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Indonesian Teachers' Knowledge of ICT and the Use of ICT in Secondary Mathematics Teaching

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ABSTRACT

Indonesia, like many other countries, see Information and Communication Technology (ICT) as a potential tool for enhancing the quality of education. However, there is a lack of research examining Indonesian secondary mathematics teachers' knowledge in the integration of ICT. In this study, we aimed to investigate Indonesian secondary teachers' knowledge in the use of ICT in secondary mathematics classrooms. The study employed a quantitative method with a cross-sectional survey approach. It was conducted in one of Indonesia's provinces where the data were collected from 341 secondary mathematics teachers through a questionnaire survey. The findings suggest that, to a large extent, Indonesian secondary mathematics teachers have a largely inadequate knowledge of ICT and knowledge of ICT use in teaching. Based on the findings, we argue that it is crucial to improve Indonesian teachers' knowledge of both aspects, and more training courses for teachers' knowledge development are needed.

Keywords: ICT, Indonesian mathematics education, teacher education, teacher knowledge

INTRODUCTION

Like many other countries in the world, the current secondary mathematics curriculum in Indonesia emphasises the use of ICT in the practice of teaching and learning. This is clearly stated in the secondary school mathematics' curriculum document, as it says "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" (MoEC, 2007, p. 397).

The Indonesian government implemented a reformed curriculum in 1984 which signalled the first attempted policy directive to integrate modern technologies into mathematics classrooms (Mailizar, Manahel and Fan, 2014). It was an example of the government's efforts to strengthen mathematics education in the country (Ruseffendi, 1988, p. 102). This indicates that the integration of modern technology in teaching and learning has been a feature for quite a long time of the mathematics curriculum in the country. In a sense, this also explains that the integration of modern technology in teaching and learning has been a feature of the Indonesian mathematics curriculum for quite a long time.

It is widely believed that teachers play a significant role in the integration of ICT in the classroom. Therefore, while earlier research on the integration of ICT has mostly focused on the students' outcome (e.g., Hennessy, Fung, & Scanlon, 2001; Sinclair & Jackiw, 2005; Smeets, 2005; Witte & Rogge, 2014), more recent studies have shifted focus to teachers' development of their knowledge (Clark-Wilson, Robutti, & Siclair, 2014). Researchers in many countries have conducted studies on teachers' knowledge of ICT or the use ICT in teaching, for example, Archambault and Crippen (2009) and Debbagh and Jones (2018) in the United States, Loveless (2007) in the United Kingdom, Doukakis, Koilias, Adamopoulos, and Giannopoulou (2011) in Greece, Al Harbi (2014) in Saudi Arabia, Owusu, Lindsey, and Chris (2015) in New Zealand, Koh, Woo, and Lim (2013) in Singapore, to name a few.

Contribution of this paper to the literature

- The study adopted TPACK framework, therefore, it enhances the literature regarding the application of the framework to investigate secondary mathematics teachers knowledge through a questionnaire survey.
- The study is the first empirical study in Indonesia to investigate secondary teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching that involved a relative large numbers of participants.
- As a developing country that has the fourth largest education system in the world, the findings of this study has implications not only for Indonesia but for other developing countries that are keen to integrate ICT in the classroom.

In mathematics education, researchers have also investigated mathematics teachers' knowledge about ICT and the integration of ICT in mathematics classrooms, such as that by Handal, Campbell, Cavanagh, Petocz, and Kelly (2013) in Australia, Stoilescu (2015) in Canada, and Agyei and Voogt (2011) in Ghana. Those studies found that mathematics teachers did not have sufficient knowledge about ICT and how to use ICT in teaching.

However, the previous studies have left several gaps to be filled. First, 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, it appears clear that there have been a limited number of publications reporting on this issue for developing countries, including Indonesia. Second, in the Indonesian context, the previous studies on teachers' knowledge about the use of ICT in teaching (e.g., Marzal, 2013; Puspiratini, Sunaryo, & Suryani, 2013; Rimilda, 2015) also had left 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 the schools they were doing teaching practicum. As a result, those studies were not aimed to, nor did they fully reveal Indonesian secondary mathematics teachers' knowledge of ICT integration. Therefore, this study seeks to investigate Indonesian secondary mathematics teachers' knowledge of ICT and the use of ICT in mathematics teaching.

AIMS AND RESEARCH QUESTION

The aim of this study was to investigate Indonesian secondary mathematics teachers' knowledge about ICT and the use of ICT. Specifically, the study seeks to answer the following research questions: What knowledge do Indonesian secondary mathematics teachers have about ICT and its use in teaching? This study addressed teachers' knowledge into two domains: knowledge of ICT and knowledge of ICT use in teaching. Details of both concepts are explained conceptual framework section below.

CONCEPTUAL FRAMEWORK

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

Researchers (e.g., Angeli & Valanides, 2009; Brantley-Dias, Kinuthia, Shoffner, de-Casto, & Rigole, 2007; Chinnappan & Thomas, 2008; Mishra & Koehler, 2006; Niess, 2005; Pierson, 2001) extended Shulman's framework to gain insights to understand and define teachers' knowledge about the use of digital technologies. They argue that teachers need knowledge that build on and intersect with what Shulman (1986) described to use the digital tool effectively in the classroom. Therefore, 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).

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. 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.

Furthermore, in the same year as Niess (2005), based on their study on collaborative design of online courses by teacher educators and master students, Koehler and Mishra (2005) conceptualised the knowledge that a teacher would need to effectively teach with technology. They extended *Pedagogical Content Knowledge* (PCK) (Shulman, 1986) as a conceptual basis for conceptualisation of *Technological Pedagogical Content Knowledge* (TPCK), which was
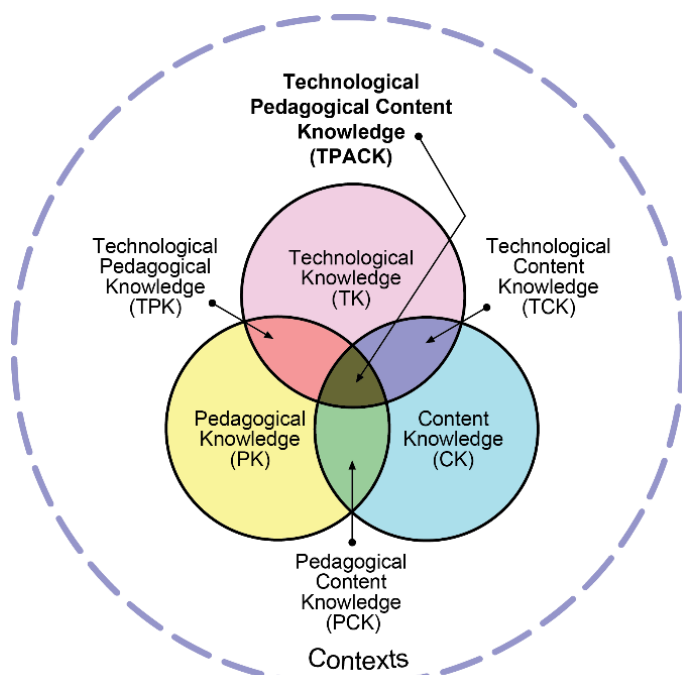
Figure 1. The components of the TPACK framework (Mishra & Koehler, 2006)

Table 1. 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

then abbreviated as TPACK by Thompson and Mishra (2008). According to Voogt, Fisser, Pareja Roblin, Tondeur, and van Braak (2013), the TPACK framework (see **Figure 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.

Chai, Koh, and Tsai (2013) define each construct of TPACK as presented in **Table 1**. These definitions of TPACK components seem concise and distinctive for the elements particularly in relation to TCK, TPK and TPCK.

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

The two models share some common principle elements. First, 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 effectively in the classroom and to recognise when ICT can assist them in achieving the goal of teaching and learning. Second, the integration of ICT in teaching requires teachers to understand the existence of various ICT tools and their pedagogical affordance (see Angeli & Valanides, 2009;
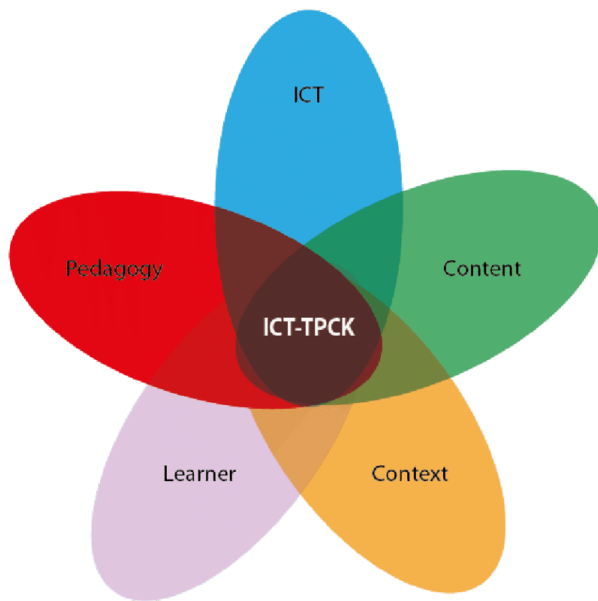
Figure 2. ICT-TPCK (Angeli & Valanides, 2009)

Mishra & Koehler, 2006). Finally, both 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, we classified constructs of knowledge investigated in this study as follows.

We adopted Angeli and Valanides's (2009, p. 158) definition to define knowledge of ICT that is knowing how to operate a computer and how to use a multitude tools/software as well as troubleshoot in problematic situation. This is similar to Chai et al. (2013) definition which is knowledge about how to use hardware and software and associated peripherals. 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.

Knowledge of ICT use in teaching is a complex notion, and it is a challenge to develop a concise definition of this concept. We defined it based on TPCK (Mishra & Koehler, 2006) that has seven components namely TK, CK, PK, PCK, TCK, TPK, TPCK. Handal et al. (2013) adopted the TPCK model to investigate secondary mathematics teachers' knowledge through administration of an instrument called TPCK-M (Technological Pedagogical Content Knowledge of Mathematics) n consisted of three major theoretically-based constructs: technological content knowledge (TCK), technology pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK). The instrument of teachers' knowledge of ICT use in teaching consisted of TCK, TPK and TPCK, which we then reframed as: ICT-Content Knowledge (ICT-CK), ICT-Pedagogical Knowledge (ICT-PK) and ICT-Pedagogical Content Knowledge (ICT-PCK).

Finally, based the discussion above, the construct of teachers' knowledge investigated in this study is presented in **Table 1**.

METHOD

Research Design

The study adopted a quantitative approach, as it is considered to provide more reliability, validity, objectivity and generalizability to the findings. More specially, a questionnaire can be administered to a large number of participants. As it has been argued, if the researchers collects data based on a representative sample of the population, by employing a quantitative approach, they are more able to generalise statements made about the topic being examined (Fraenkel & Wallen, 2009).

Research Participants

Indonesia is a large country, and due to practical reasons we were unable to collect data throughout the whole country. The population for this study was, in a strict sense, all the upper secondary mathematics teachers who teach grade 10-12 students in one of Indonesia's provinces, which has 367 senior secondary schools and 1,443

Table 2. Construct of knowledge of ICT and knowledge of ICT use in teaching

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

mathematics teachers. To determine the sample size, we referred to the table for determining minimum returned sample size developed by Barlett, Kotrlik, and Higgins (2001). According to the table, with a confidence interval (margin of error) of +/- 5%, and a confidence level of 95%, about 306 participants were required for the sample. We randomly selected schools from each city and regency in the province. In total, there were 93 secondary schools selected for the distribution of 440 copies of the questionnaires. In total, 355 questionnaires were returned. However, 14 questionnaires were found incomplete. Participants' demographic backgrounds are presented in **Table 2**.

Research Instrument

We developed a questionnaire that included two parts, namely, teacher' demographic backgrounds and teachers' knowledge. With regard to teachers' knowledge of ICT, as previously discussed in the conceptual framework section, this study refers to the definition proposed by Angeli and Valanides (2009, p. 158). In terms of teachers' knowledge of ICT use in teaching, as previously discussed, this study refers to Mishra & Koehler's TPACK (2006) and Handal et al. (2013). Some questionnaire items about teachers' knowledge of ICT use into teaching were adopted from Handal et al. (2013). This is because, as mentioned earlier, they also adopted the TPACK model to develop a questionnaire called TPCK-M that consists of three constructs: technological content knowledge (TCK), technology pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK). Furthermore, all the responses on teachers' knowledge were coded in a 5-point scale, ranging from 1 = strongly disagree to 5 = strongly agree (See. **Appendix**).

Reliability and Validity

Reliability. Internal consistency reliability was employed to examine the instrument's reliability. The inter-item correlation was assessed by using Cronbach's coefficient alpha of over 0.7 (Muijs, 2004). The result showed that data the instrument has reasonably high reliability with an alpha coefficient of .974.

Validity. Content and construct validity were used to evaluate the validity of the questionnaire. Regarding content validity, as mentioned previously, the development 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 experts reviewing the instrument aiming to enhance content validity of the instrument. Confirmatory factor analysis was use to examine 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. The results showed that a value of scales of teachers' knowledge is .944, which falls into the range of being superb. Moreover, 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).

Data Analysis Procedure

All responses on teachers' knowledge were coded in a 5-point scale. Descriptive and inferential statistical analysis were employed to answer the research questions. Regarding descriptive analysis, a frequency distribution of responses on all the items of teachers' knowledge was calculated and presented in tables. Furthermore, Means of all the items were also explained by using Handal et al.'s (2013) questionnaire score range (See **Table 3**). For inferential statistical analysis, a repeated measure ANOVA and paired- t test were employed to examine significant differences in teachers' knowledge across survey items.

Table 3. Participants Demographic Background

Demographic Background	Frequency	Percentage
Gender		
Male	213	62.6
Female	128	37.4
Age		
30 Years or Less	17	5
31-35 Years	71	20.8
36-45 Years	94	27.5
46-55 Years	100	29.4
Over 55 Years	59	17.3
Teaching Experience		
Over 30 years	58	16.9
21-30 Years	93	27.2
11-20 Years	76	21.9
6-10 Years	82	24.6
1-5 Years	32	9.5
Highest Level of Education		
Post Graduate Degree	29	8.6
Undergraduate Degree	310	90.8
Post-Secondary Degree	2	0.6

Table 4. Questionnaire score range

Score Range	Score Range
$1.0 \leq x < 1.5$	Very low
$1.5 \leq x < 2.0$	Low
$2.0 \leq x < 2.5$	Moderately low
$2.5 \leq x < 3.0$	Slightly below average
3.0	Average
$3.0 < x \leq 3.5$	Slightly above average
$3.5 < x \leq 4.0$	Moderately high
$4.0 < x \leq 4.5$	High
$4.5 < x \leq 5.0$	Very high

RESULTS

As previously discussed, the study investigated secondary mathematics teachers' knowledge and of ICT and teachers' knowledge of ICT in teaching. We present results of both types of knowledge from the survey. We first present mean scores and standard deviations for each items, which is then followed by results of repeated measure ANOVA and a paired-t test.

Teachers' Knowledge of ICT

We present the results of the teachers' knowledge of ICT in **Table 4**, including 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 which indicates 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 teachers' knowledge of general software was 2.71, indicating that the participants' knowledge of this was slightly below average. It also showed that the participants' knowledge of word processing software was higher than their knowledge of the other general software. The results revealed that teachers' knowledge of mathematical software was moderately low (Mean = 2.07). For this type of software, the results 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 teaching and learning resources was higher than their knowledge of learning management system software. As most mean scores fall into the low category, it can be concluded that teachers had insufficient knowledge of ICT.

A repeated measures ANOVA was run in order to determine if there was statistically significant difference in teachers' knowledge of hardware, teachers' knowledge of general software, and teachers' knowledge of

Table 5. Mean scores of participants' responses to items of ICT knowledge

Teachers' Knowledge of ICT	Mean	Standard Deviation
Knowledge of hardware		
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	
Knowledge of general software		
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	
Knowledge of Mathematical software		
a. Computer Algebra System (e.g., Maple and Maxima)	2.09	1.10
b. Dynamic Geometric Software (e.g., Geometer's Sketchpad and Cabri Geometry)	2.04	1.01
c. Dynamic Mathematics Software (e.g., Geogebra and Autograph)	2.32	1.06
d. Statistical Software (e.g., Tinkerplots and Fathom)	1.87	0.92
Mean	2.07	
Knowledge of online tools		
a. Online Learning Resources (e.g., Khan Academy)	2.21	1.18
b. Learning Management System (e.g., Moodle)	2.07	1.06
Mean	2.14	

mathematical software across the items. In terms of teachers' knowledge of hardware, Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(2) = 28.07$, p = 0.00, therefore the degree of freedom was corrected using Huynh-Feldt estimate of sphericity (ε = .92). The results show that there was significant difference in teachers' level of knowledge of hardware across the items, i.e., from high to low, knowledge about computer/laptop, tablet/mobile device, and graphing calculators (F (1.84, 540.01) = 163.21, p = 0.00).

Regarding teachers' knowledge of general software, Mauchly's test indicated that the assumption of sphericity had been violated, x^2 (20) = 516.59, p=0.00, therefore the degree of freedom was corrected using the Greenhouse-Geisser estimate of sphericity (ε=.48). The results show that there was a significant difference in teachers' level of knowledge of general software across the items, from the highest about word processor software (e.g., MS Word), presentation software (e.g., MS PowerPoint) and spreadsheet software (e.g., MS Excel) to the lowest about three dimensional visualisation software (e.g., Sketch Up), online presentation software (e.g., Prezi) and mind mapping software (e.g., Inspiration) (F(2.86, 686.55) = 461.36, p = .00).

In terms of teachers' knowledge of mathematical software, Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(44) = 615.47, p = 0.00$, therefore the degree of freedom was corrected using the Greenhouse-Geisser estimate of sphericity ($\varepsilon = .69$). The results showed that there was a significant difference in teachers' level of knowledge of mathematical software across the items, from the highest to the lowest, about Dynamic Mathematics Software (e.g., Geogebra and Autograph), about Computer Algebra System (e.g., Maple and Maxima), about Dynamic Geometric Software (e.g., Geometer's Sketchpad and Cabri Geometry), and about Statistical Software (e.g., Tinkerplots and Fathom) (F (6.38, 1665.11) = 35.48, p = 0.00).

Moreover, a paired t-test was carried out to examine if there was a statistically significant difference in teachers' knowledge of online resources across the two items. The results showed that there was a significant difference in the score for teachers' knowledge for online learning resources (M = 2.21, SD = 1.18) and learning management systems (M 2.07, SD = 1.06); t (287) = 4.15, p= .00, implying that, according to the responses, the teachers' knowledge regarding online learning resources is significantly better than their knowledge about learning management system.

Teachers' Knowledge of ICT Use in Teaching

As aforementioned, in this study, teachers' knowledge of ICT use in teaching consisted of three components, namely ICT-content knowledge, ICT-pedagogical knowledge and ICT-pedagogical content knowledge. **Table 5** depicts the participating teachers' responses to all the related questionnaire items in the survey in terms of the mean scores.

Table 6. Mean scores of participants' responses to items of ICT-content knowledge

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

The results show that teachers' ICT-content knowledge (Mean = 2.96), ICT-pedagogical knowledge (Mean = 2.97) and ICT-pedagogical content knowledge (Mean = 2.87) were slightly below average. The results suggest that teachers had insufficient knowledge of ICT use in teaching.

In order to determine if there was a statistically significant difference in teachers' knowledge across the categories, we run repeated measures ANOVA. Mauchly's test indicated that the assumption of sphericity had been violated, $x^2(2) = 97.98, p = 0.00$, therefore the degree of freedom was corrected using Huynh-Feldt estimate of sphericity ($\varepsilon = .80$). The results showed that there was significant differences in teachers' level of knowledge of ICT use in teaching across those three components, i.e., from high to low, about ICT-pedagogical knowledge, about ICT-content knowledge and about ICT-pedagogical content knowledge (F (1.59, 513.85) = 48.9, p = .013). The results suggest that teachers' ICT-pedagogical content knowledge was the lowest one across all categories of teachers' knowledge of ICT use in teaching.

DISCUSSION

The study of teachers' knowledge of the use of ICT in teaching has gained more attention in this decade. Such study continues to be relevant for understanding and improving the integration of digital technology in the classroom. As this study focused on teachers' knowledge of ICT and teachers' knowledge of ICT use into teaching, we discuss and relate the finding to the literature regarding both types of knowledge.

To a large extent, the findings revealed that Indonesian secondary mathematics teachers had insufficient knowledge of ICT and ICT use in teaching. Regarding the knowledge of hardware, the findings revealed that the participants' knowledge of computers/laptops was higher than their knowledge of tablets/handheld devices, which is higher than their knowledge about graphing calculators. It is not surprising that teachers perceived their knowledge of computers/laptops to be high due to the fact they need to use this tool in daily life. However, that the lowest level of teachers' knowledge was found in the area of graphing calculator, is quite surprising to us. According to the literature (see Mailizar, Manahel, & Fan, 2014; Ruseffendi, 1988), the integration of calculators in Indonesian secondary mathematics classrooms has been attempted since 1984. It seems that a long history of the use of this digital tool in policy directives does not have a significant impact on teachers' knowledge of this tool. Furthermore, according to Mailizar (2018), only 25.5 % of the mathematics teaches had learned how to use the graphic calculator.

Along with knowledge of operating hardware, we also looked at teachers' knowledge of general hardware and mathematical software. The results showed that the participants' knowledge of general software was higher than their knowledge of mathematical software. This finding supports Fuglestad's (2007) study which revealed that teachers had some basic knowledge of software for general use such as word processing and the spreadsheets but

the teachers had lack of knowledge of specific mathematics software such as dynamic geometry software. This finding indicates that, with widely available specific software for teaching and learning mathematics, Indonesian secondary mathematics teachers need to enhance knowledge of mathematical software as it is widely believe such knowledge plays significant role in designing and implementing ICT-based mathematics lessons in the classroom.

The majority of participants reported 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). The finding is not surprising since such software are widely available and commonly used on many occasions. It is in line with Kazoka and William's (2016) study in Tanzania revealing that the majority (75%) of secondary school teachers were able to use MS Word and 50% of teachers were able to use MS PowerPoint. In the Indonesian context, this finding supports Marzal's (2013) study showing that over 60% of science and mathematics teachers have knowledge of using MS PowerPoint, MS Word, and the Internet while less than 10% of the teachers are able to use specific software such as SPSS. However, teachers' knowledge of general software might not has significant impact on the integration of ICT in mathematics classrooms since such software do not have features for facilitating students to construct their mathematical knowledge.

When it comes teachers' knowledge of mathematical software, the findings revealed that teachers' knowledge of this category of software was lower than their knowledge of general software. As mentioned earlier, in this study, we investigated teachers' knowledge of several types of mathematical software: Dynamic Mathematics Software (DMS), Dynamic Geometry Software (DGS), Computer Algebra System (CAS), and Statistical Software. The results revealed that teachers' knowledge of DMS and DGS to be higher than their knowledge about Statistical Software and CAS. Jones (2005) also found the similar finding and suggested 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 software in schools all over the world. To gain a better understanding on teachers' knowledge of DMS and DGS, we looked specific software and found that teacher knowledge of GeoGebra was the highest one across DMS and DGS software. As open source software, GoeGebra is widely available and easily accessible for students and teachers. This condition might have had an impact on teachers' knowledge of this software. We believe that it is potential to improve Indonesian mathematics teachers' knowledge of mathematical software, as it has been emerged over small numbers of teachers.

The last aspect of teachers' ICT knowledge is knowledge of online resources. The results show that teachers' had low knowledge of these resources in which their knowledge of learning management systems (LMS) was lower than knowledge of online learning resources. According to Pynoo et al. (2012) LMS is relatively new technology in secondary education as this technology was first adopted in higher education. As a new technology, it is not surprising that the teachers do not have the sufficient knowledge to use it.

As described earlier, the second aspect of teachers' knowledge investigated in this study was teachers' knowledge of ICT use in teaching. The finding revealed teachers do not have sufficient knowledge of ICT use in teaching. As discussed in the conceptual framework, this study adapted the TPACK framework in investigating this knowledge. Hence, the findings are discussed and related to previous studies using the framework.

The finding is consistent with previous studies using the TPACK framework to understand 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 (not limited to mathematics teachers) have a low to moderate level of TPACK knowledge.

Concerning mathematics teachers, the similar finding was also found by Agyei and Voogt (2011) and Handal et al. (2013). This indicates mathematics teachers' lack of knowledge about integrating ICT has been an issue 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). Consequently, it becomes a challenge for education stockholders in countries across the globe, including Indonesia, to improve teachers' knowledge of this aspect in order to support the integration of the technology.

As discussed in the conceptual framework section, teachers' knowledge in the use of ICT consists of three aspects: ICT-Content Knowledge, ICT-Pedagogical Knowledge, and ICT-Pedagogical Content Knowledge. The results revealed that teachers' ICT-Content Knowledge and ICT-Pedagogical Knowledge were higher than teachers' ICT-Pedagogical Content Knowledge which is in line with Al Harbi's (2014) study. This indicates that ICT-Pedagogical Content Knowledge is more sophisticated and complex than ICT-Pedagogical Knowledge and ICT-Content Knowledge. Consequently, teachers find it much more difficult to gain this knowledge.

It appears clear from this study that Indonesian secondary mathematics teachers' lack of knowledge of both ICT and ICT use might link to the deficiency of training programs as it was found by Mailizar (2018) that revealed that 35% of Indonesian secondary mathematics teachers had never participated in any ICT-related training course. Furthermore, a large number (46%) of Indonesian secondary mathematics teachers are aged over 46 years old and they are described by Harendita (2013) as digital migrants. Digital migrants are widely believed to be less quick to

adopt new technologies than digital native and they need more professional development and training concerning ICT and its use in classroom.

Finally, this study suggests that it is crucial to equip Indonesian secondary mathematics teachers with knowledge of ICT and knowledge of ICT use in teaching through providing training courses emphasising on connection of pedagogical and mathematical content of ICT integration rather than simply training on technical knowledge for the use of ICT resources. This has been strongly supported by research evidence in the literature (e.g., Becta, 2004; Hew & Brush, 2007; Koehler & Mishra, 2005). For example, Koehler and Mishra (2005) argue that, when training teachers to integrate ICT in teaching, it is important to teach ICT in contexts that represent the connection between technology, content and pedagogy.

CONCLUSION

This study investigated Indonesia secondary mathematics teachers' knowledge of ICT and teachers' knowledge of ICT use in teaching. The results of this study revealed that, to large extent, Indonesian secondary mathematics teachers had insufficient knowledge of ICT and knowledge of ICT use in teaching. It revealed that teachers' knowledge of computer was higher than their knowledge of handheld devices and graphing calculator. The finding also suggested that teachers' knowledge of general software was higher than their knowledge of mathematical software. Regarding knowledge of ICT use in teaching, this study depicted that teachers' ICT-Pedagogical Content Knowledge was lower than teachers' ICT-Pedagogical Knowledge and ICT-Content Knowledge.

Based on the findings, we suggest several important points that need to take into account. For future research, it needs a further study to examine the development of Indonesian secondary school's mathematics teacher's knowledge in the use of ICT for teaching a specific content of mathematics, such as Geometry and Algebra. Furthermore, regarding practical implication, the study suggests that Indonesian education stakeholders need to facilitate secondary mathematics teachers in improving their knowledge of ICT and knowledge of ICT use in teaching. Particularly, the Indonesian government needs to provide ICT training courses to improve not only teachers' technical knowledge of the use of ICT and their pedagogical and mathematical content knowledge of ICT integration.

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APPENDIX

Main Items of the Questionnaire

1. Please indicate your response to the following statements

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. I know how to operate a Graphing calculator	□5	□4	□3	□2	□1
b. I know how to operate a Tablet/Mobile Device	□5	□4	□3	□2	□1
c. I know how to operate a Computer/Laptop	□5	□4	□3	□2	□1

2. 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

3. Please indicate your response to the following statements

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
a. I know how to use the Maple software	□5	□4	□3	□2	□1
b. I know how to use the Mathematica software	□5	□4	□3	□2	□1
c. I know how to use the Maxima software	□5	□4	□3	□2	□1
d. I know how to use the Geometer's Sketchpad software	□5	□4	□3	□2	□1
e. I know how to use the Cabri Geometry software	□5	□4	□3	□2	□1
f. I know how to use the GeoGebra software	□5	□4	□3	□2	□1
g. I know how to use the Autograph software	□5	□4	□3	□2	□1
h. I know how to use the Tinkerplots software	□5	□4	□3	□2	□1
i. I know how to use the Fathom software	□5	□4	□3	□2	□1
j. I know how to use the SPSS software	□5	□4	□3	□2	□1

4. 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

5. 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

6. 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

7. 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

http://www.ejmste.com