in the description of each participant, in terms of "change classroom didactic contract", there were only three teachers (Rina, Anton and Hari) who showed that they employed ICT in ways that the digital technology was introduced as a new 'authority' other than the teacher. In their classes, students were expected to be more active. Moreover, students were assigned to use the digital technology to support their own mathematical explorations and to communicate their findings to the teacher and the class. For instance, Anton employed a discovery-learning approach utilising teaching activities such as discussions, questions and answers, and tasks. Anton set four tasks for the students to work in groups with ICT. In this teacher's classroom, the didactic changed where students were expected to provide their own explanations and make their own generalisations and discoveries rather than relying on the teacher to provide such information. Students shared their findings, including student's presenting their work for the rest of the class to see and publicly explaining their graphs and their reasons for the conclusion. Moreover, in Anton's class, social dynamic also changed as his students worked collaboratively and discussed graphic trigonometry functions in groups.

In the interviews, three teachers (Rina, Anton and Laila) explicitly mentioned that the use of MAS in their teaching has changed their classroom didactic contract. One of the teachers has been presented above. Moreover, Laila revealed that:

> When I taught with ICT, I hoped students experienced learning of mathematics in an interesting and fun way, so I wanted students to apply mathematics in a real-life context or in other school subjects. For example, in learning Differential, students can apply it in Physics; therefore, students do not just memorise the formula of mathematics and solve mathematics problem.

Classroom Social Dynamic

Based on the classroom observation, as illustrated in the description of each participant, the use of ICT by six teachers (Rina, Mir, Anton, Hari, Abu and Laila) had changed their classroom dynamics. For instance, Laila used GeoGebra to explore and teach students about several types of the reflection, and she then assigned students to work in a group of three to four students to solve several problems, one of which was to find the reflection of $x^2 + y^2 - 4x + 2y - 4 = 0$ in y = x. Then, each group was assigned to select one problem and present it in front of the class while the other groups were assigned to check the answer by using GeoGebra. The classroom dynamics were changed when students interacted in groups discussing their answers and checked their answers by using the software. However, Laila remained the main source of knowledge authority.

The findings were reinforced in the interviews in which those six teachers described how the use of ICT in the classroom has changed their classroom social dynamics. Rina said:

> The interaction between students and me and interaction between students and students was improved, and I liked it because two-way communication took place in the classroom; there were questions and answers, discussion among and between students. In the observed class, I was not satisfied because there was one group that had too many students. Normally, I assigned students to work in a group of two students in order to minimise the number of students who are not active. Thus, students discussed in pairs.

It was revealed that, in Rina's classroom, the social dynamics have changed when she integrated MAS in her teaching practices. Moreover, Mir was another teacher who confirmed that her classroom dynamics had changed. She said:

> The interaction between me and the student went well, actively, and interactively. In the teaching and learning process, I assigned students in heterogenetic groups of two students, in that one group consisted of one high competence student and one low competence students, thus the high competence student could share his or her knowledge to the low competence student. I hoped each student whould have the same opportunities in the implementing the Autograph software actively, taking responsibility and they discipline in completing the worksheet.

It shows that at the classroom level, Mir took the pedagogical opportunities in her classroom practice to change the classroom social dynamics.

Table 7-3 summarises findings from classroom observation and interviews about teachers' use of ICT at the classroom level.

Table 7-3: Summary of participants' use of ICT at the classroom level

Parts.	Classroom Level
Rina	Change classroom didactic contract; Change classroom social dynamics
Mir	Change classroom social dynamics
Muti	-
Anton	Change classroom didactic contract; Change classroom social dynamics
Abu	Change classroom social dynamics
Laila	Change classroom social dynamics
Din	-
Hari	Change classroom social dynamics
Alfin	-
Bute	-

In conclusion, at the subject level, the majority of the participants did not use ICT for rebalancing emphasis on skills, concepts and application of mathematics, and they did not change their approaches to mathematical topics. In relation to the task level, 'explore regularity and variation', 'link representation', and 'learn pen –and- paper skill' were three most dominant tasks set by the teachers. Furthermore, at the classroom level, more than half of the participants changed their classroom social dynamic. On the other hand, a very small numbers of the participants changed their didactic contract. Finally, it can be concluded that most of the participants still valued ICT as a tool for students' drill and practice while a small number of the participants valued the digital technology as a tool for facilitating of students' knowledge construction.

7.2 Relationship between Teachers' Knowledge and Classroom Practice

In terms of the relationship between teacher knowledge and classroom practices, I present patterns that appeared in the three levels of classroom practices based on the participants' level of knowledge of ICT and knowledge of ICT use in teaching. It is important to note that in order to search the pattern of the relationships I set the following process. First, I looked at teacher knowledge of ICT and teacher knowledge of ICT use in teaching from the quantitative results as the quantitative analysis suggested that there were positive correlations between both knowledge and classroom practices. Second, as described in section 5.7, I grouped level of teachers' knowledge into two main categories, sufficient knowledge (very high, high, moderately high and slightly above average) and insufficient knowledge (average, slightly below average, moderately low, low and very low).

Based on the categories mentioned above, Table 7-4 shows that there were four participants with sufficient knowledge of ICT (Rina, Mir, Alfin and Abu). On the contrary, the other participants (Anton, Hari, Bute, Muti, Laila and Din) had insufficient of ICT. Furthermore, there were six participants who indicated they had sufficient knowledge of ICT use in teaching (Rina, Mir, Anton, Hari, Alfin and Abu). In contrast, four participants had insufficient knowledge of ICT use in teaching (Bute, Muti, Laila and Din).

Sections 7.2.1 and 7.2.2 present the pattern of the relationship between teachers' knowledge and classroom practices based on teacher level knowledge and their use of ICT at the classroom level, the subject level and the task level.

Table 7-4: Summary teachers' knowledge and classroom practices

Parts	Level of Knowledge (Quantitative)		Lesson Observed	Classroom Practices		
	K of ICT	K of ICT use		Classroom Level	Subject Level	Task Level
Rina	4.68 (sufficient)	4.9 (sufficient)	Transformation geometry (Reflection)	Change classroom didactic contract, Change classroom social dynamics	Rebalance emphasis on skills, concepts and applications, and build metacognition and overview	Explore regularity and variation, and link representation
Mir	3.86 (sufficient)	4.17 (sufficient)	Transformation geometry (Reflection)	Change classroom social dynamics	Rebalance emphasis on skills, concepts and applications, and build metacognition and overview	Explore regularity and variation, and link representation
Anton	2.94 (insufficient)	4.27 (sufficient)	Trigonometry (Graph of trigonometric functions)	Change classroom didactic contract, Change classroom social dynamics	Rebalance emphasis on skills, concepts and applications	Explore regularity and variation, and link representation
Hari	2.64 (insufficient)	3.64 (sufficient)	Transformation Geometry (Reflection)	Change classroom social dynamics	Rebalance emphasis on skills, concepts and applications, and build metacognition and overview	Explore regularity and variation, and link representation
Alfin	3.58 (sufficient)	3.79 (sufficient)	Three-dimensional geometry (the distance between a point and a line segment)	-	-	Learn pen –and- paper skill, explore regularity and variation
Abu	3.63 (sufficient)	3.64 (sufficient)	Differential Calculus	Change classroom social dynamics	-	Learn pen –and- paper skill
Bute	2.18 (insufficient)	2.91 (insufficient)	Inverse functions	-	-	Learn pen –and- paper skill
Muti	2.15 (insufficient	2.97 (insufficient)	Transformation geometry (Translation)	-	-	Learn pen-and- paper skill

Laila	2.18 (Insufficient)	3.00 (Insufficient)	Transformation Geometry	Change classroom social dynamics	-	Learn pen –and- paper skill
Din	2.23 (Insufficient)	2.71 (Insufficient)	Geometry (Circle Equation)	-		Link representation

7.2.1 Relationship between Teachers' Knowledge of ICT and Classroom Practice

As mentioned previously, four participants had sufficient knowledge of ICT (Rina, Mir, Alfin and Abu) while six participants had insufficient knowledge of ICT (Anton, Hari, Bute, Muti, Laila and Din). In the following section, I explore the relationship between teachers' knowledge of ICT and their classroom practice at each level.

Classroom Level

In relation to the use of ICT at the classroom level, three out of four participants with sufficient knowledge of ICT showed that their classroom social dynamics had changed when they used ICT, and one of them showed a change of classroom didactic contracts. For example, Rina's classroom became more active by having students to explore several tasks and to present their work in front of the class.

Three out of six teachers with insufficient knowledge of ICT indicated that they changed classroom social dynamics and one of them changed didactic contracts. Anton, for instance, although he perceived that he had insufficient knowledge of ICT. In the observed class and the interview, he showed that his classroom dynamic and didactic contract had been changed.

In summary, there was no strong evidence showing the relationship of knowledge of ICT and teacher classroom practice at the classroom level since the classroom practices did not obviously appear different between both groups of the teachers.

Subject Level

The data revealed that two out of four teachers with sufficient knowledge of ICT changed the focus of mathematics topics by rebalancing emphasis on skills, concepts and the applications of mathematics. Moreover, the teachers also showed that they changed approaches to mathematics topics such as by starting a lesson with the applications of mathematics instead of detailed concepts of mathematics. In addition, there was no participant with sufficient knowledge of ICT who showed that they took opportunities to exploit the contrast of ideal and machine mathematics.

On the other hand, two out of six teachers with insufficient knowledge of ICT demonstrated changes of mathematics topics' focus. Only one of them changed approaches to the mathematics topics. In addition, there was no teacher who showed that they took opportunities to exploit the contrast of ideal and machine mathematics.

The results indicated that, to some extent, teachers with sufficient knowledge of ICT changed their approaches and their emphasis on mathematics topics by rebalancing emphasis on skills, concepts and application. There was no strong evidence that showed teachers with insufficient knowledge of ICT changed their classroom practices at all aspects of the subject level. It can be concluded that it indicated a relationship between teacher knowledge of ICT and classroom practice particularly in the aspect of building metacognition and overview.

Task Level

The data showed that three out of four teachers with sufficient knowledge of ICT set more than one type of task in one lesson. The majority of them set tasks of ‘explore regularity and variation’. For instance, Rina assigned her students to move a triangle to several positions and to write down the coordinates of vertices of the original triangles and the images.

On the other hand, across six teachers with insufficient knowledge of ICT, only two of them designed more than one type of task in a lesson. These two teachers set tasks of ‘explore regularity and variation’ and ‘link representation’. However, the majority of them set the task of ‘learn pen-and-paper skill’. For example, Muti, in the observed class, presented and explained the concept of translation. The teacher then assigned students to use pen and paper for solving several problems. Finally, the teacher asked students to check their answer by using GeoGebra software.

In conclusion, there were two important findings. First, teachers with sufficient knowledge of ICT were most likely set more than one type of tasks into one lesson while teachers with insufficient knowledge most likely designed one type of task in one lesson. Moreover, teachers with sufficient knowledge of ICT most likely set ‘explore regularity and variation’ tasks. On the other hand, teachers with insufficient knowledge set only one type of tasks in one lesson, and they most likely set ‘learn pen-and-paper skill’ tasks. It can be concluded that the relationship between teachers’ knowledge of ICT and their classroom practices at the task level appeared in terms of the number of tasks and type of tasks set in one lesson.

Summary of the relationship between teachers' knowledge of ICT and classroom practices

In summary, the relationship between teacher ICT knowledge and classroom practices to some extent appeared at the subject level and the task level. At subject level, aspects of build metacognition and overview obviously appeared different between both groups of the teachers, while at the task level, it seemed there were differences of classroom practices of both groups in terms of the number of tasks and type of tasks set in one lesson. On the other hand, it did not show the relationship and the classroom level.

7.2.2 Relationship between Teachers' Knowledge of ICT Use in Teaching and Classroom Practices

As presented earlier, six participants had sufficient knowledge of ICT use in teaching (Rina, Mir, Anton, Hari, Alfin and Abu). On the other hand, Bute, Muti, Laila and Din indicated that they had insufficient knowledge of ICT use in teaching. The connection between teachers' knowledge and their classroom practice is elaborated in the following sections.

Classroom Level

As illustrated in Table 7-4, six teachers had sufficient knowledge of ICT use in teaching. Five out of the six teachers showed that their use of ICT changed their classroom social dynamic. For instance, Anton seemed to teach in a discovery-oriented manner. In the observed class, Anton assigned his students to work in a group of three students to complete the assigned tasks by using dynamic geometry. Students were expected to discuss in the group and draw conclusions about the tasks. Finally, at the end of the class, students were asked to present their work in front of the class.

On the other hand, the table shows that only one out of four teachers with insufficient knowledge of ICT use in teaching changed their social classroom dynamic. It seemed that teachers with insufficient knowledge had difficulty making the classroom interaction become more dynamic when they integrated ICT in the classroom. For instance, Muti valued pedagogical use of dynamic geometry for supporting pen and paper skill by having students to check the answers of pen-and-paper works. In her class, the teachers still play a major role in presenting and explaining the concept of translation. She showed students some examples and then asked the students to complete the task.

In terms of classroom didactic contract, as illustrated in Table 7-4, only two out of six participants with sufficient knowledge changed their classroom didactic contracts. One of them was Rina, who changed her expectation in the classroom as she expected her students to make discoveries and make a general statement about the mathematical concept.

In contrasts, there was no participant with insufficient knowledge of ICT use in teaching who changed their classroom didactic contracts. It appeared that they had difficulty to take the opportunity offered by mathematical software when they integrated the digital technology in the classroom.

In summary, teachers with sufficient knowledge of ICT use in teaching changed their classroom social dynamic. However, there was no strong evidence showing the teachers changed their classroom didactic contract. Furthermore, the results showed that teachers with insufficient knowledge did not change classroom social dynamic and didactic contacts in their mathematics classrooms. It can be concluded that there is a relationship between teachers' knowledge of ICT use in teaching and classroom practices in the aspect of classroom social dynamic.

Subject Level

Table 7-4 shows that four out of six teachers with sufficient knowledge rebalanced emphasis on skills, concept and application when they used ICT in the classroom. Moreover, three of them used ICT to support their new approach to mathematics topics. For instance, Hari, according to his teaching approach described in section 7.1, changed his approach to mathematics topics by starting from the application of mathematics concepts. In the observed class, he started a topic of reflection by randomly selecting a picture of nature, such as flower, butterfly, kite, and inserted those pictures into Autograph software to determine whether the objects were symmetrical or not. Then, he linked the symmetry concept and the reflection concept. The class would then revisit the details of the concept of reflection at the end of the class.

There were no teachers with insufficient knowledge of ICT use in teaching who valued the use of ICT to rebalance emphasis on skills, concepts and applications and build metacognition and overview. The teachers started a topic with detail and provided students examples before the students completed the tasks.

Moreover, in the observed classes, it showed that students still devoted a significant amount of time for drilling and practices. For example, Muti allocated a significant amount of time for her students to do pen-and-paper works and check their work by using GeoGebra software.

Another opportunity offered by MAS is to exploit the contrast of ideal and machines mathematics. However, the results showed that neither teachers with sufficient knowledge nor teachers with insufficient knowledge took the opportunity of the use of MAS to exploit contrast of ideal and machine mathematics.

In conclusion, the findings showed that teachers with sufficient knowledge of ICT use in teaching used ICT to rebalance emphasis on skills, concepts and applications. Moreover, they also seemed to adopt new approaches to mathematics topics by starting the new topic from different points, such as from application rather than from a detailed concept of mathematics. On the other hand, teachers with insufficient knowledge seemed to maintain their traditional practices. It can concluded that a relationship teachers' knowledge of ICT use in teaching and classroom practices appeared in aspects of rebalancing of emphasis on skills, concepts and application, and building metacognition and overview.

Task Level

Table 7-4 shows that five out of six teachers with sufficient knowledge set more than one type of tasks. Most of them designed 'explore regularity and variation' and 'link representation' tasks. For example, Mir, in the observed class, set the following task for the students. Given figure PQRST with coordinates P (6,-5), Q (9,3), R (6,5), S (1,3) and T (2,3) reflected in Y-axis, the students were assigned to move the pre-image to several different positions and determine the general formula of the reflection. Students were expected to find the solutions to problems by exploring different representations of the reflection of figure PQRST. Moreover, this teacher also deliberately took the opportunity to link the geometric representation with the coordinates of the vertices of figure PQRST.

In contrast, all teachers with insufficient knowledge of ICT use in teaching employed only one type of task. Three of them used 'learn pen-and-paper skill' tasks. For instance, Bute valued the pedagogical use of dynamic geometry for supporting 'pen-and-paper skill' by assigning students to check their pen-and-paper works when students were learning the inverse function.

In summary, teachers with sufficient knowledge used more than one type of tasks in one lesson, which were 'explore regularity and variation' and 'link representation. In contrast, teachers with insufficient knowledge used only one type of the task, and 'learn pen-and-paper skill' was the most common task set by the teachers. It can be concluded that there us a relationship between teachers' knowledge of ICT use and teacher' classroom practice, particularly in the aspects of the number of tasks and types of tasks set in a mathematics lesson.

Summary of the relationship between teachers' knowledge of ICT use in teaching and classroom practices

In short, the relationship between teachers' knowledge of ICT use in teaching and classroom practices appeared at the classroom level, the subject level and the task level. It showed differences of practices between both groups of the teachers in aspects of classroom social dynamic, rebalancing emphasis on skills, concepts and application, building metacognition and overview, number of tasks and types of tasks set in a mathematics lesson.

7.3 Summary

This chapter has reported teacher's classroom practices as well as the relationship between teachers' knowledge and their classroom practices. Based on the results of data analysis, I draw the following conclusions.

In terms of teachers' classroom practices, at the subject level, less than half of the participants rebalanced emphasis on skills, concepts and applications, and built metacognition and overview. There was no participant who took opportunities in using ICT to explore the contrast of ideal and machine mathematics. Moreover, at the classroom level, more than half of the participants changed the classroom social dynamic and only two participants changed the classroom didactic contract. In addition, in terms of task level, the majority of the participants still valued ICT as a tool for students' drilling and practice. Therefore, it can be concluded that the majority of the participants did not value the digital technology as a tool for facilitating of students' knowledge construction.

Overall, it appeared that there is a relationship between teachers' knowledge and classroom practices in the use of ICT in the classroom. However, the relationship between teachers' knowledge of ICT use in teaching and classroom practices more obviously appeared than the relationship between teachers' knowledge of

ICT and classroom practices. The relationship between teacher ICT knowledge and classroom practices, to some extent, appeared at the subject level and the task level, while the relationship between teachers' knowledge of ICT use in teaching and classroom practices appeared at the classroom level, the subject level and the task level.

In the next chapter, findings from quantitative and qualitative data are interpreted and discussed regarding the elated literature in the field.

Chapter 8 Discussion of the Findings

In this chapter, the quantitative and qualitative findings are integrated, interpreted, and discussed with the related literature. This study has investigated teachers' knowledge, classroom practices and barriers to the use of ICT in secondary mathematics teaching in Indonesia as well as the relationship between teachers' knowledge and classroom practices by employing a quantitative method with survey design subsequently followed by collecting qualitative data from semi-structured interviews and classroom observations.

Discussion of quantitative and qualitative findings in this study is guided by the following research questions:

1. What knowledge do Indonesian secondary mathematics teachers have about ICT and its use in teaching?
2. How do Indonesian secondary mathematics teachers use ICT in their teaching practices?
3. What is the relationship between teachers' knowledge and classroom practices in the use of ICT in mathematics teaching?
4. What barriers do Indonesian secondary mathematics teachers face in the use of ICT in the classroom?
5. Are there significant differences in terms of teachers' knowledge and classroom practices according to their backgrounds?

As discussed in Section 5.2, research question #1, research question #4 and research question #5 were investigated using quantitative data while research question #2 and question #3 were examined using both quantitative and qualitative data. Hence, this chapter provides an in-depth discussion of both quantitative and qualitative findings regarding the research questions. The interpretations are discussed regarding related literature in the field.

8.1 Research Question 1

What knowledge do Indonesian secondary mathematics teachers have about ICT and its use in teaching?

To respond to this research question, there are two main aspects investigated: (1) teachers' knowledge of ICT; and (2) teachers' knowledge of ICT use in teaching. As previously discussed in Section 5.4, this research question was investigated by employing a questionnaire. Therefore, regarding this research question, only quantitative findings are interpreted and discussed based on the related literature.

Findings: Quantitative Phase

The results suggested that Indonesian secondary mathematics teachers had insufficient knowledge of both ICT and ICT use in teaching. In terms of knowledge of ICT, the results revealed that teachers' knowledge of computer was higher than their knowledge of other hardware. The results also showed that the level of teachers' knowledge of general software was higher than the level of their knowledge of mathematical software. Regarding teachers' knowledge of ICT use in teaching, teachers' ICT Pedagogical Content Knowledge was lower than ICT-Pedagogical Knowledge and ICT-Content Knowledge.

Discussion

Teachers' knowledge of ICT

Overall, the findings showed that Indonesian secondary mathematics teachers had insufficient knowledge of ICT. Regarding knowledge of hardware, the findings disclosed that participants' knowledge of computers/laptops was higher than their knowledge of tablets/handheld devices and graphing calculators. This is quite surprising, as the level of teachers' knowledge was lowest about graphing calculators. According to the literature (see Mailizar et al., 2014; Ruseffendi, 1988), the integration of calculators in Indonesian secondary mathematics classrooms have been attempted to be introduced since 1984. It seems that a long history of the integration of the tool does not have a significant impact on teachers' knowledge in of this tool. However, it is not surprising that teachers perceived their knowledge of computers/laptops to be the highest one due to the fact they need to use this tool in daily life. Moreover, according to the data from

Aceh Provincial Office of Education (2015), almost all of the schools in Aceh province are equipped with computers.

Regarding knowledge of software, the findings showed that teachers' knowledge of general software was higher than their knowledge of mathematical software. This finding supports Fuglestad's (2007) study revealing that teachers had some basic knowledge of general software such as the spreadsheets. Nevertheless, they revealed a lack of knowledge about specific mathematics software such as dynamic geometry software.

The majority of the participants revealed that their knowledge of word processor software (e.g., Ms Word) was the highest one which then followed by their knowledge of presentation software (e.g., Ms PowerPoint) and knowledge of spreadsheet software (e.g., Ms Excel) respectively. It is not surprising that participants perceived that their knowledge of using those three types of software was higher than their knowledge of the other general software (e.g., Mind Mapping & Animation software) since they are widely available and commonly used on many occasions. This finding is in line with Kazoka and William's (2016) study in Tanzania which revealed that the majority (75%) of secondary school teachers were able to use Ms Word, and 60% of teachers were able to use MS Excel and only 50% of teachers were able to use MS PowerPoint. In the Indonesian context, this finding supports Marzal's (2013) study revealing that over 60% of science and mathematics teachers have knowledge of using Microsoft Word, Microsoft PowerPoint and the Internet. In contrast, less than 10% of the teachers are able to use specific software such as SPSS, Edmodo, Adobe Flash and Movie Maker.

Teachers' knowledge of mathematical software was moderately low, and the result suggests that teachers' knowledge of this software was lower than their knowledge of general software. This finding supports Fuglestad's (2007) study that claimed that teachers have basic knowledge of general software such as spreadsheets but they generally have a lack of knowledge of mathematical software such as dynamic geometry software. To discuss this in detail, as mentioned in Section 4.1, mathematical software consists of four types of software: Dynamic Mathematics Software (DMS) (e.g., GeoGebra); Dynamic Geometry Software (DGS) (e.g., Autograph and Cabry Geometry); Computer Algebra System (CAS) (e.g., Maple, Mathematics, and Maxima); and Statistical Software (e.g., Tinkerplots, Fathon, SPSS). The results showed that the participants perceived their knowledge of DMS and DGS to be higher than they perceived their knowledge in the use Statistical Software and CAS. This finding is consistent with what Jones (2005a) claimed that it is reasonable for teachers to rate their knowledge of DGS higher than their knowledge of other types of software since DGS has become the most widely used piece of software in schools all over the world. Furthermore, when it comes to a closer look at DMS and DGS, the finding shows that teacher knowledge of DMS (e.g., GeoGebra) software was highest. GeoGebra is open-source software, which is widely available. Hence, teachers and students can download and use it at home. This circumstance might have had an influenced on teacher knowledge of this software.

Teachers' knowledge of learning management systems (LMS) was low, and it was lower than their knowledge of online learning resources. The finding is not surprising as this digital technology is quite new in the secondary education. LMS originated in the nineties and their adoption rate is high in higher education and later in secondary education (Pynoo et al., 2012).

It can be concluded that Indonesian secondary mathematics teachers need to improve their knowledge of ICT. Particularly, they need to improve their knowledge of mathematics software especially CAS and Statistical Software. In addition, they need to pay more attention to developing their knowledge of software of Learning Management System.

Teacher knowledge of ICT use in teaching

Overall, the findings showed that Indonesian secondary mathematics teachers had insufficient knowledge of ICT use in teaching. As discussed in the conceptual framework, this study adapted the TPACK framework in investigating teachers' knowledge of ICT use in teaching. Hence, the findings are discussed and interpreted in terms of previous studies using the framework.

Firstly, overall the finding is consistent with previous research using the TPACK framework for investigating teachers' knowledge in other countries such as (e.g., Al Harbi, 2014; Archambault & Crippen, 2009). For instance, Al Harbi found that Saudi high school teachers have a low to moderate level of TPACK knowledge.

With regard to mathematics teachers, this finding is also consistent with the findings of the previous studies using the TPACK framework in investigating mathematics teachers' knowledge of ways to integrate ICT in teaching (e.g., Agyei & Voogt, 2011; Handal et al., 2013). Mathematics teachers' lack of knowledge about integrating ICT across the mathematics curriculum has been found not only in developing countries such as Ghana (see Agyei & Voogt, 2011) but also in developed countries such as Australia (see Handal et al., 2013).

As discussed in the conceptual framework chapter, teachers' knowledge in the use of ICT consists of three aspects: ICT-Content Knowledge, ICT-Pedagogical Knowledge, and ICT-Pedagogical Content Knowledge. The results suggested that teachers' ICT-Content Knowledge and ICT-Pedagogical Knowledge were slightly higher than teachers' ICT-Pedagogical Content Knowledge. This is consistent with the findings of Al Harbi's (2014) study. This is one of the indications that ICT-Pedagogical Content Knowledge is more complex and sophisticated than to ICT-Content Knowledge and ICT-Pedagogical Knowledge. Therefore, teachers find it much more difficult to acquire this knowledge.

Finally, it can be concluded that Indonesian secondary mathematics teachers had insufficient knowledge of both ICT and ICT use in teaching. This could be because of the deficiency of training programs: as was found in the present study, 35.19% of the participants had never participated in any training course for ICT. Across participants who had participated in a training course, 14.90% of them had never participated in a training course for the integrating of ICT in teaching. Moreover, the data also showed that a large number of Indonesian secondary mathematics teachers (46%) are aged over 46 years old. These teachers as described by Harendita (2013) as digital migrants.

It is important to provide courses on the ICT integration that consider activities around pedagogical and content training rather than simply training teachers in technical knowledge for the use of ICT resources. This has been supported by research evidence in the literature (e.g., Becta, 2004; Hew & Brush, 2006; Koehler & Mishra, 2005). For instance, according to Koehler and Mishra (2005), when training teachers to effectively use ICT, it is important to teach ICT in contexts that represent the high connections between ICT, content and pedagogy.

8.2 Research Question 2

How do Indonesian secondary mathematics teachers use ICT in their teaching practices?

To respond to this research question, there were two main aspects investigated: (1) Teachers' use of hardware, software and online resources in mathematics teaching; and (2) Teachers' functional and pedagogical activities in the use of ICT in mathematics teaching. In relation the pedagogical activities, this study focused on the subject level, the classroom level and the task level. As previously presented in Section 5.4, this research question was explored through the questionnaire, classroom observations, and semi-structured interviews. The classroom observations and the interviews, which focused on the teachers' use of Mathematics Analysis Software, aimed to enrich the findings of the questionnaire on teachers' pedagogical practices in the use of ICT.

Findings: Quantitative Phase

In total, 67% of the teachers had used ICT in their teaching of mathematics at least once. A large number of the participants had been using ICT for only 1 to 3 years and used it in teaching a limited number of mathematics lessons. Computers/laptops and presentation software (e.g., PowerPoint) were the most commonly used ICT tools in mathematics teaching. Furthermore, teachers mostly used ICT to present contents of mathematics and give classroom instruction as well as doing arithmetic and drawing graphs. Geometry was the most commonly taught topics using ICT and there was no significant difference in the frequency use of teacher-centred approaches and student-centred approaches. In addition, "Learning pen-and-paper skills" and "use real data" were the two most frequently set tasks for the students.

Findings: Qualitative Phase

Findings of the qualitative phase showed that, at the subject level, the majority of the participants still did not value ICT for rebalancing emphasis on skills, concepts and applications in mathematics and did not change their approaches to mathematics topics. Moreover, there was no participant who took the opportunities in the use of ICT to exploit contrast of ideal and machine mathematics. At the classroom level, the majority of the participants did not change their didactic contract. However, over half of the participants changed their classroom social dynamics. In relation to the task level, 'exploring regularity and variation', 'linking representation', and 'learning pen –and- paper skills' were the three most dominant types of the tasks set by the teachers. In short, most of the participants still valued ICT as a tool for students' drill and practice while a small number of the participants valued the digital technology as a tool for facilitating of students' knowledge construction.

Discussion

The quantitative findings showed that significant numbers of the secondary mathematics teacher (33%) in Aceh Province, Indonesia, never integrated ICT in their mathematics teaching. This finding indicated that not all secondary mathematics teachers had implemented the Indonesian government's policy on the integration of digital technology in the classroom as stipulated in Indonesian Law Number 14 of 2005. Furthermore, the findings also point to the conclusion that not all the teachers fully followed the current curriculum emphasising on the use of ICT in teaching and learning practices.

The findings showed that a significant number of the participants (43.32%) had been integrating ICT for only 1 to 3 years. As mentioned earlier, policy on ICT integration was stipulated over a decade ago. Yet, this finding indicates that the majority of the mathematics teachers did not implement the policy immediately. As it has emerged, however, the findings are good signs for the integration of ICT in secondary mathematics classrooms in the country. In addition, the findings showed the majority of the participants used ICT for teaching of limited numbers of mathematics lessons. Therefore, teachers and the policymaker need focus on their effort in increasing the number of lessons taught with ICT.

In relation to the use of hardware, the quantitative findings showed that computers/laptops were the most frequently used hardware for mathematics teaching. This is supported by the qualitative findings from classroom observations and the semi-structured interviews. In the classroom observations, all the participants used computers/laptops when they integrated MAS in their mathematics teaching. This is in line with the finding relating to teachers' knowledge of ICT showing that the level of teachers' knowledge of computers/laptops was the highest one. However, this finding is quite surprising for the following reasons.

Firstly, the increasing presence of handheld devices such as smartphones and tablets, including in Indonesia where those digital technologies have become widely available and used in daily life, has not affected the use of those digital technologies for teaching and learning purposes. This indicates that the teachers have not been able to capitalise on this resource for educational purposes. Secondly, calculators have been used in mathematics classrooms since the mid-1980s. Moreover, it is widely believed that handheld devices and graphing calculators offer various advantages such as to extend experimental and discovery learning (Drijvers & Weigand, 2010); to help learners to analyse and reflect on the relationship between data (Clements, 2000; Hennessy, 2000); to stimulate both the use of realistic contexts in mathematics and exploratory learning approaches (Drijvers & Doorman, 1996). However, this study found that this digital tool was not commonly used in Indonesian secondary mathematics classrooms. A decline in the use of calculators seems also occurred in other countries such as Australia (see Handal, Cavanagh, Wood, & Petocz, 2011). This is probably due to the increasing use of free web-based calculators.

In terms of the use of software, the quantitative findings showed that the use of mathematical software was relatively rare. On the other hand, the use of ICT was dominated by presentation-oriented software such as PowerPoint. This is in agreement with the finding relating to teachers' knowledge of ICT showing that the level of teachers' knowledge of presentation-oriented software was higher than the level of teachers' knowledge of mathematical software. This finding supports the previous studies (e.g., Bretscher, 2014; Helen J Forgasz, 2002; Loong et al., 2011; Polly, 2014). Forgasz's study, for instance, found that generic software applications such as spreadsheets, word processors, and internet browsers were used more frequently than mathematics-specific applications such as Geometer's Sketchpad and Graphmatica. On the other hand, it is widely known that there is various software or computer applications available for mathematics teaching that have better properties for mathematics teaching than general software. Hence, a lack of use of mathematical software in Indonesian mathematics classrooms indicates that the teachers were not able to capitalise on the presences of the tools for teaching and learning purposes. The use of general software such as Ms PowerPoint in mathematics teaching seems not to offer many advantages in teaching and learning of mathematics as this digital tool does not have features that facilitate students to work on rich mathematical tasks.

It is important to remind the reader that this study also looked at the type of mathematical software that teachers commonly used in the classroom. As previously discussed in Section 4.1, four types of mathematical software are DMS, DGS, CAS, and Statistical Software. The quantitative findings showed that DMS and DGS were the two most commonly used types of mathematical software in the mathematics classroom. This result is reinforced by the qualitative findings revealing that, in the classroom observations and interviews, showed the majority of participants used DMS or DGS. The qualitative findings also suggested that

DMS, particularly GeoGebra, was the most commonly used of mathematical software in mathematics teaching.

There are some possible reasons why DMS (e.g., GeoGebra) was the most popular type of mathematical software over others. Firstly, GeoGebra is free software which has been translated into forty languages including Indonesian and is used extensively around the globe (see Hohenwarter & Lavicza, 2007). Secondly, this type of software offers features that accommodate a wide range of mathematics topics including Algebra, Geometry, and Statistics. Thirdly, the findings of the present study have revealed that teachers' knowledge of GeoGebra was the highest one across teachers' knowledge out of all types of mathematics software. Therefore, it is not surprising that the finding showed that GeoGebra was the most commonly used type of mathematical software in Indonesian secondary mathematics classrooms.

Another quantitative finding regarding types of ICT used in the classroom was that teachers less frequently used LMS than online learning resources. This finding was reinforced by the qualitative finding that revealed that there was no participant indicated they used LMS. The finding is consistent with the finding by Kitchen et al. (2007). Low adoption rate of LMS in secondary schools was also found by Pynoo et al. (2012). Teachers' low knowledge of LMS may lead to low adoption of this digital tool in Indonesian secondary mathematics teaching.

In relation to functional activities of ICT, the quantitative finding showed that doing arithmetic and drawing graphs were of two most common activities conducted by teachers with ICT. This finding is not surprising as software for mathematical graphing was amongst the earliest computer applications developed for educational use (see K Ruthven, Deaney, & Hennessy, 2009). In addition, Dynamic Mathematics Software offers features that allow users to easily draw graphs and do arithmetic. This related to the finding that showed that DMS software was the most frequently used of all the types of mathematics software.

Furthermore, two of the most common classroom activities with ICT were presenting contents of mathematics and giving classroom instruction. This is relevant to the finding on types of software used. As previously discussed, presentation software (e.g., Ms PowerPoint) was the most commonly used of the type of software in mathematics classrooms. This type of software is potentially used for presenting contents of lessons and classroom instructions. Such activities with ICT do not increase the value of ICT integration. This finding indicates that teachers less frequently used ICT for doing constructive activities such as facilitating students in exploratory and inquiry activities.

The quantitative finding showed that there was no statistically significant difference in the frequency of use teacher-centred approaches and student-centred approachs. However, the qualitative findings revealed that teacher-centred approaches were more dominant compared to student-centred approaches.

This finding support the findings of other studies (e.g., Cuban et al., 2001; Law, 2009; Lim & Chai, 2008; Petras, 2010) which also found that when ICT is used, it is not typically used to support student-centred instruction. Regarding mathematics teaching, these findings are consistent with Pelgrum and Voogt's (2009) study which revealed that mathematics teachers in countries with low percentage use of ICT applied a teacher-centred approach more often than teachers in countries with a high percentage of ICT use. Even in a developed country like England, teacher-centred practices still frequently occurred amongst all teachers (see Bretscher, 2014). In the Indonesian context, this finding supports Rimilda's (2015) study that found Indonesian pre-service mathematics teachers mostly used direct instruction when integrating ICT in the classroom.

At the task level, the quantitative findings are supported by the qualitative findings that showed that most of the participants still valued ICT as a tool for students' drill and practices by setting learn paper–and-pen skills' tasks for the students. Teachers set 'drill and practice tasks' more frequently than they set other types of tasks. According to Cavanagh and Mitchelmore (2011), drill and practice tasks have no significant bearing on students' learning achievements since their format resembles rote learning exercises. This indicates that the majority of teachers set behaviourism-oriented tasks. As a result, the majority of the teachers still did not set rich mathematical tasks when they integrated ICT in the classroom. Hence, the Indonesian teachers need to facilitate students in learning by designing constructivist-oriented tasks such as 'exploring regularity and variation' and 'simulating real situations'.

Finally, at the subject level, the quantitative result showed that Geometry was the most commonly taught topic with ICT. This was reaffirmed in the classroom observations and the interviews revealing the same finding. Furthermore, the qualitative finding added insights to show that the majority of the participants still employed a traditional approach to mathematics topics; for example, they started a lesson by teaching a concept of mathematics, showed examples to the students, and asked them to work on tasks. This indicates that they did not take the opportunity to build metacognition and overview. However, the literature (e.g., M. Thomas, Monaghan, & Pierce, 2004) notes that higher level thinking may be supported by the use of ICT such as CAS if the teacher takes the opportunity to use this digital technology to support tasks which encourage metacognition and overview.

Moreover, the qualitative findings also showed that the majority of teachers did not use ICT to alter the balance in teaching between skills, concepts and applications. The literature has revealed this opportunity offered by digital technology. For instance, Vincent (2003) used dynamic geometry in a geometry class to shift the balance in the class away from learning facts and supporting students' argumentation, helping them to connect conjecture and proof.

Finally, it can be concluded that behaviourism paradigm still dominated the integration of ICT in Indonesian secondary mathematics classroom. The findings of this study are consistent with the previous studies in other countries suggesting that teachers have not yet achieved a high level of ICT use (e.g., Kozma, 2003; Mueller et al., 2008; Tondeur, Van Braak, & Valcke, 2007). That most of the teachers failed to use ICT in constructive ways was also found by Hennessy et al. (2005), and most of the teachers used ICT for an established form of practices (e.g., Kenneth Ruthven & Hennessy, 2002). This is in spite of the fact that, according to M. Cox et al. (2003), the most effective integrations of ICT are those in which teachers and digital tools can challenge students' understanding and thinking.

8.3 Research Question 3

What is the relationship between teachers' knowledge and classroom practices in the use of ICT in mathematics teaching?

As discussed in the conceptual framework, this study also examined the relationship between teachers' knowledge and classroom practices in the use of ICT. This issue was investigated quantitatively by employing a Spearman's correlation. In addition, the relationship was also explored qualitatively based on the data from classroom observations and interviews.

Findings: Quantitative Phase

There was a strong positive correlation between teachers' knowledge of ICT use in teaching and their classroom practices (r_s = .645, p<.01). Moreover, a Spearman's correlation analysis also showed a strong positive correlation between teachers' knowledge of ICT and their classroom practices (r_s = .524, p<.01). It is important to emphasise that the results showed that the relationship between teachers' knowledge of ICT use in teaching and their classroom practices was stronger than the relationship between teachers' knowledge of ICT and their classroom practices.

Findings: Qualitative Phase

In the qualitative phase, the relationship between teachers' knowledge and classroom practices appeared. The relationship between teachers' knowledge of ICT use in teaching and their classroom practices more obviously appeared than the relationship between teachers' knowledge of ICT and classroom practices. The relationship between teachers' knowledge of ICT and classroom practices appeared at the subject level and the task level while the relationship between teachers' knowledge of ICT use in teaching and classroom practices appeared at the classroom level, the subject level and the task level.

Discussion

Over the last 30 years, teachers' knowledge has become one of the most important concerns of the educational research. It has been assumed that teachers who know more teach better. In relation to this idea, researchers have investigated the relationship between teachers' knowledge and their classroom practice (e.g., Borko & Putnam, 1995; Cochran-Smith & Lytle, 1999; Copur-Gencturk, 2015; Gilbert & Gilbert, 2013; Shechtman et al., 2010). The literature reveals that teachers' knowledge significantly influences their classroom practices. For instance, Gilbert and Gilbert (2013) showed that mathematics teachers' content knowledge for teaching is closely linked to classroom practices.

As discussed in the conceptual framework, in relation to teachers' knowledge, this study looked at teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching. The quantitative findings showed a positive correlation between teachers' knowledge of ICT and their pedagogical practices in the use of ICT. This finding is in agreement with the previous studies (e.g., Buabeng-Andoh, 2012; Sorgo, Verckovnik, & Kocijancis, 2010; Tezci, 2010) who found a positive relationship between teachers' ICT knowledge and their use of ICT in the classroom.

In relation to knowledge of ICT use in teaching, as mentioned in the conceptual framework chapter, the present study adapted the TPACK framework. The quantitative findings of this study showed that teachers' knowledge of ICT use in teaching has a strong positive correlation with teachers' use of ICT in the classroom. This is consistent with Al Harbi (2014) and Kafyulilo and Keengwe (2014) who also adopted the TPACK framework and found a positive correlation between teachers' Technological Pedagogical Content Knowledge and the integration of ICT in the classroom.

It is important to highlight that the quantitative findings also showed that the relationship between teachers' knowledge of ICT and their classroom practices was less significant than the relationship between teachers' knowledge of ICT use in teaching and their classroom practices. Consequently, it indicates that teachers need to improve their knowledge of how to use ICT in teaching more than their need to improve their knowledge of ICT.

To explore these relationships in more depth, as mentioned previously, this study also looked at this issue through a qualitative lens. Regarding the qualitative findings, there are several interesting points to highlight. Firstly, the relationship between teachers' knowledge and classroom practices in the use of ICT was apparent. However, the relationship between teachers' knowledge of ICT use in teaching and their classroom practices was more apparent than the relationship between teachers' knowledge of ICT and their classroom practices.

Secondly, the relationship between teachers' knowledge of ICT and classroom practices was apparent at the subject level and the task level. At the subject level, teachers with sufficient knowledge of ICT changed their approach to mathematics topics while teachers with limited knowledge kept the traditional approach. One of the possible reasons for this finding is that teachers with sufficient knowledge of ICT were able to explore various capabilities available on mathematical software. For instance, by using GeoGebra teachers can link symbolic expression. A teacher could not make use of such capabilities if they do not have a good knowledge of the software.

Furthermore, at the task level, teachers with sufficient knowledge of ICT set 'exploring regularity and variation' tasks while teachers with limited knowledge of ICT designed 'learning pen-and-paper skills' tasks such as having students to check their answers by using GeoGebra software. The finding indicates that when teachers use MAS they need sufficient technical knowledge in order to be able to fully explore the properties of the software. Therefore, they will be able to set a constructivist-oriented task such as exploring regularity and variation.

In addition, at the classroom level, there was no difference in teachers' classroom practices between teachers with sufficient knowledge of ICT and teachers with insufficient of ICT. This finding indicates that technical knowledge does not play a significant role in terms of teacher classroom practices at the classroom level. It is understandable that a relationship between teachers' knowledge of ICT and teachers' practice at the classroom level was not apparent, as at this level, more teachers' pedagogical knowledge than teachers; technical knowledge is required.

On the other hand, the relationship between teachers' knowledge of ICT use in teaching and classroom practices appeared not only at the subject level and the task level but also at the classroom level. At the classroom level, teachers with sufficient knowledge of ICT use in teaching had a more dynamic classroom environment than teachers with limited knowledge had. It can be concluded that, to some extent, these support the quantitative finding that the relationship between teachers' knowledge of ICT use in teaching and their classroom practices was stronger than the relationship between teachers' knowledge of ICT and their classroom practices.

The finding of the present study indicates that teachers need knowledge of ICT in order to integrate ICT in the classroom. However, teachers' knowledge of ICT use in teaching is more important to enable teachers to effectively use ICT in the teaching and learning process. This finding is consistent with the assumption that focusing on teachers' technical knowledge alone is insufficient to acquire successful ICT integration.

Thus, these findings support the TPACK theory (Koehler & Mishra, 2005; Mishra & Koehler, 2006) in which a teacher with the deeper Technological Pedagogical Content Knowledge demonstrates the more effective ICT implementation, and the TPACK theory proposes that teachers need technological pedagogical and content knowledge rather than simply technical knowledge (Mishra & Koehler, 2006). In short, teachers should know how to use ICT to facilitate student learning as Ertmer and Ottenbreit-Leftwich (2010) stated that to use ICT to support effective student learning, teachers need to be equipped with additional knowledge of pedagogical methods that facilitate student learning, and the specific ways in which technology can support those methods. The knowledge of technological tools is not enough; what teachers really need is knowledge of how to use these tools effectively in order to facilitate students' learning processes.

8.4 Research Question 4

What barriers do Indonesian secondary mathematics teachers face in using ICT in the classroom?

As described in the conceptual framework chapter, teachers' barriers consist of three levels that are the school level, the teacher level and the curriculum level. Furthermore, as mentioned previously, this research question investigated using the questionnaire alone. As a result, only quantitative results are interpreted and discussed in this section.

Findings: Quantitative Phase

The quantitative results showed that teachers' lack of time to prepare ICT-based lessons was the main barrier at the school level while teachers' lack of confidence was the main barrier at the teacher level. In addition, students' assessment not being in line with the integration of ICT was the main barrier at the curriculum level.

Discussion

The previous studies have shown that the barriers to integrating ICT in the classroom differ from country to country. The lack of teacher knowledge to use ICT in teaching has been identified by other researchers as the main barrier to the integration in developing countries (see Pelgrum, 2001). Lack of teacher knowledge of ICT integration as a barrier to ICT integration was also found even in a developed county like Australia as reported by Forgasz (2006). The results of quantitative data showed that Indonesian secondary mathematics teachers had insufficient knowledge of both ICT and ICT use in teaching. Therefore, it is safe to conclude that teachers' lack of knowledge is one of the barriers to ICT integration in Indonesian secondary mathematics classrooms. This section discusses the other barriers faced by the secondary mathematics teachers in implementing ICT in their classrooms.

As presented in Section 4.3.3, this study classified barriers on the school level, the teacher level and the classroom level. The findings showed the main barriers from each category were teachers' lack of time to prepare ICT-based lessons, teachers' lack of confidence and students' assessments was not being in line with ICT integration. This finding is elaborated on and discussed based on the literature as follows.

The findings of this study revealed that teachers' lack of confidence in the use of ICT was the main barrier at the teacher level. This finding supports the previous studies (e.g., Assude et al., 2010; Bingimlas, 2009; Kafyulilo & Keengwe, 2014; Schoolnet, 2006; Scrimshaw, 2004) which reported that teachers' lack of confidence is one of the barriers to ICT integration. However, in the Indonesian context, there was no publication which had reported on this barrier to ICT integration of ICT in Indonesian classrooms. As a result, the finding of this study has added to the information regarding barriers faced by secondary mathematics teachers, especially in the Indonesian context. One of possible reasons is that Indonesian mathematics teachers had insufficient knowledge of both ICT and ICT use in teaching and this may lead to teachers' lack confidence in the use of ICT in the classroom, as it is widely known that teachers' knowledge a has strong correlation to teachers' confidence (see Mccormack, 2015).

Regarding barriers at the school level, the findings showed that teachers' lack of time to prepared ICT based lessons is one of the main barriers at this level. It is similar to those reported by other researchers (e.g., Al-Alwani, 2005; Keong et al., 2005; Preston, Cox, & Cox, 2000; Sicilia, 2007) who revealed that the most common challenge faced by all teachers was lack of time to plan technology-based lessons. For instance, Al-Alwani reported that lack of time was a barrier to ICT integration in Saudi Arabian science education. Teachers' lack of time was also found in Malaysia as reported by Keong et al. (2005). However, the findings of the present study challenge a long-established understanding in the Indonesian context that the main barrier at the school level was lack of ICT infrastructure. In the Indonesian context, one highly possible reason for this finding is that the current regulation requires certificated teachers to teach at least 24 hours per week. As a result, the teachers have very limited time for teaching's preparation. On the other hand, a lot of time and efforts are needed to prepared ICT-based lessons (see Kubilinskiene & Dagiene, 2010).

At the curriculum level, the finding revealed that assessment constituted teachers' main barriers at the curriculum level. This finding corroborates Fox and Henri's (2005) study which found that pressures related to testing gave Hong Kong teachers little time to attempt new instructional methods involving ICT. This is also in line with Butzin (2004) who noted that teachers were pressured to meet high scores on standardized tests; therefore, they feel they can cover more material when they employ direct instruction where they talk in front of a class, rather than using ICT that requires additional time for planning and identifying appropriate software to match lesson objectives. Indonesian secondary mathematics teachers also need to prepare students to take a standardised test called the 'National Examination'. Students have to pass this test in order to graduate from the secondary school. Consequently, it is widely believed that, in Indonesia, teachers are pressured to prepare their students to pass the test. The standardised test might be one of the possible reasons that led the finding that the teachers had barriers related to students' assessments. Therefore, as Hennessy et al. (2005) argued, there is a need to adapt to the requirements of traditional examinations in order to successfully integrate ICT in the classroom.

In the Indonesian context, the previous studies, which were not specific to mathematics teachers, have identified several barriers such as lack of knowledge and technical support (Marwan, 2008); lack of hardware and software (Quah, 2007); lack of software in Indonesian language (Harendita, 2013). The findings of the present study add a new perspective regarding Indonesian teachers' barriers to ICT integration, namely lack of time to prepare lessons, lack of teacher's confidence and students' assessments not fitting into the ICT integration.

The findings of the present study have several implications. Firstly, the policymaker should take into account teachers' teaching time in order to support ICT integration. Secondly, regarding the finding that assessment is not in line with ICT, ss discussed previously, Indonesian secondary mathematics teachers need to prepare students to take a standardised test called the 'National Examination', and they are pressured to prepare their students to pass this test. Thus, the policymaker needs to adjust the standardized test in order to support the implementation of ICT in the classroom. Finally, as Ertmer and Ottenbreit-Leftwich (2010) argued, the integration of ICT is a complex process and involves a various a number of influencing factors. Therefore, successful ICT integration requires overcoming the factors that hinder the success of this process.

8.5 Research Question 5

Are there significant differences in terms of teachers' knowledge and classroom practices according to their backgrounds?

As mentioned in Section 5.6, this research question was solely investigated using quantitative data. Mann-Whitney and Kruskal-Wallis tests were employed to examine this issue. Dunn's pairwise tests were carried out to enrich the results of Kruskal-Wallis tests.

This research question serves to enhance information about Indonesian secondary mathematics teachers' knowledge and their classroom practices, which have been explored through the first and the second research questions. In addition, it is important to note that teachers' knowledge refers to both knowledge of ICT and knowledge of ICT use in teaching. Key findings regarding this research questions are as follows.

Findings: Quantitative Phase

Teachers' knowledge was statistically significantly different across groups for all background categories (Gender, Teacher Certification, Level of education, Teaching experience and Type of schools). However, teachers' use of ICT was statistically significantly different only across groups in terms of gender and level of education.

Discussion

As previously discussed, teachers' backgrounds investigated in the present study are gender, level of education, teacher certification, teaching experience, and type of school. The aim of this research question was to enrich information about teachers' knowledge and classroom practices regarding their background. Hence, this study would offer comprehensive implications for practices for the Indonesian policymaker by providing information about teachers' knowledge and classroom practices based on the backgrounds of the teachers. Moreover, the findings for this research question gives additional insights into the findings of teachers' knowledge and classroom practices by highlighting the particular aspects of the Indonesian context including the teacher certification programme and type of school.

As presented previously, teachers' knowledge was statistically significantly different across groups for all background categories while teachers' classroom practices were statistically significantly different only across groups in terms of the level of education and gender. The directions of the differences showed that female teachers had stronger knowledge than male teachers. Moreover, teachers with a post-graduate degree had stronger knowledge than teachers who had an undergraduate degree and post-secondary education while non-certificated teachers had stronger knowledge than certificated-teachers. In addition, teachers with teaching experience of 1 to 5 years and 6 to10 years had higher knowledge than the other groups of the teachers had. Finally, MoRA teachers had higher scores for knowledge than MoEC teachers. Teachers' classroom practices in the use of ICT, however, were statistically significantly different only across groups in terms level of education and gender. The result suggested that teachers with a post-graduate degree more frequently used ICT than teachers with an undergraduate degree and teachers with a post-secondary degree. In addition, the results showed female teachers had higher score for classroom practices than male teachers. The following sections discuss the finding based on the teachers' characteristics including gender, teaching experience, level of education, teacher certification and the type of schools.

Gender

Since the introduction of computers, ICT-related activities have been viewed as a 'male domain' (Panteli, Stack, & Ramsay, 1999). For instance, Tezci (2010) and Vitanova, Atanasova-Pachemska, Iliev and Pachemska (2015) found that male teachers had higher scores than female teachers in terms of ICT competence. Thirty years ago, Loyd and Gressard (1986) found male teachers to be more confident about computers compared to female teachers. In addition, Markauskaite (2006) also reported that male teachers' technical ICT capabilities were significantly higher than female teachers' capabilities.

However, the domination of male teachers over female teachers in the use of ICT is no longer valid. It has has been revealed by King, Bond and Blandford (2002) and North and Noyes (2002) that computing should no longer be viewed as a male domain since it has become an ordinary part of the workplace setting. The findings of the present study echo this view by showing that female teachers had a higher knowledge and classroom practice than male teachers. Thi is in accordance with a study in Turkey conducted by Altun (2013) that found that female teachers had higher scores than their male colleagues in terms of Technological Content Knowledge.

It is important to note, however, that there is a limitation to draw a firm conclusion about this finding since, in terms of gender, the participants of the survey did not represent the population well (see Section 6.1.1). Yet, the difference between the percentage of the population and the percentage of the sample was not too significant. Hence, the finding is still eloquent in supporting the view that computing in no longer a male domain, particularly ampong male mathematics teachers.

Therefore, in terms of the implications for practice, the findings of this study suggest that the Indonesian government needs to pay attention to male teachers in relation to the development of teachers' knowledge in the use of ICT in the classroom. At the same time, of course, the policymaker should not neglect female teachers' need for professional development on ICT integration.

Years of teaching experiences

The findings showed that there were statistically significant differences in teachers' knowledge at least on pair of groups. Dunn's pairwise tests showed a significant difference between the groups of the teachers. Teachers who had teaching experience for 6-10 years had higher level of knowledge than 10-20 years and 21-30 years groups. Therefore, overall, it can be concluded that teachers with fewer the number of years of teaching experience have more knowledge of ICT and knowledge of ICT use in teaching. However, regarding teacher classroom practices, the results show that median scores of teachers' ICT use were not statistically significantly different across the groups. This indicates that having high level of knowledge does not guarantee the teachers will frequently use ICT in the classroom.

This finding is in line with the previous studies in different countries such as Buabeng-Andoh (2012) in Ghana, Wells and Lewis (2006) in the. U.S., Vitanova et al. (2015) in Macedonia and Tezci (2010) in Turkey which reported that the less number of years of experiences, the higher teachers' knowledge of ICT teachers have.

It is often considered that greater experience in teaching is important to develop the skills required for effective teaching (see OECD, 2005). However, this common view is not in accordance with ICT integration as teachers with fewer years of experience had higher knowledge in using ICT than teachers with more teaching experience. In the Indonesian context, I think one of the reasons is that most Indonesian teachers are digital migrants (see Harendita, 2013). It is widely known that teachers' teaching experience is in line with their age. Thus, it is sound to conclude that the majority of the digital migrants are teachers with long years of teaching experience.

The data showed that 66.1% of participants had teaching experience of 10 years or more. This study suggests that the Indonesian policymaker should focus its attention on improving knowledge of those teachers in order to support them to successfully use of ICT in the classroom. As digital migrants, those teachers need to improve not only their knowledge of ICT use in teaching but also their knowledge of ICT.

Level of education

The findings of the present study suggested that teachers with different levels of education had statistically significant differences in terms of teachers' knowledge and classroom practices in the use of ICT. Dunn's pairwise tests showed very strong evidence of a difference of knowledge between the group of tachers who had a post-graduate degree and an under graduate degree and between teachers who had post-graduate degree and teachers who had post-secondary degree. Moreover, in terms of classroom practices, there was also a strong evidence of difference between the group of the teachers who had post-secondary degree and post-graduate degree. Therefore, it can be concluded that teacher level of education plays important role in teacher knowledge and classroom practices in the use of ICT. This is in agreement with the typical view that teachers' education levels are regarded as one of the characteristics that are related to teacher quality (see Zhang, 2008).

In Indonesia, an increase in levels of teachers' education has become one of the essential targets of the teacher reform. It involves the upgrading of teachers' level of education from the post-secondary to the undergraduate degree and from the undergraduate degree to the post-graduate degree. It seems this reform has an advantage in supporting the integration of ICT. For instance, in the interviews, several teachers said that they learned how to use ICT in the classroom when they did their post-graduate studies. This indicates that some teachers might not have had a chance to learn about ICT when they did a post-secondary study or an undergraduate study as they did it a long time ago. Therefore, by pursuing study to post-graduate level, they most likely would obtain this opportunity.

The findings of this study suggested that the higher of education the teachers had the higher knowledge and classroom practices they had regarding the use of

ICT. Hence, this reveals that upgrading teachers' levels of education has played an important role in the integration of ICT in secondary mathematics classrooms in Indonesia.

Teachers' certification

In Indonesian, teacher certification is a priority of the teacher reform programmes aiming to enhance education, particularly in terms of teachers' competence in teaching and learning. As previously mentioned in Section 2.5, the teacher certification programme was initiated in 2005 and it is still running until now.

The findings of this study showed that there was a statistically significant difference in teachers' knowledge between certificated teachers and non-certificated teachers whereby non-certificated teachers had stronger knowledge than certificated teachers. This is an anomaly as one of the aims of the certification programme is to improve teacher quality. One of the possible reasons for this circumstance is that the teacher's certification programme was based on the number of years of teaching experience and teachers with many years of services have priority over novice teachers for certification. Thus, most of the teachers with fewer the number of years of teaching experience, who typically had stronger ICT-related knowledge, have not been certified yet.

This finding for the present study indicates that the policymaker's efforts to improve teachers' knowledge and classroom practice through the teacher certification programme has not had a significant impact on teacher knowledge of ICT and teacher knowledge of ICT use in teaching. This, to some extent, supports Cerdan-Infantes et al. (2013) and Ree and Jaitze (2016) who reported that the teacher certification programme in Indonesia contributes little to the improvement of national education quality.

Type of school

As discussed in Chapter 2, the education system in Indonesia has two main sub-systems. The first one is under the management of the Ministry of Education and Culture (MoEC) while the second one, religious education, is under the management of the Ministry of Religious Affairs (MoRA). Both systems use the same core curriculum for general subjects such as mathematics and science (Kingham & Parsons, 2013).

In terms of teacher knowledge, the findings showed MoRA teachers had higher scores of knowledge than MoEC teachers. This finding is quite surprising since religious schools are known to receive insufficient funding to support their programmes (see Ghozali, Mudjahid, & Hayati, 2013). Hence, it is widely believed in Indonesia that MoEC schools perform better than MoRA schools. However, in terms of teachers' knowledge of ICT and knowledge of ICT use in teaching, the findings of this study adds a new perspective to views of teachers' competencies from both the ministries.

As a final thought, it is interesting that teachers' knowledge was statistically significantly different across the groups for all teachers' backgrounds yet teachers' classroom practices were only statistically significantly different in across categories of teachers' education levels and gender. This is one of the indications that having knowledge does not guarantee that teachers will use ICT frequently since there are many factors that might hinder them from putting their knowledge into practice. In the case of the teacher certification, for instance, non-certified teachers with higher knowledge did not show their use of ICT to be statistically significantly higher than certified teachers. As teachers with less the number of years of teaching experience, non-certified teachers might be dealing with many other challenges such as lack of confidence.

8.6 Summary

This chapter has presented the integration of quantitative and qualitative findings, interpreted and discussed them based on the literature. The findings have revealed that Indonesian secondary mathematics teachers have insufficient knowledge of both ICT and ICT use in teaching. Moreover, the findings have also suggested that teachers have not yet achieved a high level of ICT use as most of them still used it to extend existing classroom practices. This study indicates that Indonesian secondary mathematics teachers need to enhance their knowledge of ICT as well as improving their knowledge of ICT use in teaching. The improvement of teachers' knowledge of ICT use in teaching becomes more important since it has a stronger positive correlation with teachers' classroom practices. Having knowledge of ICT and knowledge of ICT use in teaching does not guarantee Indonesian secondary mathematics teachers will implement ICT in the classroom since they still faced other barriers such as teachers' lack of confidence, teachers' lack of time to prepare ICT-based lessons, and students' assessments not supporting ICT integration.

Chapter 8

The next chapter describes the summary of the study as well as the significance of the study and contributions to knowledge. It also provides implication for practices, limitations of the study and recommendations for future research.

Chapter 9 Conclusion

In this last chapter, the summary of the present study including research design and findings are presented. The significance of the study and contributions to knowledge are also addressed in this chapter, and it is then followed by elaborating implications for practices. In the next section, limitations of the study were highlighted. Finally, the chapter ends by presenting recommendations for future research.

9.1 Summary

The aims of this study were to investigate Indonesian teachers' knowledge and classroom practices in the use of ICT in secondary mathematics classrooms as well as to examine the relationship between teachers' knowledge and their classroom practices. In addition, this study sought to reveal barriers faced by teachers to using ICT in their classrooms. By employing a sequential mixed methods approach, the quantitative survey was conducted in the first phase, and followed by obtaining qualitative data from classroom observations and semi-structured interviews. The study was conducted in one of Indonesia's province, Aceh province. In total, 341 secondary mathematics teachers participated in the quantitative phase and 10 of them involved in the qualitatitive phase.

Futhermore, the aims of the study were addressed by the following research questions:

1. What knowledge do Indonesian secondary mathematics teachers have about ICT and its use in teaching?
2. How do Indonesian secondary mathematics teachers use ICT in their teaching practices?
3. What is the relationship between teachers' knowledge and classroom practices in the use of ICT in mathematics teaching?
4. What barriers do Indonesian secondary mathematics teachers face in the use of ICT in the classroom?
5. Are there significant differences in terms of teachers' knowledge and classroom practices according to their backgrounds?

The empirical findings reveal that, overall, Indonesian secondary mathematics teachers had insufficient knowledge of both ICT and ICT use in teaching. The findings suggest that female teachers overall had a stronger knowledge than male teachers. Moreover, teachers who hold a post-graduate degree had stronger knowledge than teachers who hold an undergraduate degree and a post-secondary degree. Non-certificated teachers had a higher level of knowledge than certificated teacher. In addition, teachers who had been teaching for 1 to 5 years and 6 to 10 years had a higher level of knowledge than the other teachers.

In relation to teachers' classroom practices in the use of ICT, 67% of Indonesian mathematics teachers use ICT in their teaching at least once. The majority of the teachers had been using it for 1 to 3 years and in 21% to 50% of their mathematics lessons. The most common use of hardware by the teachers was computers/laptops. The teachers used general software (e.g., PowerPoint) more frequently than they used mathematical software while Dynamic Mathematics Software was the most common use of mathematical software in mathematics classrooms. Furthermore, the most common use of ICT by the teachers was for doing arithmetic and drawing graphs as well as presenting contents of mathematics and giving classroom instruction. Geometry was the most commonly taught topics using ICT and there was no significant difference in the frequency use of teacher-centred approaches and student-centred approaches. In terms of teachers' backgrounds, teachers' use of ICT was statistically significantly different only across groups in terms of gender and level of education in which teachers with a post-graduate degree more frequently used ICT than teachers with an undergraduate degree and teachers with a post-secondary degree, and female teachers more frequenly used ICT than male teacher.

Findings of the qualitative data showed that, at the subject level, the majority of the secondary mathematics teachers still did not value ICT for rebalancing emphasis on skills, concepts and applications for mathematics and did not change their approaches to mathematics topics. Moreover, there was no teacher who took the opportunity to exploit the contrast of ideal and machine mathematics. Furthermore, at the classroom level, the majority of the teachers did not change their didactic contract while over half of the teachers changed their classroom social dynamics. In relation to the task level, 'exploring regularity and variation', 'linking representation', and 'learning pen –and- paper skills' were the three most dominant types of the tasks set by the teachers. It can be concluded that most of the mathematics teachers still valued ICT as a tool for students's drill and practice while a small number of the participants valued the digital technology as a tool for facilitating of students' knowledge construction. Hence, the teachers had not yet achieved a high level of ICT use since most of them still used it for an established form of classroom practices.

The findings of the study suggested that both teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching had a positive correlation with teachers' classroom practices using ICT. It is important to highlight that the relationship between teachers' knowledge of ICT use in teaching and their classroom practices was stronger than the relationship between teachers' knowledge of ICT and their classroom practices. This strong correlation also appeared in the qualitative phase where the relationship between teachers' knowledge of ICT and classroom practices was apparent at the subject level and the task level while the relationship between teachers' knowledge of ICT use in teaching and classroom practices was apparent at the classroom level, the subject level and the task level.

Finally, the findings showed that, along with insuficient knowledge, the teachers also faced other barriers to implementing ICT in the classroom. It revealed that teachers' lack of time to prepare ICT-based lessons was the main barrier at the school level while teachers' lack of confidence was the main barrier at the teacher level. In addition, students' assessmens not in line wit the integration of ICT was the main barrier at the curriculum level.

9.2 Significance of the Study and Contribution to Knowledge

The present study has several significant outcomes. Firstly, regarding the research instrument, this study has provided information related to reliability and validity of the scale used to examine teachers' knowledge, classroom practices, and barriers to the use of ICT. The questionnaire items on teachers' knowledge in the use of ICT in teaching were adapted from Handal et al. (2013) and Schmidt et al. (2009). Moreover, the items on teachers' classroom practices in the use of ICT were developed based on the pedagogical map of MAS (Pierce & Stacey, 2010) as well as some items which were adapted from Law et al. (2008). In addition, the items for the barrier scale were developed based on Hew and Brush's (2006) and Thomas' (2006) studies.

Secondly, with regard to teachers' knowledge, this study adapted the TPACK framework (Mishra & Koehler, 2006) to investigate Indonesian secondary mathematics teachers' knowledge of ICT use in teaching. In mathematics education, the TPCK model has been used to explore how teachers articulate content, pedagogy, and technology and to enrich the discourse on using ICTs within mathematics subjects (e.g., Grandgenett, 2008; Johnston-Wilder & Pimm, 2004; Niess, 2005; Niess et al., 2009; Polly & Barbour, 2009). Moreover, Handal et al. (2013) claim that their study was the first attempt to conduct an empirical study to apply the TPACK framework in secondary mathematics education through a questionnaire survey. Therefore, the present study enhances the literature regarding the application of the TPACK framework in an empirical study through an investigation of secondary mathematics teachers.

Thirdly, as noted earlier, the findings of this study provide an understanding of ways in which ICT is currently being used by Indonesian secondary mathematics teachers by making use of the *Pedagogical Map for Mathematics Analysis Software* (Pierce & Stacey, 2010). The present study portrays not only the types of ICT but also pedagogical activities enacted when the digital tools are integrated into the classroom. This was in contrast to the previous studies on the use of ICT in Indonesian schools, which only focused on examining types of ICT being used and/or frequency of use (KOMINFO, 2011; Mullis et al., 2008; Mullis et al., 2011; Rimilda, 2015). Therefore, the findings add to the literature, particularly in the field of ICT in mathematics education in Indonesia. This study also amplifies the literature showing that direct instructions along with student drill and practices involving ICT are still dominant practices in secondary mathematics classrooms. This indicates that behaviourism-oriented classroom practices still dominated the integration of ICT in Indonesian secondary classroom.

Fourthly, in relation to teachers' barriers, this study examined barriers at the teacher level, the school level and the curriculum level. It presents a relatively comprehensive picture of barriers faced by Indonesian secondary mathematics teachers in the use ICT in their classrooms. The findings of this study contribute to the literature which demonstrates that, in most of the developing countries, the main barriers to ICT integration are due to lack of ICT infrastructure in schools. On the other hand, the present study revealed other barriers, namely teachers' lack of time to prepare ICT based lessons, teachers' lack of confidence, and students' assessments not supporting the ICT integration.

Fifth, the present study provides valuable information about secondary mathematics teachers' knowledge, classroom practices, and barriers to the use of ICT in a time when the Indonesian government has taken a major step towards teacher reform and the integration of ICT in the classroom. The findings of this study may benefit the Indonesian Ministry of Education and Culture, the Indonesian Ministry of Religious Affairs and education stockholders in Indonesia. They will become more knowledgeable about the current states of these issues that should guide and motivate the policymaker to take suitable action to enhance the integration of ICT in secondary mathematics classrooms.

Finally, as discussed in the conceptual framework chapter, this study adapted the TPACK model (Mishra & Koehler, 2006) to explore teachers' knowledge of ICT use in teaching and the Pedagogical Map of Mathematics Analysis Software (Pierce & Stacey, 2010) to describe teachers' classroom practices in the use of ICT. The present study contributes to knowledge in examining the link between teachers' knowledge and classroom practices in the use of ICT in secondary mathematics classrooms. As a contribution to knowledge, this study demonstrates that mathematics teachers' knowledge has a significant positive correlation with the integration of ICT in mathematics teaching. It is important to highlight that this study revealed that the relationship between teachers' knowledge of ICT use in teaching and teachers' classroom practices is stronger than the relationship between teachers' knowledge of ICT and their classroom practices. Hence, this finding adds this insight to the literature in the field of ICT in mathematics education.

9.3 Implications for Practice

At the practice level, it was hoped that the results of this study can help offer evidence-based recommendations for enhancing the integration of ICT in Indonesian secondary mathematics classrooms. The findings of the present study have several practical implications for those who are responsible for the integration of ICT in Indonesia. Overall, it is clear that the findings showed that Indonesian secondary mathematics teachers had insufficient knowledge of both ICT and ICT use in teaching. Moreover, the findings also suggested that the teachers faced lack of time to prepare ICT based lessons, lack of confidence, and students' assessments which do not fit with ICT integration. Hence, teachers have not yet achieved a high level of ICT use in teaching as most of them still use it to extend existing classroom practices. Therefore, to acquire the successful implementation of ICT in the secondary mathematics classrooms in Indonesia, both teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching must both be improved as well as overcoming the identified barriers. Futhermore, this study highlights areas that need to receive more attention.

Firstly, the findings of the study showed that Indonesian secondary mathematics teachers have insuficient knowledge of ICT and knowledge of ICT use in teaching. It also revealed that there was a significant positive correlation between teachers' knowledge and their classroom practices in the use of ICT. This correlation indicates that Indonesian secondary mathematics teachers need an appropriate level of knowledge of ICT and knowledge of the use of ICT in teaching in order to successfully integrate ICT in the classroom. The findings also indicate that teachers need knowledge of ICT use in teaching more than knowledge of ICT. Therefore, to develop teachers' knowledge, it is recommended that teachers should be trained not only on technical aspects but also pedagogical aspects of ICT use.

Secondly, the findings showed that the level of mathematical software (e.g., DMS, DGS, CAS) knowledge and use of this type of software are lower than the level of their knowledge and use of general software (e.g., PowerPoint). This finding also revealed that teachers more frequently used the presentation software (e.g., Ms PowerPoint) than they used mathematical software. Therefore, training courses on the use of specific mathematical software such as Dynamic Geometry Software, CAS, and Statistical Software should be provided for secondary mathematics teachers. When it comes to a comparison of mathematical software, the finding indicates that teachers need to improve their knowledge of CAS and Statistical Software as the findings showed teachers had a lower knowledge and use of these software compared to other types of mathematical software.

Thirdly, along with the need to enhance teachers' knowledge, the Indonesian government should also take into account the following aspects. Indonesian secondary mathematics teachers have limited time to prepare lessons as the policymaker requires certificated teachers to teach at least 24 hours per week. It is important to review this policy in order to allow teachers more time for teaching preparation including preparing ICT-based lessons. Also, the policymaker should re-evaluate the standardised test called the 'National Examination' as this type of test is not fitted to the integration of ICT in the classroom.

Finally, as mentioned previously, this study also sought to identify differences in teachers' knowledge and the use of ICT based on their background. The findings of this study indicate that there are groups of teachers that need to receive more attention from the policymaker as they had insufficient knowledge and/or limited use of ICT use in their classrooms. These groups are male teachers, certified teachers, teachers with an undergraduate and a post-secondary level of education, and teachers with long years of teaching experience. Of course, paying more attention to these groups of teachers does not mean the policymaker should leave the other groups without improvement.

9.4 Limitations of the Study

This study was subject to several limitations. Firstly, in terms of the research design, as it mentioned in Section 5-10, the population of this study was only mathematics teachers in Aceh province. Therefore, this may limit the generalisability of the study findings to all Indonesian provinces since the findings can only be generalised to the population. Moreover, the classroom observations were conducted only once for each participant. This may have led to incomplete pictures of classroom practices.

Secondly, as discussed in Section 5.6, there was a potential bias since some questionnaires were not directly distributed to the participants instead they received the questionnaires from their colleagues. However, it is hoped that this potential bias does not affect the findings of the study as targeted schools had been randomly selected before the distribution of the questionnaires.

Finally, observer effects may occur in the observed classess since the participants were aware that their behaviours were being observed. However, to avoid this bias, the classroom observation data were triangulated with the interview data. In addition, the number of participants in the qualitative phase did not statisfy the ideal one as one of the participants withdrew from the study and another one was not qualified to participate in the qualitative phase.

9.5 Recommendations for Future Research

This research raises several issues that could be investigated in the future. Firstly, the present study relied on random samples drawn from one province in Indonesia. Hence, research investigating Indonesian mathematics teachers' knowledge, classroom practices and barriers to the use of ICT across a wider and more diverse selection of provinces in the country is necessary in order to gain a complete picture of these issues throughout Indonesia.

Secondly, in the qualitative phase, classroom observations were taken place in only one lesson for each participant. Thus, the future studies should employ a longitudinal approach, observing the classroom practices for several times during one semester or one academic year. Such observations may give a more complete picture of Indonesian teachers' actual classroom practices in the use of ICT.

Thirdly, this research investigated all topics related to senior secondary mathematics which may lead to a lack of depth in the investigation. Therefore, the future studies should focus on knowledge and classroom practice in the use of ICT for teaching specific topics of mathematics. Such studies would provide and in-depth understanding of these issues.

Fourthly, in relation to teachers' knowledge, the further study needs to employed research instruments that can investigate teachers' actual knowledge through, for example, a task-based interview for specific content on mathematics. In terms of teachers' classroom practices, this research mainly focused on teachers. Therefore, the future studies should also look through students' views on the use of ICT in the classroom, by including perceptions from students' points of views. Such a study would provide rich data to produce rich results to enhance the findings.

Finally, this study showed the strong relationship between teachers' knowledge and their classroom practices in the use of ICT. Yet, as mentioned previously, the ultimate goal of integration of ICT in the classroom is to improve students' learning. Consequently, it needs further study to examine the relationship and/or impact of teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching on students' learning and achievements in mathematics. Moreover, as the findings of the study showed, integration of ICT has emerged in Indonesia's secondary mathematics classrooms. Therefore, it needs a further large-scale study to examine impacts of the ICT integration on students' learning experiences and outcomes.

Appendices

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Appendix A : Participant Recruitmen Letters

A.1 Consent Form

CONSENT FORM
(Classroom Observations and Interview)

Study title: Investigating Indonesian Teachers' Knowledge and Use of ICT in Mathematics Teaching.
Researcher name: Mailizar Mailizar / *Student number*: 26471388
Ethics reference: 18991

Please initial the boxes if you agree with the statements:

I have read and understood the classroom observation and interview information sheet (28th of January 2016 version 1) and this document, and have had the opportunity to ask questions about the study.	☐
I agree to take part in this research project and agree for my data to be recorded and used for the purpose of this study	☐
I understand that my responses will be anonymised in reports of the research	☐
I understand my participation is voluntary and I may withdraw at any time without my legal rights being affected	☐

Data Protection

I understand that information collected about me during my participation in this study will be stored on a password protected computer and that this information will only be used for the purpose of this study

Thank you for your time and cooperation

Name of participant (print name) ....
Signature of participant...
Date...

A.2 Participant Information Sheet

Participant Information Sheet

(Observations and Interviews)

Study Title: Investigating Indonesian Teachers' Knowledge and Use of ICT in Mathematics Teaching

Researcher: Mailizar Mailizar **Ethics number**: 18991

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?

I am a PhD research student at the University of Southampton, the UK. The research project is part of my PhD degree thesis. It explores the integration of ICT in secondary mathematics classrooms in Indonesia. The main aim of this study is to investigate the current Indonesian teachers' knowledge and classroom practice of the ICT use in secondary mathematics teaching. This study also intends to figure out barriers to the ICT integration. Along with these aims, this study also sets out to explore the relationship between teacher knowledge and the use of ICT in mathematics teaching.

Why have I been chosen?

The participants in this research project are secondary mathematics teachers in Aceh Province, Indonesia. Your voluntary participation is highly valuable to collecting the data needed for this study.

What will happen to me if I take part?

If you agree to take part, we will arrange for a time and a place of your convenience within your school. You will be observed in one lesson of your teaching which takes about 90-100 minutes (depends on the length of your lesson), and then it is followed up by a semi-structured interview for up 40 minutes. The observation will be recorded in written notes while the interview will be audio recorded to be analysed later.

Are there any benefits in my taking part?

You might find this study interesting and makes you reflect and think consciously about your knowledge, practice and barriers to the integration of ICT in the classroom. Moreover, this study can be a medium where you can express your opinions. The results of this study will benefit teachers, the Indonesia government and researchers in secondary education in Indonesia.

Are there any risks involved?

There are no real risks to being involved in this research.

Will my participation be confidential?

Appendix A.2

All the information obtained in this study will be kept strictly confidential. The information gathered will be kept on a password protected computer and will not be shared with anyone, except the research supervisors. This information will be later destroyed when it is no longer needed. Pseudonyms will be used to hide the identity of participants and any descriptions which may make the identifiable will be altered. Information will be kept safe in line with the UK Data Protection Act and University of Southampton policy.

What happens if I change my mind?

Participation in this study is voluntary. You can withdraw from this study at any time.

What happens if something goes wrong?

If you have any concerns or complaints about this study, you may contact:

Head of Research Governance, rginfo@soton.ac.uk, phone +44 (0) 238 595058

Where can I get more information?

If you have any questions about the study, you can contact me using the following details:

Mailizar Mailizar

Southampton Education School

University of Southampton

Email: m.mailizar@soton.ac.uk or mailizar.af@gmail.com

Phone: Indonesia: 08126948265 UK: +44 (0) 7522102060

Supervisor: Professor Lianghuo Fan, L.Fan@soton.ac.uk, phone +44 (0)23 8059 34

A.3 University of Southampton Ethical Approval Letter

Your Ethics Submission (Ethics ID:18991) has been reviewed and approved

ERGO [ergo@soton.ac.uk]
Submission Number: 18991
Submission Name: Investigating Indonesian Teachers' Knowledge and Use of ICT in Mathematics
Teaching
This is email is to let you know your submission was approved by the Ethics Committee.
You can begin your research unless you are still awaiting specific Health and Safety approval (e.g.
for a Genetic or Biological Materials Risk Assessment)
Comments
1.Good luck with your study.
Click here to view your submission

ERGO : Ethics and Research Governance Online
http://www.ergo.soton.ac.uk

DO NOT REPLY TO THIS EMAIL
Sent: Tuesday, February 23, 2016 1:20 PM

To: Mailizar

A.4 Indonesian Government Research Approval Letter

PEMERINTAH ACEH
DINAS PENDIDIKAN
Jalan Tgk. H. Mohd Daud Beureueh Nomor 22 Banda Aceh Kode Pos 23121
Telepon (0651) 22620, Faks (0651) 32386
Website : disdik.acehprov.go.id, Email : disdik@acehprov.go.id

Banda Aceh, 10 Februari 2016

Nomor : 421.3 /D.I/ 373 /2016
Sifat : Biasa
Lampiran : -
Hal : ***Permohonan Penelitian***

Yang Terhormat,
Kepala Pusat Penelitian Pendidikan
Matematika, Sains dan Kesehatan
di -
Tempat

Sehubungan dengan surat Saudara tanggal 06 Februari 2016 hal Permohonan Penelitian Program Doktor dengan judul *"Investigating Indonesian Teachers' Knowledge and Use of ICT in Mathematics Teaching"* tujuan utama dari penelitian ini adalah untuk mengetahui pengetahuan dan kegiatan pembelajaran guru dalam menggunakan ICT di Sekolah Menengah Atas (SMA) di Provinsi Aceh. Mengingat kegiatan tersebut akan bermanfaat untuk guru SMA, maka untuk maksud tersebut kami sampaikan beberapa hal sebagai berikut :

1. Kami sangat mendukung/membantu Penelitian Saudara Meilizar di SMA Kabupaten/Kota se – Aceh.
2. Untuk kelancaran/izin pelaksanaan penelitian tersebut kami mohon Saudara berkoordinasi dengan Dinas Pendidikan Kabupaten/Kota se – Aceh.
3. Semua biaya yang dikeluarkan untuk kegiatan tersebut, tidak dibebankan kepada Sekolah.

Demikian kami sampaikan, atas kerjasamanya kami haturkan terimakasih.

KEPALA DINAS PENDIDIKAN

DINAS PENDIDIKAN

Drs. HASANUDDIN DARJO. MM
PEMBINA UTAMA MADYA
NIP. 19580917 198403 1 003

Tembusan :
1. Dinas Pendidikan Kabupaten/Kota se Aceh;
2. Arsip.

Appendix BQuantitative Instruments

B.1 Questionnaire in English

Mathematics Teacher Questionnaire

This questionnaire is designed as part of my PhD research project to investigate what Indonesian secondary mathematics teachers know about ICT and its use in teaching, how they use ICT in lessons, and what barriers to the use of ICT.

Information About this questionnaire

The term 'ICT' refers to computers, calculators, tablets or other handheld devices, software and the internet or online resource that are potentially used for teaching and learning mathematics.

This questionnaire comprises the following parts:

- Part I : Teachers' demographic characteristic
- Part II : Teachers' knowledge of ICT and its use in teaching
- Part III : Teachers' classroom practices
- Part IV : Teachers' barriers to use ICT

Guideline

- It takes approximately 20 minutes to complete this questionnaire.
- The questionnaire is anonymous, where participants do not have to write their names or any other information that may enable anyone to identify them. Thus, the data collected will not be accessible to anyone, except the researcher and the supervisors.
- Guidelines of answering the questions are typed in *italic* form.
- Please tick in a box as shown ☐
- Feel free to add additional information or comments as you may feel appropriate.
- If you have any question or concern on this questionnaire, feel free to contact me through email: m.mailizar@soton.ac.uk or phone at 08126948265

Your assistance in taking some of your valuable time to fill it in is much appreciated and I thank you in advance for doing so.

Researcher

M. Mailizar

Part I: Background Information

Personal Information (*Please tick one box)*

1. What is your gender?
   - Female ☐
   - Male ☐

2. What is your age?
   - 30 years or less ☐
   - 31-35 years ☐
   - 36-45 years ☐
   - 46-55 years ☐
   - More than 55 years ☐

3. Including this school year, how long have you been teaching (at any school)?
   - Less than a year ☐
   - 1-5 years ☐
   - 6-10 years ☐
   - 11- 20 years ☐
   - 21-30 years ☐
   - More than 30 years ☐

Education Background (*Please tick one box)*

4. Do you have a bachelor degree in mathematics education or mathematics?
   - No ☐
   - Degree in Mathematics Education ☐
   - Degree in Mathematics ☐

5. Do you have teaching license or certificate? ☐ No ☐ Yes

6. What is your highest level of education?
   - Post-secondary education (e.g., teacher college) ☐
   - Bachelor's degree ☐
   - Master's degree or above ☐

Information about your school

7. What type of school do you teach? ☐MoEC School ☐ MoRA School

   District/City (*Fill in*): ………………………………………………………………………………

8. Which grade do you teach (*You may tick more than one box*)?

   ☐ Grade 12th ☐ Grade 11th ☐ Grade 10th

9. What is the average number of students in your class? (*Fill in)* …… students

Professional Development

10. In the last two years, have you participated in any ICT courses related to the use of ICT? (*If NO, Please go to question **12***)	□Yes	□ No

11. Have you undertaken professional development in the following area? (*You may tick more than one)*	Yes	No
a. Course on the integration of ICT in teaching	□	□
b. Course on the use of the Internet		
c. Course on general software (e.g. MS PowerPoint. Spreadsheet, etc.)	□	□
d. Course on mathematics specific software or application (e.g. *GeoGebra, Geometers' Sketchpad, Autograph, Cabri, etc.*)	□	□
e. Couse on the use of graphic/scientific calculator	□	□
f. Other (Please specify ……………………………………………)	□	□

Part II: Teachers' Self Perceived Knowledge of ICT and Its Use in Teaching

12. Please indicate your response to the following statements

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. I know how to operate Graphing calculator	□5	□4	□3	□2	□1
b. I know how to operate Tablet/Mobile Device	□5	□4	□3	□2	□1
c. I know how to operate Computer/Laptop	□5	□4	□3	□2	□1

13. Please indicate your response to the following statements

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. I know how to use word processor software(e.g. Ms Word)	□5	□4	□3	□2	□1
b. I know how to use presentation software (e.g. Ms PowerPoint)	□5	□4	□3	□2	□1
c. I know how to use online presentation software (e.g. Prezi)	□5	□4	□3	□2	□1
d. I know how to use Spreadsheet software (e.g., Ms Excel)	□5	□4	□3	□2	□1
e. I know how to use mind mapping software (e.g. Inspiration)	□5	□4	□3	□2	□1
f. I know how to use animation software (e.g. Macromedia Flash)	□5	□4	□3	□2	□1
g. I know how to use three-dimensional visualisation software (e.g., SketchUp)	□5	□4	□3	□2	□1

14. Please indicate your response to the following statements					
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. I know how to use software Maple	□5	□4	□3	□2	□1
b. I know how to use software Mathematica	□5	□4	□3	□2	□1
c. I know how to use software Maxima	□5	□4	□3	□2	□1
d. I know how to use software Geometer's Sketchpad	□5	□4	□3	□2	□1
e. I know how to use software Cabri Geometry	□5	□4	□3	□2	□1
f. I know how to use software GeoGebra	□5	□4	□3	□2	□1
g. I know how to use software Autograph	□5	□4	□3	□2	□1
h. I know how to use software Tinkerplots	□5	□4	□3	□2	□1
i. I know how to use software Fathom	□5	□4	□3	□2	□1
j. I know how to use software SPSS	□5	□4	□3	□2	□1

15. Please indicate your response to the following statements					
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. I know how to use Web based applications (e.g., *rumah belajar*, *m-edukasi, Youtube, and KhanAcademy*) in teaching	□5	□4	□3	□2	□1
b. I know how to use Learning management system (e.g. Blackboard, Moodle) in teaching	□5	□4	□3	□2	□1

16. Please indicate your response to the following statements					
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. I can use ICT to represent mathematical ideas.	□5	□4	□3	□2	□1
b. I can use ICT to communicate mathematical processes.	□5	□4	□3	□2	□1
c. I can use ICT to solve mathematical problems	□5	□4	□3	□2	□1
d. I can use ICT to explore mathematical ideas	□5	□4	□3	□2	□1

17. Please indicate your response to the following statements					
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. I can use ICT in teaching by employing direct instruction	□5	□4	□3	□2	□1
b. I can use ICT in teaching by employing inquiry based learning	□5	□4	□3	□2	□1
c. I can use ICT in teaching by employing project based learning	□5	□4	□3	□2	□1
d. I can use ICT in teaching by employing discovery learning	□5	□4	□3	□2	□1
e. I can use ICT in teaching by employing collaborative learning	□5	□4	□3	□2	□1

18. Please indicate your response to the following statements					
	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. I can use ICT to teach topics of mathematics that are better learned when employing specific teaching approaches	□5	□4	□3	□2	□1
b. I can use strategies that combine mathematical content, ICT and teaching approaches to support students' understandings as they are learning mathematics	□5	□4	□3	□2	□1
c. I can use ICT in teaching that enhances mathematical content and how it taught	□5	□4	□3	□2	□1
d. I can use ICT to incorporate authentic tasks in teaching of mathematics through project based learning	□5	□4	□3	□2	□1
e. I can use ICT to teach students to develop their mathematics problem solving through inquiry-based learning	□5	□4	□3	□2	□1

Part III: Mathematics Teacher's use of ICT

19. Have you used ICT in your teaching at least once? (*if the answer is 'NO', please go to question 31 about barriers to the use of ICT)* □ Yes □No

20. How many years have you been using ICT in teaching?

- Less than 1 year □
- Between 1 to 3 years □
- Between 4 to 6 years □

- More than 6 years ☐

21. What percentage of your teaching was used ICT the past 12 months?

- More than 70% of all lessons ☐
- 51 to 70% of all lessons ☐
- 31 to 50% of all lessons ☐
- 21 to 30% of all lessons ☐
- 11 to 20 % of all lessons ☐
- Less than 10% of all lessons ☐

22. In the last 12 months, how often did you use the following hardware in your teaching?					
	Never	Rarely	Sometimes	Often	Always
a. I use a calculator (e.g. Scientific and Graphing calculator) in teaching	□1	□2	□3	□4	□5
b. I use a computer/laptop in teaching	□1	□2	□3	□4	□5
c. I use a tablet or a handheld device (IPad, tab, mobile phone, etc.) in teaching	□1	□2	□3	□4	□5

23. In the last 12 months, how often did you use the following general software in your teaching?					
	Never	Rarely	Sometimes	Often	Always
a. I use Word Processor (e.g. Microsoft Word) in teaching	□1	□2	□3	□4	□5
b. I use Presentations software (e.g. *PowerPoint*) in teaching	□1	□2	□3	□4	□5
c. I use Spreadsheet software (e.g. *Microsoft Excel*) in teaching	□1	□2	□3	□4	□5
d. I used Mind Mapping Software (e.g. Inspiration) in teaching	□1	□2	□3	□4	□5
e. I used 3D Visualisation Software (e.g. SketchUp) in teaching	□1	□2	□3	□4	□5

24. In the last 12 months, how often did you use the following specific mathematics software in your teaching?					
	Never	Rarely	Sometimes	Often	Always
A. I use Computer Algebra System (e.g. *Maple, Mathematica*) in teaching	□1	□2	□3	□4	□5
B. I use Dynamic Mathematics and Dynamic Geometry Software (e.g. Geogebra, *Geometer's Sketchpad, Autohraph, Cabri*) in teaching	□1	□2	□3	□4	□5
C. I use Statistical Software (e.g. *Tinkerplots and Fathom)* in teaching	□1	□2	□3	□4	□5

Appendix B.1

25. In the last 12 months, how often did you use of the following web based application in your teaching?						
		Never	Rarely	Sometimes	Often	Always
a.	I use Web based applications (e.g *rumah belajar*, *m-edukasi, hotmath, SMILE, Youtube, KhanAcademy*) in teaching	□1	□2	□3	□4	□5
b.	I use Learning management system (e.g. Blackboard, Moodle) in teaching	□1	□2	□3	□4	□5

26. In the last 12 months, how often did you employ the following teaching approaches when you use ICT in the classroom?						
		Never	Rarely	Sometimes	Often	Always
a.	I employ teacher-centred approach (e.g. Direct instruction) in teaching	□1	□2	□3	□4	□5
b.	I employ student-centred approach (e.g. Inquiry based learning; project based learning; and cooperative learning) in teaching	□1	□2	□3	□4	□5

27. In the last 12 months, how often did you use ICT to do the following activities?						
		Never	Rarely	Sometimes	Often	Always
a.	I use ICT to present content of mathematics	□1	□2	□3	□4	□5
b.	I use ICT to give classroom instruction	□1	□2	□3	□4	□5
c.	I use ICT to guide students in exploratory and inquiry activities	□1	□2	□3	□4	□5
d.	I use ICT to assess students' learning through test or quizzes	□1	□2	□3	□4	□5
e.	I use ICT to provide feedback to individual and/or small group of students	□1	□2	□3	□4	□5
f.	I use ICT to provide remedial to individual students and/or small group of students	□1	□2	□3	□4	□5

28. In the last 12 months, how often did you use ICT to teach following topics of mathematics?						
		Never	Rarely	Sometimes	Often	Always
a.	I use ICT to teach Geometry	□1	□2	□3	□4	□5
b.	I use ICT to teach Algebra	□1	□2	□3	□4	□5
c.	I use ICT to teach Statistics and Probability	□1	□2	□3	□4	□5
d.	I use ICT to teach Calculus	□1	□2	□3	□4	□5
e.	I use ICT to teach Trigonometry	□1	□2	□3	□4	□5

29. In the last 12 months, how often did you use ICT to do the following activities?	Never	Rarely	Sometimes	Often	Always
a. I use ICT to do arithmetic	□1	□2	□3	□4	□5
b. I use ICT to draw graphs	□1	□2	□3	□4	□5
c. I use ICT solve equations	□1	□2	□3	□4	□5
d. I use ICT to construct diagrams	□1	□2	□3	□4	□5
e. I use ICT to measure lengths and angles	□1	□2	□3	□4	□5
f. I use ICT to create visualisation of three-dimensional objects	□1	□2	□3	□4	□5

30. In the last 12 months, how often did you set the following tasks for your students when you use ICT in the classroom?	Never	Rarely	Sometimes	Often	Always
a. I assign students to do “pen-and-paper skills” tasks (e.g., drill and practice, check pen and paper’s work with ICT)	□1	□2	□3	□4	□5
b. I assign students to use real data when the use ICT (e.g., work on real problem)	□1	□2	□3	□4	□5
c. I assign students to explore regularity and variation of mathematics concepts with ICT (e.g., Search for patterns, Observe effect of parameters)	□1	□2	□3	□4	□5
d. I assign students to simulate real situation with ICT (e.g., Collect data for analysis, Use ICT to generate data sets)	□1	□2	□3	□4	□5
e. I assign students to link representation of mathematical concepts by using ICT (e.g., move between geometric, numeric, graphic and symbolic representations)	□1	□2	□3	□4	□5

Part IV: Barriers to Use ICT in Mathematics Teaching

31. Please indicate your response to the following statements	Strongly disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly agree
a. I am not confident to use ICT in the classroom	□1	□2	□3	□4	□5
b. I had negative experience with ICT in the past	□1	□2	□3	□4	□5
c. I believe that ICT does not enhance learning	□1	□2	□3	□4	□5

32. Please indicate your response to the following statements					
	Strongly disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly agree
a. I do not have access to hardware at my school	□1	□2	□3	□4	□5
b. I do not have access to software at my school	□1	□2	□3	□4	□5
c. My school does not have internet connection	□1	□2	□3	□4	□5
d. My school's policy does not support the use of ICT	□1	□2	□3	□4	□5
e. Textbooks do not incorporate information about the use of ICT	□1	□2	□3	□4	□5
f. My school does not provide technical support	□1	□2	□3	□4	□5
g. I do not have enough time to prepare ICT-based lessons	□1	□2	□3	□4	□5

33. Please indicate your response to the following statements					
	Strongly disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly agree
a. In my school, student's assessment is not in line with the use of ICT	□1	□2	□3	□4	□5
b. Structure of Mathematics' content that I teach is not in line with the use of ICT	□1	□2	□3	□4	□5

Note: Completion of the part below is not necessary for return of this questionnaire

Are you willing to take part in the classroom observation and interview of this study?

Yes   No

If **Yes**, Please provide the required information and your contact details, thus I will contact you to arrange the classroom observation and interview at your convenience.

Name: ………………………………………….

Phone: ……………………………………………… or Email ………………………………………………………………….

The topic you will teach during the classroom observation: ………….

ICT (Hardware/Software) you will use in teaching: ……………………………………………………………………………

Thank you for taking time out to participate in my survey.

I truly value the information you have provided

B.2 Questionnaire (Indonesian Language)

Questioner Untuk Guru Matematika

Questioner ini dirancang sebagai bagian dari penelitian program S3 saya yang mengkaji tentang tentang pengetahuan, kegiatan pembelajaran dan tantangan yang dihadapi guru matematika di Indonesia dalam mengunakan ICT dalam pembelajaran.

Informasi tentang questioner

Kata 'ICT' disini ditujukan untuk software, hardware (contohnya: computer, laptop, kalkulator, and tablet) and internet yang berpontensi untuk digunakan dalam pembelajaran matematika.

Questioner ini terdiri dari bagian-bagian berikut ini:

- Bagian I : Informasi tentang latar belakang anda
- Bagian I : Pengetahuan anda tentang ICT and penggunaannya
- Bagian III: Kegiatan pembelajaran dengan ICT
- Bagian IV : Tantangan penggunaan ICT dalam pembelajaran

Cara Mengisi Questioner

- Partisipan dalam penelitian ini tidak diminta menulis nama atau informasi pribadi lainnya, sehingga peneliti tidak akan mengetahui siapa yang menjawab questioner ini. Selanjutnya, data yang dikumpulkan dalam penelitian ini tidak akan diketahui oleh pihak lain selain peneliti dan pembimbing penelitian
- Petunjuk cara menjawab pertanyaan ditulis dangan huruf *miring*
- Silakan memberikan tanda contreng dalam kotak ☐ seperti ini
- Silakan menambah informasi atau komentar di kolom yang disediakan jika menurut anda perlu untuk disampaikan.
- Jika ada pertanyaan tentang penelitian atau questioner ini, silakan menghubungi peneliti melalui alamat email: m.mailizar@soton.ac.uk dan no telpon: 08126948265

Saya sangat menghargai dan mengapresiasi atas waktu dan bantuan anda mengisi questioner ini. Atas bantuannya, saya mengucapkan terima kasih.

Peneliti

M. Mailizar

Appendix B.2

Bagian I: Informasi Latar Belakang Anda

Informasi Pribadi (*Silakan mencontreng satu kotak*)

1.Apakah jenis kelamin anda?

- Perempuan □
- Laki-Laki □

2. Berapakah umur anda?

- 30 tahun atau kurang □
- 31-35 tahun □
- 36-45 tahun □
- 46-55 tahun □
- Lebih dari 55 tahun □

3. Termasuk tahun ini, sudah berapa lama anda mengajar (*termasuk di semua sekolah*)?

- Kurang dari 1 tahun □
- 1-5 tahun □
- 6-10 tahun □
- 11- 20 tahun □
- 21-30 tahun □
- Lebih dari 30 tahun □

Latar Belakang Pendidikan (*Silakan mencontreng satu kotak*)

4. Apakah anda memiliki gelar sarjana dalam bidang pendidikan matematika atau matematika?

- Tidak □
- Sarjana Pendidikan Matematika □
- Sarjana Matematika □

5. Apakah anda sudah lulus sertifikasi guru? □ Tidak □ Ya

6. Apakah tingkat pendidikan tertinggi anda?

- D3 □
- S1 □
- S2 atau diatas □

Informasi tentang sekolah anda

7. Apakah sekolah anda? □ SMA □ MA
   Kabupaten/Kota (silakan diisi) ……………………………………………….

8. Kelas berapa anda mengajar (*Boleh mencontreng lebih dari satu*)?
   □ Kelas 12 □ Kelas 11 □ Kelas 10

9. Berapa jumlah rata-rata siswa di kelas anda? (*Silakan diisi*) …….Orang

Pengembangan Profesional		
10. Apakah anda pernah mendapatkan pelatihan tentang penggunaan ICT? (*Jika TIDAK, Silakan langsung menjawab pertanyaan no 12 dan seterusnya)*	□ Ya	□ Tidak
11. Apakah anda pernah mengikuti pelatihan yang berkaitan dengan ICT berikut ini? (*Boleh mencontreng lebih dari satu)*	Yes	No
a. Pelatihan tentang penggunaan ICT dalam pembelajaran	□	□
b. Pelatihan tentang penggunaan internet	□	□
c. Pelatihan tentang penggunaan software secara umum (contohnya. MS Power Point. Excel. dll.)	□	□
d. Pelatihan tentang penggunaan software khusus untuk pembelajaran matematika (contohnya. *GeoGrebra, Geometers' Sketchpad, Autograph, Cabri, dll.*)	□	□
e. Pelatihan tentang penggunaan Grafik Kalkulator	□	□
f. Lainya (silakan disebutkan ………………………)	□	□

Bagian II: Penilaian guru terhadap pengetahuan mereka sendiri tentang ICT

12. Silakan menilai pengetahuan anda dalam mengoperasi hardware berikut ini (*contreng satu pilihan untuk setiap item*)

	Sangat Setuju	Setuju	Netral	Tidak Setuju	Sangat Tidak setuju
a. Saya tau cara menggunakan Kalkulator Grafik	□ 5	□ 4	□ 3	□ 2	□ 1
b. Saya tau cara mengunakan Tablet	□ 5	□ 4	□ 3	□ 2	□ 1
c. Saya tau cara menggunaakan Komputer/Laptop	□ 5	□ 4	□ 3	□ 2	□ 1

13. Silakan menilai pengetahuan anda dalam mengunakan software berikut ini (*contreng satu pilihan untuk setiap item*)

	Sangat Setuju	Setuju	Netral	Tidak Setuju	Sangat Tidak setuju
a. Saya tau cara menggunakan word processor (Cth. Ms Word)	□ 5	□ 4	□ 3	□ 2	□ 1
b. Saya tau cara menggunakan software presentasi (Cth. Power Point)	□ 5	□ 4	□ 3	□ 2	□ 1
c. Saya tau cara menggunakan software presentasi online (Cth. Prezi)	□ 5	□ 4	□ 3	□ 2	□ 1
d. Saya tau cara menggunakan software spreadsheet (Cth. Excel)	□ 5	□ 4	□ 3	□ 2	□ 1
e. Saya tau cara menggunakan software pemetaan (Cth. Inspiration)	□ 5	□ 4	□ 3	□ 2	□ 1

f. Saya tau cara menggunakan software animasi (Cth. Macromedia Flash)	□ 5	□ 4	□ 3	□ 2	□ 1
g. Saya tau cara menggunakan software visualisasi tiga dimensi (Cth. SketchUp)	□ 5	□ 4	□ 3	□ 2	□ 1

14. Silakan menilai pengetahuan anda dalam menggunakan software matematika berikut ini (*contreng satu pilihan untuk setiap item*)

	Sangat Setuju	Setuju	Netral	Tidak Setuju	Sangat Tidak setuju
a. Saya tau cara menggunakan software Maple	□ 5	□ 4	□ 3	□ 2	□ 1
b. Saya tau cara menggunakan software Mathematica	□ 5	□ 4	□ 3	□ 2	□ 1
c. Saya tau cara menggunakan softare Maxima	□ 5	□ 4	□ 3	□ 2	□ 1
d. Saya tau cara menggunakan software Geometer's Sketchpad	□ 5	□ 4	□ 3	□ 2	□ 1
e. Saya tau cara menggunakan software Cabri Geometry	□ 5	□ 4	□ 3	□ 2	□ 1
f. Saya tau cara menggunakan software GeoGebra	□ 5	□ 4	□ 3	□ 2	□ 1
g. Saya tau cara menggunakan software Autograph	□ 5	□ 4	□ 3	□ 2	□ 1
h. Saya tau cara menggunalan software Tinkerplots	□ 5	□ 4	□ 3	□ 2	□ 1
i. Saya tau car menggunakan software Fathom	□ 5	□ 4	□ 3	□ 2	□ 1
j. Saya tau cara menggunakan software SPSS	□ 5	□ 4	□ 3	□ 2	□ 1

15. Silakan menilai pengetahuan anda dalam menggunakan aplikasi online berikut ini (*contreng satu pilihan untuk setiap item*)

	Sangat Setuju	Setuju	Netral	Tidak Setuju	Sangat Tidak setuju
a. Saya mampu menggunakan aplikasi berbasis web untuk pembelajaran (Cth. *Rumah belajar, m-edukasi, Youtube and KhanAcademy)*	□ 5	□ 4	□ 3	□ 2	□ 1
b. Saya mampu menggunakan software management pembelajaran (Cth. Blackboard, Moodle)	□ 5	□ 4	□ 3	□ 2	□ 1

16. Silakan menilai pengetahuan anda dalam menggunakan ICT untuk melakukan kegiatan berikut ini (*contreng satu pilihan untuk setiap item*)					
	Sangat Setuju	Setuju	Netral	Tidak Setuju	Sangat Tidak setuju
a. Saya mampu menampilkan materi matematika dengan ICT	□ 5	□ 4	□ 3	□ 2	□ 1
b. Saya mampu mengkomunikasikan proses matematis dengan ICT	□ 5	□ 4	□ 3	□ 2	□ 1
c. Saya mampu memecahan masalah matematika dengan ICT	□ 5	□ 4	□ 3	□ 2	□ 1
d. Saya mampu mengekplorasi ide-ide matematis	□ 5	□ 4	□ 3	□ 2	□ 1

17. Silakan menilai pengetahuan anda dalam menggunakan ICT pada model pembelajaran berikut ini (*contreng satu pilihan untuk setiap item*)					
	Sangat Setuju	Setuju	Netral	Tidak Setuju	Sangat Tidak setuju
a. Saya mampu menggunakan ICT dengan pembelajaran langsung	□ 5	□ 4	□ 3	□ 2	□ 1
b. Saya mampu menggunakan ICT dengan pembelajaran berbasis inquiry	□ 5	□ 4	□ 3	□ 2	□ 1
c. Saya mampu menggunakan ICT dengan pembelajaran berbasis proyek	□ 5	□ 4	□ 3	□ 2	□ 1
d. Saya mampu menggunakan ICT dengan pembelajaran berbasis discovery	□ 5	□ 4	□ 3	□ 2	□ 1
e. Saya mampu menggunakan ICT dengan pembelajaran cooperative	□ 5	□ 4	□ 3	□ 2	□ 1

18. Silakan menilai pengetahuan anda dalam hal berikut ini (*contreng satu pilihan untuk setiap item*)					
	Sangat Setuju	Setuju	Netral	Tidak Setuju	Sangat Tidak setuju
a. Saya mampu mengajarkan topik matematika yang lebih baik diajarkan dengan bantuan ICT dan menggunakan model pembelajaran tertentu	□ 5	□ 4	□ 3	□ 2	□ 1
b. Saya mampu menggunakan strategi yang mengkombinasikan konsep matematika, ICT and model pembelajaran untuk meningkatkan pemahaman siswa	□ 5	□ 4	□ 3	□ 2	□ 1

terhadap materi pembelajaran					
c. Saya menggunakan ICT dalam pembelajaran untuk mengembangkan konsep matematika and meningkatkan pembelajaran	□ 5	□ 4	□ 3	□ 2	□ 1
d. Saya mampu menggunakan ICT dengan memasukkan tugas-tugas dari kehidupan nyata melalui pembelajaran berbasis masalah	□ 5	□ 4	□ 3	□ 2	□ 1
e. Saya mampu menggunakan ICT untuk mengajarkan siswa mengembangkan kemampuan pemecahan masalah matematika melalui pembelajaran inquiry	□ 5	□ 4	□ 3	□ 2	□ 1

Bagian III: Penggunaan ICT oleh Guru Matematika

19. Pernahkah anda menggunakan ICT dalam pembelajaran? (*jika jawabanya TIDAK, silakan anda langsung menjawab pertanyaan no **31** dan seterusnya tentang kendala dalam penggunaan ICT*) □ Ya □ Tidak

20. Berapa lama anda sudah menggunakan ICT dalam pembelajaran?

- Kurang dari 1 tahun □
- 1 sampai 3 tahun □
- 4 sampai 6 tahun □
- Lebih dari 6 years □

21. Berapa kira-kira waktu yang telah anda gunakan dalam menggunakan ICT di kelas anda dalam 12 bulan terakhir?

- Lebih dari 70% dari semua pembelajaran □
- 51 sampai 70% dari semua pembelajaran □
- 31 to 50% dari semua pembelajaran □
- 21 to 30% dari semua pembelajaran □
- 11 to 20 % dari semua pembelajaran □
- Kurang dari 10% dari semua pembelajaran □

22. Dalam 12 bulan terakhir, seberapa sering anda mengunakan hardware berikut ini dalam pembelajaran? (*contreng satu pilihan untuk setiap item*)					
	Tidak Pernah	Jarang	Kadang-Kadang	Serin g	Selalu
a. Saya menggunalan kalkulator (Cth. Scientifik dan Grafik Kalkulator) dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5
b. Saya menggunakan komputer atau Laptop dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5

c. Saya menggunakan tablet atau peralatan lainnya (Ipad, tab, mobile phone, dsb) in pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5

23. Seberapa sering anda menggunakan software berikut ini dalam pembelajaran? (*contreng satu pilihan untuk setiap item*)					
	Tidak Pernah	Jarang	Kadang-Kadang	Sering	Selalu
a. Saya menggunakan Word Processor (Cth. Microsoft Word) dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5
b. Software Presentasi (Cth. *Power Point*) dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5
c. Spreadsheet (Cth. *Microsoft Excel*) dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5
d. Software Mind Maping (Cth. Inspiration) dalampembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5
e. Software Visualisasi 2D atau 3D (Cth. SkecthUp) dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5

24. Seberapa sering anda menggunakan software kusus metematika berikut ini dalam pembelajaran? (*contreng satu pilihan untuk setiap item*)					
	Tidak Pernah	Jarang	Kadang-Kadang	Sering	Selalu
a. Saya menggunakan Software System Komputer Aljabar (Cth. *Maple, Mathematica*) dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5
b. Software Dinamik Matematika and Dinamik Geometri (Cth. Geogebra, *Geometer's Sketchpad, Autohraph, Cabri*) dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5
c. Software Statistik (Cth. *Tinkerplots, Fathom, SPSS)* dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5

25. Seberapa sering anda menggunakan aplikasi online berikut ini dalam pembelajaran? (*contreng satu pilihan untuk setiap item*)					
	Tidak Pernah	Jarang	Kadang-Kadang	Sering	Selalu
a. Saya menggunakan aplikasi dalam bentuk web (Cth. *rumah belajar*, *m-edukasi, hotmath, SMILE, Youtube and KhanAcedemy*) dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5
b. Saya menggunakan Sistem Manajemen Pembelajaran (Cth. Blackboard, Moodle) dalam	□ 1	□ 2	□ 3	□ 4	□ 5

pembelajaran					

26. Seberapa sering anda menggunakan ICT ketika anda mengajar dengan model pembelajaran berikut ini? (*contreng satu pilihan untuk setiap item*)					
	Tidak Pernah	Jarang	Kadang-Kadang	Sering	Selalu
a. Saya menggunakan pembelajaran bepusat pada guru (Cth. Pembelajaran langsung)	□ 1	□ 2	□ 3	□ 4	□ 5
b. Saya menggunakan pembelajaran berpusat pada siswa (Cth. Pembelajaran berbasis penyelidikan; pembelajaran berbasis proyek; and Pembelajaran kooperatif)	□ 1	□ 2	□ 3	□ 4	□ 5

27. Seberapa sering anda menggunakan ICT ketika anda melakukan aktifitas berikut ini dalam pembelajaran? (*contreng satu pilihan untuk setiap item*)					
	Tidak Pernah	Jarang	Kadang-Kadang	Sering	Selalu
a. Saya menggunakan ICT untuk mempresentasi materi pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5
b. Saya menggunakan ICT untuk memberikan instruksi dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5
c. Saya menggunakan ICT untuk membimbing siswa dalam kegiatan eksplorasi dan penyelidikan	□ 1	□ 2	□ 3	□ 4	□ 5
d. Saya menggunakan ICT unutuk menguji kemampuan siswa melalui tes atau latihan	□ 1	□ 2	□ 3	□ 4	□ 5
e. Saya menggunakan CIT untuk memberikan umpan balik untuk beberapa orang siswa atau beberapa kelompok siswa	□ 1	□ 2	□ 3	□ 4	□ 5
f. Saya menggunakan ICT untuk remedial untuk beberapa orang siswa atau beberapa kelompok siswa	□ 1	□ 2	□ 3	□ 4	□ 5

28. Seberapa sering anda menggunakan ICT dalam mengajar topik berikut ini? (*contreng satu pilihan untuk setiap item*)					
	Tidak Pernah	Jarang	Kadang-Kadang	Serin g	Sel alu
a. Saya menggunakan ICT untuk mengajar Geometri	□ 1	□ 2	□ 3	□ 4	□ 5
b. Saya menggunakan ICT untuk mengajar Aljabar	□ 1	□ 2	□ 3	□ 4	□ 5
c. Saya menggunakan ICT untuk Statistik dan Peluang	□ 1	□ 2	□ 3	□ 4	□ 5

d. Saya menggunakan ICT untuk mengajar Kalkulus	□ 1	□ 2	□ 3	□ 4	□ 5
e. Saya menggunakan ICT untuk mengajar Trigonometri	□ 1	□ 2	□ 3	□ 4	□ 5

29. Seberapa sering anda menggunakan ICT dalam pembelajaran untuk melakukan hal-hal berikut ini? (*contreng satu pilihan untuk setiap item*)					
	Tidak Pernah	Jarang	Kadang-Kadang	Sering	Selalu
a. Mengerjakan hitungan	□ 1	□ 2	□ 3	□ 4	□ 5
b. Menggambar grafik	□ 1	□ 2	□ 3	□ 4	□ 5
c. Menyelesaikan Persamaan	□ 1	□ 2	□ 3	□ 4	□ 5
d. Mengkontruksikan diagram	□ 1	□ 2	□ 3	□ 4	□ 5
e. Mengukur jarak dan sudut	□ 1	□ 2	□ 3	□ 4	□ 5
f. Membuat visualisasi tiga dimensi	□ 1	□ 2	□ 3	□ 4	□ 5

30. Seberapa sering anda memberikan tugas berikut ini kepada siswa ketika anda mengajar dengan menggunakan ICT? (*contreng satu pilihan untuk setiap item*)					
	Tidak Pernah	Jarang	Kadang-Kadang	Serin g	Selalu
a. Saya menugaskan siswa mengerjakan tugas “pulpen-and kertas” (Cth. Latihan, memeriksa hasil pekerjaan dengan ICT)	□ 1	□ 2	□ 3	□ 4	□ 5
b. Saya menugaskan siswa untuk menggunakan data dari kehidupan sehari-hari (Cth. Mengerjakan masalah dalam kehidupan)	□ 1	□ 2	□ 3	□ 4	□ 5
c. Saya menugaskan siswa untuk mengekplorasi aturan-aturan matematis dengan mencoba berbagai macam kemungkinan (Cth. Mencari formula, observasi efek dari perubahan parameter)	□ 1	□ 2	□ 3	□ 4	□ 5
d. Saya menugaskan siswa mengsimulasikan situasi nyata kehidupan sehari-hari (Cth. Mengumpulkan data untuk analysis, menggunakan ICT untuk menghasilkan data)	□ 1	□ 2	□ 3	□ 4	□ 5
e. Saya menugaskan siswa unutk menghubungkan tampilan symbol, angka dan grafik (Cth. Berpindah dari tampilan geometry, angka, grafik and simbol)	□ 1	□ 2	□ 3	□ 4	□ 5

Appendix B.2

Part IV: Kendala dalam menggunakan ICT dalam pembelajaran Matematika

31. Silakan menentukan sejauh mana faktor-faktor berikut ini menghambat anda dalam menggunakan ICT dalam perbelajaran (*contreng satu pilihan untuk setiap item*)					
	sama sekali tidak setuju	kurang setuju	netral	setuju	sangat setuju
a. Saya Kurang percaya diri menggunakan ICT	□ 1	□ 2	□ 3	□ 4	□ 5
b. Saya Punya pengalaman yang tidak baik dalam menggunakan ICT	□ 1	□ 2	□ 3	□ 4	□ 5
c. Menurut saya bahwa ICT tidak bermafaat dalam pembelajaran	□ 1	□ 2	□ 3	□ 4	□ 5

32. Silakan menentukan sejauh mana faktor-faktor berikut ini menghambat anda dalam menggunakan ICT dalam perbelajaran *(contreng satu pilihan untuk setiap item)*					
	sama sekali tidak setuju	kurang setuju	netral	setuju	sangat setuju
a. Sekolah saya tidak punya Hardware	□ 1	□ 2	□ 3	□ 4	□ 5
b. Sekolah saya tidak punya Software	□ 1	□ 2	□ 3	□ 4	□ 5
c. Sekolah saya tidak punya jaringan internet	□ 1	□ 2	□ 3	□ 4	□ 5
d. Peraturan sekolah saya tidak mendukung penggunaan ICT	□ 1	□ 2	□ 3	□ 4	□ 5
e. Buku teks yang saya gunakan tidak mencantumkan cara penggunaan ICT	□ 1	□ 2	□ 3	□ 4	□ 5
f. Saya tidak mendapat bantuan teknis dari pihak sekolah	□ 1	□ 2	□ 3	□ 4	□ 5
g. Saya tidak punya cukup waktu untuk mempersiapkan bahan ajar berbasis ICT	□ 1	□ 2	□ 3	□ 4	□ 5

33. Silakan menentukan sejauh mana faktor-faktor berikut ini menghambat anda dalam menggunakan ICT dalam perbelajaran *(contreng satu pilihan untuk setiap item)*					
	sama sekali tidak setuju	kurang setuju	netral	setuju	sangat setuju
• Di sekolah saya, system ujian siswa tidak sesuai dengan penggunaan ICT	□ 1	□ 2	□ 3	□ 4	□ 5
• Konsep matematika yang saya ajarkan tidak sesuai diajarkan	□ 1	□ 2	□ 3	□ 4	□ 5

dengan menggunakan ICT					

Catatan: Mengisi bagian dibawah ini bukanlah keharusan untuk mengembalikan questionere ini

Apakah anda bersedia berpartisipasi di tahap kedua penelitian ini dimana peneliti akan melakukan observasi kelas selama satu kali pembelajaran dan melakukan interview selama 30 menit?

Ya **Tida**

Jika anda memilih **YA**, silakan menulis identitas anda dan data lainnya di kolom yang disediakan, saya akan menghubungi anda untuk mengatur jadwal observasi kelas dan wawancara sesuai dengan dengan waktu yang paling tepat bagi anda.

Nama: ………………….....

No Telpon/HP: ………………………………………………… Atau
Email : ………………………………………………..

Materi yang akan
diajaran :……………………………………………………………………………….
………………..

Software dan Hardware yang akan
digunakan: ………………………………………………………………………

Terimakasih banyak atas waktu dan kesediaannya mengisi questioner ini,

Informasi yang anda berikan sangat bermafaat dalam penelitian ini

Appendix C Qualitative Instument

C.1 Interview Protocol in English

The Semi-structured interview protocol

Introduction	• Have you participated in ICT training? What was the content of the training? • What training do you need?
Teacher Classroom Practices	
General information about ICT use	• In which unit standard (e.g., algebra, statistics and probability, geometry, calculus and trigonometry) have you use of ICT? And what unit standard have you mostly used ICT? And what type of ICT do you used for these standards? • How often do you use ICT? • What are the most frequent software and hardware used in the classroom? • Apart from my observation in your class, can you please give me other examples of how ICT has been useful in the teaching of your students? Why do you use ICT in your classroom?
Task Level	• What task have you set for your students when you use ICT in the classroom? • Could please provide examples of the tasks you set for the student when they use ICT?
Classroom Level	• What is typical interaction between you and your students when you use ICT in the classroom? Do the students work independently or in groups? • Does the use of ICT change your classroom interaction between you and your students? Could you please provide one example? • Does the use of ICT change your and students' expectations in the classroom? Could you please provide one example? • What teaching strategies have you used in your classrooms, and do you commonly use it where ICT is involved?
Subject Level	• In your classroom, do you emphasise on applications of mathematics rather than on mathematics concepts and calculation skills? • Does the use of ICT change your emphasis on applications of mathematics rather than on mathematics concepts and calculation skill? Could you please provide one example? • Do you choose to approach mathematics topic from different entry points (e.g. starting with an overview or real-world application, and the going back to look at details) when you use ICT in the classroom? Could you

	please provide one example? • Do you use unexpected mathematics results from ICT to provoke rich mathematics discussion in the classroom? Could you please provide one example?

C.2 Interview Protocol (Indonesian Language)

The Semi-structured interview protocol

Pengantar	• Apakah anda pernah berpartisipasi dalam pelatihan ICT? Apa materi pelatihan tersebut? • Pelatihan apa yang anda butuhkan?
Penggunaan ICT dalam pembelajaran	
Informasi umum tentang penggunaan ICT	• Dalam materi apa (Cth. Aljabar, Statistik and Peluang, Geometry, Kalkulus, and trigonometry) anda telah menggunakan ICT? Dan dalam mengajar materi apa yang paling sering anda menggunakan ICT? • Berapa sering anda menggunakan ICT? • Software dan hardaware apakah yang paling sering anda gunakan dalam kelas? • Selain yang saya observasi di kelas, tolong anda berikan contoh lain bagaimana ICT telah memberikan mafaat kepada siswa anda? Kenapa anda menggunakan ICT dalam pembelajaran?
Tingakatan tugas	• Tugas seperti apa yang telah anda berikan kepada siswa ketika menggunakan ICT? • Tolong anda sebutkan contoh tugas yang anda berikan kepada siswa ketika menggunakan ICT dalam pembelajaran?
Tingakatan Kelas	• Interaksi seperti apa yang umumnya terjadi antara anda dan siswa ketika anda menggunakan ICT di dalam kelas? Apakah siswa berkerja mandiri atau secara berkelompok? • Apakah dengan penggunaan ICT merubah interaksi antara anda dan siswa anda? Tolong berikan satu contoh • Apakah dengan penggunaan ICT merubah harapan anda dan siswa anda di dalam kelas? Tolong berikan satu contoh • Strategi pembelajaran seperti apa yang telah ada gunakan dalam pembelajaran? Apakah strategi tersebut biasanya ada gunakaan ketika anda menggunakan ICT?
Tingakatan Materi Pelajaran	• Di dalam kelas anda, apakah anda menekankan pada aplikasi konsep matematika lebih dari concepts and kemampuan berhitung? • Apakah penggunaan ICT merubahan penekanan anda pada applikasi matematika daripada konsep and kemampuan berhitung? Tolong berikan satu contoh • Apakah anda memilih pendekatan kepada topik matematika dari berbagai sisi yang berbeda (Cth. Memulai dengan overview aplikasi masalah kehidupan nyata, dan kemudian baru melihat konsep matematika secara detil) ketika anda menggunakan ICT dalam kelas? Tolong berikan satu contoh? • Apakah anda menggunakan hasil-hasil yang tidak terduga dari ICT untuk memperkaya diskusi mathematika di dalam

	kelas? Tolong berikan satu contoh

C.3 Observation Sheet

Classroom Observation Sheet (Field Note)

Date	:	School	:
Subject	:	Grade	:
Topic	:	Teacher	:
Length of Lesson	:	No. of Student	:

1. ICT tool used:
    a. Hardware :
    b. Software :
    c. The Internet :
2. Description of classroom level activities

3. Description subject level activities

4. Description tasks set for students

5. Degree to which teacher employ direct instruction?

   ☐ Low/None (students are working independently and/or in students group)

   ☐ Medium

   ☐ High (Teacher directed instruction; lecture, presentation; etc.)

6. Student groupings:

   ☐ Small group (2-3 students)

   ☐ Medium group (4-5 students)

   ☐ Large group (More than 6 students)

7. Classroom Instruction: Teacher-Centred ☐ or Student-Centred ☐
8. Other important notes:

Appendix D Qualitative Data

D.1 An Example of Interview Transcript

Participant : Rina		
No	**Interviewer/ Interviewee**	**Questions/Answer**
	M (Interviewer)	*Apakah anda pernah berpartisipasi dalam pelatihan ICT? Apa materi pelatihan tersebut?*
	R (Interviewee)	setahun ini belum pernah
	M (Interviewer)	*jadi selama mengajar disini belum pernah ya?*
	R (Interviewee)	belum
	M (Interviewer)	*Pelatihan apa yang anda butuhkan?*
	R (Interviewee)	saya pingin lebih banyak lagi tau tentang software-software lainnya, selama ini kan saya baru tau cara menggunakan autograph
	M (Interviewer)	*ok, berarti lebih ke ingin belajar software yang lain ya? Contohnya kira-kira apa? Geogebra pernah pakek gak?*
	R (Interviewee)	geogebra belum tau
	M (Interviewer)	*Dalam materi apa (Cth. Aljabar, Statistik and Peluang, Geometry, Kalkulus, and trigonometry) anda telah menggunakan ICT? Dan dalam mengajar materi apa yang paling sering anda menggunakan ICT?*
	R (Interviewee)	
	M (Interviewer)	*Berapa sering anda menggunakan ICT?*
	R (Interviewee)	Tidak tergolong sering, karena tergantung materi. Jika dalam bulan tersebut ada materi yang cocok, maka lebih separuh dari total pertemuan akan saya gunakan ICT, selebihnya untuk penguatan dan pemantapan materi dengan penyelesaian soal-soal biasanya saya tidak menggunakan ICT. Jadi jika dihitung periode dalam satu bulan berapa kali, saya tidak bisa menentukan, namun jika dihitung dari 5 bab dalam satu semester, maka 4 bab saya

		ajarkan dengan ICT, baik menggukan software matematika, kalkulator, khusus bab statistika, maupun sekedar Power point saja)
	M (Interviewer)	*Software dan hardaware apakah yang paling sering anda gunakan dalam kelas?*
	R (Interviewee)	Autograph, karena cuma autograph ya bisa. Karena dengan Autograph, memungkinkan siswa saya mencoba sendiri dan menganalisis serta menemukan konsep dengan langkah-langkah yang sudah terarah di LKS. Bisa saja saya yang mengoperasikan dengan tampilan yang saya munculkan di depan dengan bantuan infocus, namun peserta didik yang saya ajarkan saat itu, kemampuan mereka dalam menggunakan ICT cukup baik, bahkan Autograph pun mereka install sendiri. Menurut saya malah seperti tidak menghargai kemampuan mereka jika saya tidak memberi kesempatan mereka untuk mengoperasikan sendiri, jika memungkinkan mereka mengoperasikan sendiri
	M (Interviewer)	*Selain yang saya observasi di kelas, tolong anda berikan contoh lain bagaimana ICT telah memberikan mafaat kepada siswa anda? Kenapa anda menggunakan ICT dalam pembelajaran?*
	R (Interviewee)	Materi yang saya ajarkan saat itu adalah transformasi geometri, sedangkan tujuan pembelajarannya adalah siswa mampu memahami konsep transformasi geometri (menentukan bentuk umum bayangan titik) dengan bantuan koordinat. Karena di antara beberapa software hanya Autograph yang lebih saya kuasai dan menurut saya Autograph juga mudah dijalankan siswa, tampilannya sederhana. Jika dimateri ini tidak saya gunakan ICT maka pilihannya saya harus menggambar manual proses transformasi, hal ini menyita waktu. Materi ini bisa dijalankan juga dengan Geogebra, namun selain tidak begitu menguasai saya juga tidak memiliki software tersebut
	M (Interviewer)	*Tolong anda sebutkan contoh tugas yang anda berikan kepada siswa ketika menggunakan ICT dalam pembelajaran?*
	R (Interviewee)	Tugas dan latihan yang menggunakan ICT, contohnya siswa harus menentukan bayangan dari setiap titik yang ditranslasi dengan translasi tertentu, lalu siswa diminta untuk memperhatikan perubahan titik asal ke titik bayangan, kemudian siswa diminta merumuskan bentuk umum (rumus) bayangan bila suatu titik ditranslasikan. Contoh lain, siswa diminta untuk menggambar

		beberapa lingkaranyang diketahui pusat dan jari-jari pada layar Autograph. Dengan memperhatikan pusat dan jari-jari, maka siswa merumuskan bentuk umum persamaan lingkaran untuk pusat (a,b) dan jari-jari r
	M (Interviewer)	*Interaksi seperti apa yang umumnya terjadi antara anda dan siswa ketika anda menggunakan ICT di dalam kelas? Apakah siswa berkerja mandiri atau secara berkelompok?*
	R (Interviewee)	Interaksi siswa dengan saya dan interaksi siswa dengan siswa jauh lebih banyak, dan saya suka, karena komunikasi yang tejadi dua arah, adanya tanya jawab, diskusi dengan sesama siswa. Pada saat observasi ada yang membuat saya kurang puas, karena 1 kelompok terlalu banyak anggota. Untuk akhir-akhir ini saya lebih sering ,mengarahkan siswa untuk berpasangan saja, untuk meminimalkan siswa yang pasif. Jadi siswa berdiskusi dengan pasangan masing-masing
	M (Interviewer)	*Apakah dengan penggunaan ICT merubah interaksi antara anda dan siswa anda? Tolong berikan satu contoh*
	R (Interviewee)	Sedikit mengubah, karena salah satu manfaat menggunakan ICT yang saya rasakan adalah saya lebih mudah mendapatkan perhatian siswa terhadap pembelajaran, dan untuk menunjukkan grafik, karena saya menggunakan Autograph, lebih ke gambar dan grafik. saya cukup menginput persamaan ke software, saya tidak perlu menggambar manual, menyita waktu, ketepatan gambar pun tidak begitu pas. Intinya saya lebih punya banyak waktu untuk memantau siswa-siswa yang membutuhkan bantuan lebih dalam pembelajaran, tanpa mengabaikan siswa-siswa yang berkemampuan lebih. Interaksi yang terjadi saat saya menggunakan ICT, biasanya dalam bentuk Tanya jawab. Sejauh ini saya lebih sering mengarahkan siswa bekerja dalam kelompok, saya lebih memilih siswa saya bekerja dalam kelompok agar sekurang-kurangnya mereka ada berinteraksi dengan teman pasangannya, ada anak yang malu untuk bertanya saat proses pembelajaran berlangsung dengan alasan malu dengan teman-teman sekelasnya. Pertanyaan yang sering muncul biasanya hanya untuk memastikan yang mereka kerjakan apa sudah tepat. Ada juga beberapa anak menanyakan langkah selanjutnya yang harus dikerjakan.
	M (Interviewer)	*Apakah dengan penggunaan ICT merubah harapan anda dan*

		siswa anda di dalam kelas? Tolong berikan satu contoh
	R (Interviewee)	Tidak, karena harapan saya tetap sama baik menggunakan ICT ataupun tidak. Karena bagi saya menggunakan ICT hanya salah satu cara untuk mencapai tujuan pembelajaran. Harapan tetap sama, saya ingin siswa saya paham konsep matematika, mampu menyelesaikan masalah dalam kehidupan sehari-hari yang berkaitan dengan matematika. Lagipula tidak semua materi cocok diajarkan menggunakan ICT (menurut saya). Misalnya bab peluang, peran ICT pada bab ini hanya sebatas Power Point saja.
	M (Interviewer)	*Di dalam kelas anda, apakah anda menekankan pada aplikasi konsep matematika lebih dari konsep dan kemampuan berhitung?*
	R (Interviewee)	Ya, contohnya pada subbab translasi, dengan menggunakan ICT, saya menginginkan siswa menemukan sendiri bentuk umum bayangan titik oleh suatu translasi melalui percobaan-percobaan di layar Autograph
	M (Interviewer)	*Apakah anda memilih pendekatan kepada topik matematika dari berbagai sisi yang berbeda (Cth. Memulai dengan overview aplikasi masalah kehidupan nyata, dan kemudian baru melihat konsep matematika secara detil) ketika anda menggunakan ICT dalam kelas? Tolong berikan satu contoh?*
	R (Interviewee)	Tidak, pendekatan tetap sama, hanya saja dengan ICT lebih mudah, lebih efektif dan efisien.
	M (Interviewer)	*Apakah anda menggunakan hasil-hasil yang tidak terduga dari ICT untuk memperkaya diskusi mathematika di dalam kelas? Tolong berikan satu contoh*
	R (Interviewee)	Tidak, tampilan tetap tampilan seperti di software, hanya saja pada pembukaan saya menampilkan contoh-contoh dalam kehidupan sehari-hari dengan menampilkan gambar-gambar, misalnya untuk pencerminan, gambar kupu-kupu, gambar orang yang sedang bercermin

D.2 An Example of Classroom Observation Transcript

T : Teacher S : Single student SN : Student new: a single student whose identity differs from the last student to speak S? : When the identity of the student (whether the speaker is S or SN) is unclear Ss : Multiple students, but not the entire class		
Time	Teacher (T) / Students (S)	Activities
00:06	T	Oke.. hari ini kita akan belajar menggambar grafik fungsi kuadrat, kita akan menganalisa karakteristik dari grafik fungsi kuadrat tersebut. Jadi saya akan membagi beberapa kelompok, seperti yang kita lakukan minggu kemarin, kemudian nanti kita akan berdiskusi, kemudian kita akan mempresentasikan hasil diskusi kita. Kita akan menggunakan aplikasi autograph yang sudah di install di laptopnya, ok?
	E	[Diam]
01:00	T	Baiklah, yang pertama saya akan menjelaskan bagaimana cara menggunakan aplikasi autograph, terutama bagaimana cara menggambar grafik fungsi trigonometry, coba semua di buka aplikasinya di laptop
	E	[Membuka Aplikasi Autograp]
01:40	T	Udah, semua sudah dibuka? Sudah ya? Oke sekarang kita buat di autograph, garisnya ini masih dalam bilangan 1 sampai 6 ya, kita mau pakai yang derajat atau radian?
	Ss	[Siswa Menjawab]
02:10	T	Oke kita pakai yang derajat, dalam trigonometrikan kita bisa pakai yang derajat, juga bisa pakai yang radian, jadi nanti bisa kita conversi aja dari derajat ke radian, oke sekarang kita edit X-nya, sebelumnya tentukan dulu bagian yg derajat, itu artinya kita bekerja di bagian derajat
	E	[mengseting gradian]
03:00	T	Kita bisa ubah ini sesuai yang kita inginkan, kita ubah ini pada Y and X nya ya, X nyan dan -90 sampai 720 kemudian Y-nya dari ke -5, nanti kalau kita perlu yang lain, kita bisa edit dari sini, nanti akan muncul seperti ini ya?
	E	[mengikuti langkah yang dikerjakan guru]
03:50	T	Grafik fungsi trigonometrykan grafik fungsi yang periodik ya, apa artinya periodik?
	Ss	[Siswa menjawab pertanyaan guru]

04:00	T	Kalau misalnya Y = Sin X, itu dia berulang tiap 360 derajat
	S	[Siswa menjawab pertanyaan guru]
04:20	T	Nah, jadi disini kalau kita menggambar grafik nanti hasilnya akan terus menerus tak hingga, jadi fungsinya itu terus menerus, jadi disini kita ambil dari 0 sampai 270, jadi ini sebagian kita ambil ya, jadi semuanya tidak mungkin, ok ya?
	Ss	ya
05:00	T	Kemudian bagaimana kita membuat persamaan grafiknya itu, kita disini pakek persamaan boleh di equation, atau ada yg dibawah sperti ini, enter equation itu bisa juga, klik disitu, nah nanti kita menggambar grafik disini, menggambar grafik itu kan kita mulai dari fungsi y= sin x atau y = cos x, macam2 ya, dari sini, Y= tanx
	Ss	[Siswa mengikuti apa yang dikerjakan guru]
05:50	T	Kalau fungsi trigonometry itu kann, Sin Tan Cos, jelas ya, ini yang sin 120 atau sumbu-Y nya 5 sampai ke -5 kan bisa kita edit ya, gimana cara editnya tadi?
	Ss	[Siswa menjawab pertanyaan guru]
06:20	T	Itu, bisa diedit disitu sesuai kebutuhan kita nanti, kita nanti akan akan membagi kelompok, kita akan membagi 5 kelompok ya, kita pakai kelompok yang kemarin aja ya
	E	[Diam menunggu guru membagi kelompok]
07:00	T	Oke kelompok I [Guru menyebutkan nama-nama siswa menurut kelompok masing]
	E	[Menunggu guru membagi kelompok]
07:40	T	Ok, sekarang silakan duduk menurut kelompok masing-masing
	E	[Siswa berpindah duduk ke kelompok masing-masing]
09:10	E	[Siswa sudah berkumpul di kelompok masing-masing]
09:15	T	Oke, sudah berkumpul di kelompok masing-masing ya, nanti saat diskusi bagaimana enaknya, enak berdiri boleh berdiri, yang penting kita semua aktif ya, nanti kita akan melihat kelompok mana yang lebih bagus dalam berdiskusi dan kerja kelompok
	Ss	[Berbicara dengan teman anggota kelompok]
09:40	T	Ok, saya akan membagikan LKS, nanti kalian akan menggambar grafik disini, sesuai dengan hasilnya disitu, gak perlu bagus sekali, yang penting kali pindahkan dari situ ke sini, kemudaian silakan kalian diskusikan bersama teman-teman
	Ss	[Berbicara dengan teman anggota kelompok]
10:05	T	Satu kelompok saya bagi dua [guru membagikan LKS kepada semua kelompok]

	Ss	[Siswa berbicara dalam kelompok masing-masing]
10:35	T	Oke sudah, silakan kalian diskusikan dengan kelompoknya, kurang lebih 25 menit
10:35	E	[Siswa Melakukan kerja kelompok dan mendiskusikan Tugas Mereka]
	T	[Guru memantau siswa saat mereka bekerja dalam kelompok] dan [guru menjawab pertanyaan jika ada pertanyaan dari siswa]
34: 00	T	Bagaimana sudah selesai?
	Ss	[Siswa menjawab] belum
	Ss	[Siswa tetap melanjutkan diskusi dan bekerja dalam kelompok]
	T	[Guru berbicara dengan beberapa kelompok]
42:20	T	Oke ya, saya kira sudah, kalau belum selesai semua gak pa2, nanti kita lanjutkan.
	T	Ok, bagaimana? Bisa semua
	Ss	[Siswa Menjawab]
42:50	T	Ok, saya mau bagian A dulu, bagian A adalah bagian pertama, Kelopok 4 bagaimana? Apa yang kamu lihat pada bagian A itu?
	Ss	[kelompok 4 menjelaskan kesimpulan mereka tentang tugas bagian A]
	E	[memperhatikan kelompok 4]
	T	Bagian satu dulu, oke periodiknya semua ketiga-tiganya berapa?
	Ss	[kelompok 4 menjelaskan tentang jawaban mereka]
	T	Apa yang berbeda? Coba kelopok yang lain memperhatikan kawannya yang sedang menjelaskan ya kemudian kita tanggapi
	Ss	[kelompok 4 melanjutkan penjelasan mereka]
	T	Berarti itu tidak berkaitan dengan periode ya? Semuanya sama kann?
	Ss	[kelompok 4 menjawab pertanyaan guru]
	T	Kira-kira ada yang menanggapi? Apa ada yang mau bertanya? Buat soal, kalau misalnya seperti ini bagaimana?
45:05	Ss	[Siswa kelompok lain diam]
	Ss	[Salah satu kelompok bertanya ke kelompok 4]
	Ss	[kelompok 4 meminta klarifikasi pertanyaannya
	T	Kalau amplitudonya semakin besar, semakin apa? Misalnya aplitudo 1000?

	Ss	[siswa dari berbagai kelompok merespon pertanyan guru]
	T	Jadi maksimumnya akan 1000, minimum?
	Ss	[siswa menjawa]
	T	Jadi itu yang dinamakan kalau dalam fungsi trigonometri Y=A sin X, kita ambil contoh salah satu fungsi Sin, ini yang kita namakan amplitude, maksimum dan minimu, nah jika A>0 ini maksimum, maka grafik itu akan maksimum dimana?
	Ss	[Siswa menjawab pertanyaan]
	T	Bukan, tadi kalau 500 maksimum nya di 500, kalau 1000 maksimumnya di 1000, nah kalau di A, maksimumnya di?
	E	[Semua siswa menjawab A]
	T	Minimumnya dimana?
	E	[Semua siswa menjawab]
	T	Nah itu maksudnya ya, utk yg bagian A
47:30	T	Ok, bagian ke 2 bagaimana? Kelompookk berapa, kelompok 2 coba?
	E	[siswa diam]
	T	Bagian ke 2, jadi kalau ada grafik seribu tadi bisakan?
	Ss	[siswa menjawab]
	T	Yang B untuk kelompok 2, apa yang kalian lihat dari bagian B? kelompok 2 siapa yang mau jawab?
	Ss	[Salah satu anggota kelompok 2 menjelaskan jawaban mereka tentang tugas B]
	T	Nah, grafik pertama pengulangannya berapa?
	Ss	[kelompok 2 menjawab]
	T	Nah, B nya berapa? B nya 1 kan?
	Ss	[Kelompok 2 menjawab]
	T	Yang lain ini, saya bukan tanya ke kelompok ini saja, kita diskusi sama-sama ya, jadi kalau kelompok sana lagi menjelaskan, tugas kita adalah mendengarkan, itu bentuk penilain sikap
	E	[Diam]
	T	Y sama dengan sin X, nah ketika X nya satu, maka periodiknya berapa?
	E	[menjawab pertanyaan]
	T	Itu soal yang nomor 1, soal yang nomor dua?

	Ss	[menjawab pertanyaan]
	T	Begitu ya, coba kita cari rumusnya bagaimana, y = sin aX, kita lihat kasus yang A dulu, periodenya gak tau berapa disini ya, disini adalah periode B
	Ss	[berbicara dengan angota kelompok]
51:00	T	[guru menjelaskan di papan tulis, tidak terekam di video], bearti kalau saya mau B saja?
	Ss	[Siswa menjawab]
	T	Nah begitu, sudah mengerti ya?
	Ss	[siswa menjawab sudah]
	T	Jadi begitu, kalau gambar yang pertama ini 180 ini 360, gambarnya adalah begini ya [guru menunjukkan gambar], ini adalah Sin X, nah ternyata kalau gambarnya Sin2x periodenya 180?
52:00	S	[Siswa bertanya kepada guru]
	T	Bagaimana coba ada yang bisa jawab? Atau mau coret-coret disini?
	SN	[menjawab pertanyaan temannya di depan kelas]
	Ss	[berdiskusi di kelompok]
	S	[menjelaskan apa yang sudah dijawab]
	Ss	[bertanya kepada siswa yang menjawab di depan kelas]
	T	Terus titik yang lain bagaimana?
	S	[Menjawab pertanyaan guru] dan [melanjutkan penjelasan di depan kelas]
	Ss	[Menanggapi apa yang dijelaskan oleh S]
	T	Apa nya yang bertambah?
	Ss	[Siswa menjawab] dan [diskusi antara siswa dan guru]
55:50	T	Coba bagaimana musmaya? Coba dengar semuanya ya?
	SN	[menjelaskan]
	T	Kalian masih berpatokan awal itu harus nol ya? Padahal periodik ke kanan dan ke kiri, berlanjut terus kan
	Ss	[berbicara dalam kelompok]
56:30	T	Ada ide lain? Bagaiman kelopok 4 ini? Coba bagaimana?

	SN	[menanggapi dan mejelaskan tentang materi yang sedang didiskusikan]
	T	Bagaimana-bagaimana? Ayo ayo yg jelas bagaimana?
	SN	[Menjawab]
	Ss	[mendiskusikan jawaban bersama guru]
	SN	[menjawab]
	Ss	[diskusi]
	T	[menjelaskan dan meyimpulkan]
58:00	T	Kelompok mana yang bisa menjawab yang benar? Coba 1 menit diskusi
	E	[Diskusi]
60:00	T	[Menyimpulkan dan mengakhiri pembelajaran]

Appendix E Results of Quantitative Analysis

E.1 Cronbach's Alpha

Items of teachers' Knowledge

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.974	.974	36

Items of Teachers' Classroom Practices

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.968	.968	37

Items of Tachers' Barriers

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.778	.779	12

E.2 Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity

Items of teachers' Knowledge

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.944
Bartlett's Test of Sphericity	Approx. Chi-Square	4616.442
	df	465
	Sig.	.000

Appendix E

Items of Teachers' Classroom Practices

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.924
Bartlett's Test of Sphericity	Approx. Chi-Square	3445.565
	df	666
	Sig.	.000

Items of Tachers' Barriers

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.737
Bartlett's Test of Sphericity	Approx. Chi-Square	691.219
	df	66
	Sig.	.000

E.3 Results of Mann-Whitney U Test

Gender

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of MEDIANknowledgetotal is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.004	Reject the null hypothesis.
2	The distribution of MEDIANIctUSE is the same across categories of Gender.	Independent-Samples Mann-Whitney U Test	.006	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Teachers' Certification

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of MEDIANknowledgetotal is the same across categories of Certification.	Independent-Samples Mann-Whitney U Test	.030	Reject the null hypothesis.
2	The distribution of MEDIANIctUSE is the same across categories of Certification.	Independent-Samples Mann-Whitney U Test	.108	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Type of School

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of MEDIANknowledgetotal is the same across categories of School.	Independent-Samples Mann-Whitney U Test	.010	Reject the null hypothesis.
2	The distribution of MEDIANIctUSE is the same across categories of School.	Independent-Samples Mann-Whitney U Test	.606	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

E.4 Results of Kruskal Wallis Test

Level of Education

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of MEDIANknowledgetotal is the same across categories of LevelEducation.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
2	The distribution of MEDIANIctUSE is the same across categories of LevelEducation.	Independent-Samples Kruskal-Wallis Test	.029	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Teaching Experience

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of MEDIANknowledgetotal is the same across categories of TeachingExperience.	Independent-Samples Kruskal-Wallis Test	.012	Reject the null hypothesis.
2	The distribution of MEDIANIctUSE is the same across categories of TeachingExperience.	Independent-Samples Kruskal-Wallis Test	.553	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

E.5 Results of Spearman Correlation

Correlations

			TeacherKnowledgeOfICT	TeacherKnowledgeOfICTUse	TeacherClassroomPractice
Spearman's rho	TeacherKnowledgeOfICT	Correlation Coefficient	1.000	.666**	.524**
		Sig. (2-tailed)	.	.000	.000
		N	224	224	224
	TeacherKnowledgeOfICTUse	Correlation Coefficient	.666**	1.000	.645**
		Sig. (2-tailed)	.000	.	.000
		N	224	224	224
	TeacherClassroomPractice	Correlation Coefficient	.524**	.645**	1.000
		Sig. (2-tailed)	.000	.000	.
		N	224	224	224

**. Correlation is significant at the 0.01 level (2-tailed).

E.6 Results of Repeated Measures/Mean Comparison

Mauchly's Test of Sphericity[a]

Measure: Knowledgeof Hardware

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
ICTknowledge	.908	28.067	2	.000	.916	.922	.500

Tests of Within-Subjects Effects

Measure: Knowledge of Hardware

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
ICTknowledge	Sphericity Assumed	188.655	2	94.328	163.211	.000	.358
	Greenhouse-Geisser	188.655	1.832	102.972	163.211	.000	.358
	Huynh-Feldt	188.655	1.843	102.360	163.211	.000	.358
	Lower-bound	188.655	1.000	188.655	163.211	.000	.358
Error(ICTknowledge)	Sphericity Assumed	338.678	586	.578			
	Greenhouse-Geisser	338.678	536.805	.631			
	Huynh-Feldt	338.678	540.014	.627			
	Lower-bound	338.678	293.000	1.156			

Mauchly's Test of Sphericity[a]

Measure: knowledge of general software

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
ICTknowledge	.114	516.594	20	.000	.477	.483	.16

Appendix E

Tests of Within-Subjects Effects

Measure: knowledge of general software

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
ICTknowledge	Sphericity Assumed	1164.510	6	194.085	461.363	.000	.658
	Greenhouse-Geisser	1164.510	2.861	407.084	461.363	.000	.658
	Huynh-Feldt	1164.510	2.899	401.728	461.363	.000	.658
	Lower-bound	1164.510	1.000	1164.510	461.363	.000	.658
Error(ICTknowledge)	Sphericity Assumed	605.776	1440	.421			
	Greenhouse-Geisser	605.776	686.548	.882			
	Huynh-Feldt	605.776	695.701	.871			
	Lower-bound	605.776	240.000	2.524			

Mauchly's Test of Sphericity[a]

Measure: knowledge of mathematical software

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
ICTknowledge	.092	615.466	44	.000	.690	.709	.111

Tests of Within-Subjects Effects

Measure: knowledge of mathematical software

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
ICTknowledge	Sphericity Assumed	93.747	9	10.416	35.478	.000	.120
	Greenhouse-Geisser	93.747	6.212	15.092	35.478	.000	.120
	Huynh-Feldt	93.747	6.380	14.694	35.478	.000	.120
	Lower-bound	93.747	1.000	93.747	35.478	.000	.120
Error(ICTknowledge)	Sphericity Assumed	689.653	2349	.294			
	Greenhouse-Geisser	689.653	1621.267	.425			
	Huynh-Feldt	689.653	1665.108	.414			
	Lower-bound	689.653	261.000	2.642			

Measure: knowledge of online resources

Paired Samples Test

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
.139	.568	.033	.073	.205	4.153	287	.000

Appendix E

Mauchly's Test of Sphericity[a]

Measure: Knowledegeof ICTuse in teaching

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
TeacherKnowledge	.731	100.932	2	.000	.788	.791	.500

Tests of Within-Subjects Effects

Measure: Knowledegeof ICTuse in teaching

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
TeacherKnowledge	Sphericity Assumed	12.581	2	6.291	29.512	.000	.084
	Greenhouse-Geisser	12.581	1.576	7.983	29.512	.000	.084
	Huynh-Feldt	12.581	1.582	7.951	29.512	.000	.084
	Lower-bound	12.581	1.000	12.581	29.512	.000	.084
Error(TeacherKnowledge)	Sphericity Assumed	137.700	646	.213			
	Greenhouse-Geisser	137.700	509.029	.271			
	Huynh-Feldt	137.700	511.099	.269			
	Lower-bound	137.700	323.000	.426			

Mauchly's Test of Sphericity[a]

Measure: ICT Pedagogical Knowledge

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
ICTPedagogicalK	.363	214.997	9	.000	.658	.667	.250

Tests of Within-Subjects Effects

Measure: ICT Pedagogical Knowledge

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
ICTPedagogicalK	Sphericity Assumed	57.312	4	14.328	24.574	.000	.103
	Greenhouse-Geisser	57.312	2.632	21.774	24.574	.000	.103
	Huynh-Feldt	57.312	2.668	21.482	24.574	.000	.103
	Lower-bound	57.312	1.000	57.312	24.574	.000	.103
Error(ICTPedagogicalK)	Sphericity Assumed	499.088	856	.583			
	Greenhouse-Geisser	499.088	563.263	.886			
	Huynh-Feldt	499.088	570.917	.874			
	Lower-bound	499.088	214.000	2.332			

Mauchly's Test of Sphericity[a]

Measure: ICT- Pedagogical Content Knowledge

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
ICTPedContKnowledge	.365	278.834	9	.000	.684	.691	.250

Appendix E

Tests of Within-Subjects Effects

Measure: ICT-Pedagogical Content Knowledge

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
ICTPedContKnowledge	Sphericity Assumed	240.323	4	60.081	176.150	.000	.388
	Greenhouse-Geisser	240.323	2.735	87.885	176.150	.000	.388
	Huynh-Feldt	240.323	2.764	86.936	176.150	.000	.388
	Lower-bound	240.323	1.000	240.323	176.150	.000	.388
Error(ICTPedContKnowledge)	Sphericity Assumed	379.277	1112	.341			
	Greenhouse-Geisser	379.277	760.196	.499			
	Huynh-Feldt	379.277	768.490	.494			
	Lower-bound	379.277	278.000	1.364			

Mauchly's Test of Sphericity[a]

Measure: use of hardware

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
ICTuse	.984	3.177	2	.204	.985	.994	.500

Tests of Within-Subjects Effects

Measure: use of hardware

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
ICTuse	Sphericity Assumed	168.042	2	84.021	132.892	.000	.394
	Greenhouse-Geisser	168.042	1.969	85.326	132.892	.000	.394
	Huynh-Feldt	168.042	1.988	84.509	132.892	.000	.394
	Lower-bound	168.042	1.000	168.042	132.892	.000	.394
Error(ICTuse)	Sphericity Assumed	257.958	408	.632			
	Greenhouse-Geisser	257.958	401.761	.642			
	Huynh-Feldt	257.958	405.647	.636			
	Lower-bound	257.958	204.000	1.264			

Mauchly's Test of Sphericity[a]

Measure: GeneralSoftwareUse

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
softwareUse	.654	81.363	9	.000	.817	.833	.250

Tests of Within-Subjects Effects

Measure: Use of General Software

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared

softwareUse	Sphericity Assumed	443.953	4	110.988	226.886	.000	.540
	Greenhouse-Geisser	443.953	3.268	135.852	226.886	.000	.540
	Huynh-Feldt	443.953	3.331	133.284	226.886	.000	.540
	Lower-bound	443.953	1.000	443.953	226.886	.000	.540
Error(softwareUse)	Sphericity Assumed	377.647	772	.489			
	Greenhouse-Geisser	377.647	630.707	.599			
	Huynh-Feldt	377.647	642.860	.587			
	Lower-bound	377.647	193.000	1.957			

Mauchly's Test of Sphericity[a]

Measure: use of mathematical Software

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
softwareUse	.904	21.307	2	.000	.912	.920	.500

Tests of Within-Subjects Effects

Measure: use of mathematical Software

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
softwareUse	Sphericity Assumed	12.009	2	6.005	17.846	.000	.078
	Greenhouse-Geisser	12.009	1.824	6.584	17.846	.000	.078

	Huynh-Feldt	12.009	1.839	6.530	17.846	.000	.078
	Lower-bound	12.009	1.000	12.009	17.846	.000	.078
Error(software Use)	Sphericity Assumed	141.991	422	.336			
	Greenhouse-Geisser	141.991	384.867	.369			
	Huynh-Feldt	141.991	388.045	.366			
	Lower-bound	141.991	211.000	.673			

Measure: use of online resources

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper			
Pair 1	PengguanaanAplikasiOnlineA - PengguanaanAplikasiOnlineB	.223	.751	.052	.120	.327	4.266	205	.000

Mauchly's Test of Sphericity[a]

Measure: use of functional activity

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]: Greenhouse-Geisser	Epsilon[b]: Huynh-Feldt	Epsilon[b]: Lower-bound
fuctionaluse	.363	214.074	14	.000	.670	.682	.200

Tests of Within-Subjects Effects

Measure: use of functional activity

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
fuctionaluse	Sphericity Assumed	21.804	5	4.361	12.822	.000	.057
	Greenhouse-Geisser	21.804	3.350	6.509	12.822	.000	.057
	Huynh-Feldt	21.804	3.410	6.394	12.822	.000	.057
	Lower-bound	21.804	1.000	21.804	12.822	.000	.057
Error(fuctionaluse)	Sphericity Assumed	362.196	1065	.340			
	Greenhouse-Geisser	362.196	713.549	.508			
	Huynh-Feldt	362.196	726.322	.499			
	Lower-bound	362.196	213.000	1.700			

Mauchly's Test of Sphericity[a]

Measure: classroom activity

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
pedagogical	.619	99.462	14	.000	.833	.852	.200

Tests of Within-Subjects Effects

Measure: classroom activity

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pedagogical	Sphericity Assumed	49.378	5	9.876	25.976	.000	.111

	Greenhouse-Geisser	49.378	4.164	11.858	25.976	.000	.111
	Huynh-Feldt	49.378	4.259	11.593	25.976	.000	.111
	Lower-bound	49.378	1.000	49.378	25.976	.000	.111
Error(pedagogical)	Sphericity Assumed	397.289	1045	.380			
	Greenhouse-Geisser	397.289	870.290	.457			
	Huynh-Feldt	397.289	890.190	.446			
	Lower-bound	397.289	209.000	1.901			

Measure: teaching approach

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	PenggunaanICTModelA - PenggunaanICTModelB	-.041	.916	.062	-.162	.081	-.661	220	.509

Mauchly's Test of Sphericity[a]

Measure: topics of mathematics

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound

mathematicstopics	.885	25.695	9	.002	.945	.964	.250

Tests of Within-Subjects Effects

Measure: topics of mathematics

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
mathematicstopics	Sphericity Assumed	11.968	4	2.992	9.073	.000	.041
	Greenhouse-Geisser	11.968	3.780	3.166	9.073	.000	.041
	Huynh-Feldt	11.968	3.857	3.103	9.073	.000	.041
	Lower-bound	11.968	1.000	11.968	9.073	.003	.041
Error(mathematicstopics)	Sphericity Assumed	279.632	848	.330			
	Greenhouse-Geisser	279.632	801.385	.349			
	Huynh-Feldt	279.632	817.746	.342			
	Lower-bound	279.632	212.000	1.319			

Mauchly's Test of Sphericity[a]

Measure: Use of ICT at task Level

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b] Greenhouse-Geisser	Huynh-Feldt	Lower-bound
pedagogicalUSE	.846	35.937	9	.000	.923	.941	.250

Tests of Within-Subjects Effects

Measure: Use of ICT at task Level

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pedagogicalUSE	Sphericity Assumed	6.031	4	1.508	5.203	.000	.024
	Greenhouse-Geisser	6.031	3.692	1.634	5.203	.001	.024
	Huynh-Feldt	6.031	3.764	1.602	5.203	.001	.024
	Lower-bound	6.031	1.000	6.031	5.203	.024	.024
Error(pedagogicalUSE)	Sphericity Assumed	250.369	864	.290			
	Greenhouse-Geisser	250.369	797.404	.314			
	Huynh-Feldt	250.369	812.991	.308			
	Lower-bound	250.369	216.000	1.159			

Mauchly's Test of Sphericity[a]

Measure: Teacher Level Barrier

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
barrier	.972	9.377	2	.009	.972	.978	.500

Appendix E

Tests of Within-Subjects Effects

Measure: Teacher Level Barrier

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
barrier	Sphericity Assumed	72.262	2	36.131	60.423	.000	.156
	Greenhouse-Geisser	72.262	1.945	37.156	60.423	.000	.156
	Huynh-Feldt	72.262	1.956	36.938	60.423	.000	.156
	Lower-bound	72.262	1.000	72.262	60.423	.000	.156
Error(barrier)	Sphericity Assumed	391.071	654	.598			
	Greenhouse-Geisser	391.071	635.967	.615			
	Huynh-Feldt	391.071	639.717	.611			
	Lower-bound	391.071	327.000	1.196			

Mauchly's Test of Sphericity[a]

Measure: school level barier

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
barrier	.538	194.589	14	.000	.821	.834	.200

Tests of Within-Subjects Effects

Measure: school level barier

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
barrier	Sphericity Assumed	160.883	5	32.177	49.820	.000	.136
	Greenhouse-Geisser	160.883	4.107	39.175	49.820	.000	.136
	Huynh-Feldt	160.883	4.168	38.603	49.820	.000	.136
	Lower-bound	160.883	1.000	160.883	49.820	.000	.136
Error(barrier)	Sphericity Assumed	1020.450	1580	.646			
	Greenhouse-Geisser	1020.450	1297.760	.786			
	Huynh-Feldt	1020.450	1316.983	.775			
	Lower-bound	1020.450	316.000	3.229			

Measure: curriculum level barier

Paired Samples Test

Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
.546	1.256	.070	.409	.683	7.848	325	.000

E.7 Results of Post-Hoc Test

Level of Education

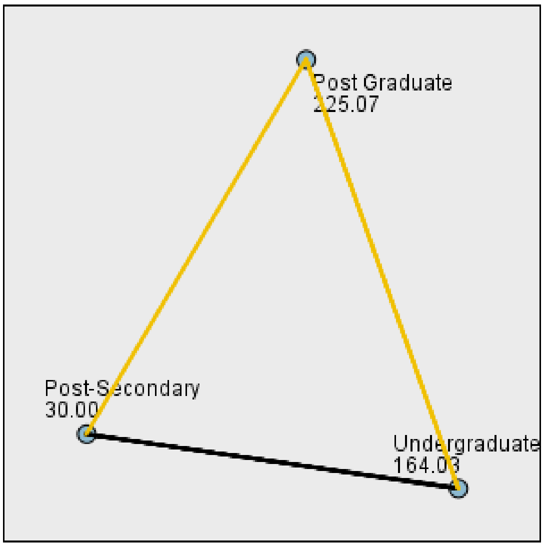
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of MEDIANknowledgetotal is the same across categories of LevelEducation.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
2	The distribution of MEDIANIctUSE is the same across categories of LevelEducation.	Independent-Samples Kruskal-Wallis Test	.029	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Teachers' Knowledge regarding teachers' level of education

Pairwise Comparisons of LevelEducation



Each node shows the sample average rank of LevelEducation.

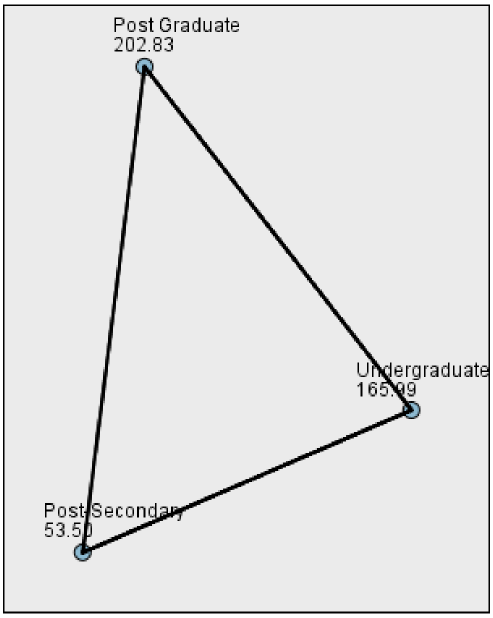
Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Post-Secondary-Undergraduate	-134.030	66.299	-2.022	.043	.130
Post-Secondary-Post Graduate	-195.069	68.323	-2.855	.004	.013
Undergraduate-Post Graduate	-61.039	18.160	-3.361	.001	.002

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.
Significance values have been adjusted by the Bonferroni correction for multiple tests.

Teachers' classroom practices regarding teachers' level of education

Appendix E

Pairwise Comparisons of LevelEducation



Each node shows the sample average rank of LevelEducation.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Post-Secondary-Undergraduate	-112.490	66.577	-1.690	.091	.273
Post-Secondary-Post Graduate	-149.328	68.609	-2.176	.030	.089
Undergraduate-Post Graduate	-36.837	18.236	-2.020	.043	.130

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.
Significance values have been adjusted by the Bonferroni correction for multiple tests.

Teaching Experience

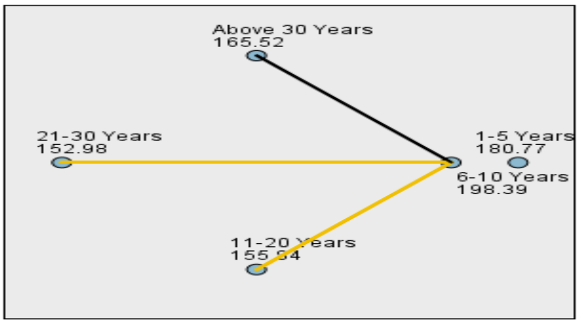
Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of MEDIANknowledgetotal is the same across categories of TeachingExperience.	Independent-Samples Kruskal-Wallis Test	.012	Reject the null hypothesis.
2	The distribution of MEDIANIctUSE is the same across categories of TeachingExperience.	Independent-Samples Kruskal-Wallis Test	.553	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Teacher knowledge regarding teaching experience

Pairwise Comparisons of TeachingExperience



Each node shows the sample average rank of TeachingExperience.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
21-30 Years-11-20 Years	2.860	14.687	.195	.846	1.000
21-30 Years-Above 30 Years	-12.539	15.855	-.791	.429	1.000
21-30 Years-1-5 Years	27.787	19.304	1.439	.150	1.000
21-30 Years-6-10 Years	45.407	14.239	3.189	.001	.014
11-20 Years-Above 30 Years	-9.680	16.576	-.584	.559	1.000
11-20 Years-1-5 Years	24.928	19.901	1.253	.210	1.000
11-20 Years-6-10 Years	42.548	15.038	2.829	.005	.047
Above 30 Years-1-5 Years	15.248	20.777	.734	.463	1.000
Above 30 Years-6-10 Years	32.868	16.180	2.031	.042	.422
1-5 Years-6-10 Years	-17.620	19.572	-.900	.368	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.
Significance values have been adjusted by the Bonferroni correction for multiple tests.

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