The role of mathematics teacher in the digital era

A Wijaya
Universitas Negeri Yogyakarta, Jl. Colombo No 1 Depok, Caturtunggal, Kabupaten Sleman, Daerah Istimewa Yogyakarta 55281, Indonesia
E-mail: a.wijaya@uny.ac.id

Abstract. The complex characteristics of the digital era requires more than just conceptual knowledge. In addition to a so called 21st century skills, ‘digital literacy’ has been raised to highlight a set of important competencies to cope with the demands of the future era. Digital literacy comprises practical and functional skills, critical thinking and evaluation, creativity, e-safety, proficient communication, collaboration, cultural and social understanding, and information processing. Developing such competencies since early education requires a big role of teacher. By putting the idea of technological pedagogical content knowledge (TPACK) into practice, there are three important areas of consideration. First, preparation stage for which teacher should design or prepare technology-based or technology-assisted tasks that focus on exploratory activities. Second, during the implementation stage teachers needs to give proper scaffolding to bring from technical exploration to mathematical exploration. Lastly, the assessment stage for which teachers could use technology to improve efficiency and accessibility.

1. Introduction
The development of information and communication technologies (ICT) has a large impact across society including education. This issue has been a concern of policy makers and organization. For example, the European Parliament and the Council in 2006 recommended Mathematical Competence and Basic Competences in Science and Technology and Digital Competence as Key Competences for Lifelong Learning [1]. Digital competence refers to critical use of ICT that includes using technology to retrieve, assess, store, produce, and present information, and communicating in collaborative networks connected by internet [2]. Attention toward the concept of digital competence and digital literacy has been increasing more than a decade. The important gate to develop individual’s digital competency is education. Through education digital competence can be developed since in early ages. With regard to education, the development of digital technologies has been stimulating educational system and teachers to integrate technology into classroom practices in order to provide students with more experiences to interact with technology as a powerful learning tool [3].

Van den Akker [4] distinguish three levels of curriculum, i.e. intended curriculum, implemented curriculum, and attained curriculum. The intended curriculum refers to the formal written curriculum developed by a government. The implemented curriculum contains the perceived curriculum and the operational curriculum as enacted by teachers in their classrooms. Lastly, the attained curriculum concerns the learned curriculum by students which is often seen from students’ outcomes. This distinction strongly suggests that teachers serve as the mediator between the curriculum intended by the government and how students could achieve the targeted goals of the curriculum. Teachers’ interpretation of the intended curriculum plays a crucial role here. To conclude, it can be said that the success of education cannot be separated from teacher aspect. Several studies confirmed this idea as
they revealed that students’ mathematical performance is largely influenced by teachers’ teaching practices [5], [6].

With respect to developing students’ digital competence to cope with the demands of modern society, it is important to pay a great attention on teachers’ readiness with and competence in the use of technology for education. Studies showed that teachers agreed that technologies contribute to students’ learning and helps students to understand mathematics [7]. Despite the great attention towards the use of technology at schools, it is revealed that there is a discrepancy between institutional expectations and teachers’ practical use of digital technologies in their classroom practices [8]. In the UK, two thirds of pupils at Key Stage 3 never or hardly ever used technologies in their mathematics lessons [9]. Furthermore, Ofsted [10] reported that opportunities for pupils to use technologies to solve or explore mathematical problems had markedly decreased. These findings indicate a need to give more attention to teachers because they are the gate to the implementation of technology in mathematics classrooms.

The present paper describes teachers’ roles in the digital era, in particular on how teachers use technologies in their classrooms. Three important areas of teachers’ roles become the concern of the study, i.e. preparation, classroom management, and assessment. Many studies shown that technologies are beneficial not only for the teaching and learning process, but also for assessment. The use of technology for assessment offers benefits for students, teachers and educational systems [11]. Students can receive immediate feedback after the assessment and, on the other hand, teachers are no longer spent too much time for grading students’ works.

2. Method

This paper summarizes results of several separated studies dealing with teachers’ teaching practices. Therefore, different methods were applied for each of the reported studies. The methods are described as follow.

The first study was a survey on teachers’ technological pedagogical content knowledge. An online questionnaire was developed to investigate teachers’: (1) knowledge about information and communication technologies (ICT) in general and ICT for learning mathematics, (2) perception towards the use of ICT for learning mathematics, and (3) use of ICT in their mathematics classrooms. The online questionnaire was distributed to 27 senior high school mathematics teachers with teaching experiences ranged from three to 30 years and an average of 16.9 years (SD = 7.3 years). All teachers have participated in a workshop on the use of ICT and calculators for mathematics learning.

The second study was a part of design research for which the main attention was designing mathematical modeling tasks and teachers’ instructions. The design was implemented in mathematics classes at undergraduate level involving 32 student teachers. The student teachers worked on the modeling task and their works were analyzed both quantitatively and qualitatively.

The third study was a part of an experimental study on the use of calculators for learning mathematics. For the purpose of this paper, only the intervention part that was reported, i.e. the calculator-supported tasks.

3. Results and Discussion

Discussing the role of mathematics teachers cannot be separated from the issue of technological pedagogical content knowledge (TPACK). Therefore, it is important to have a general overview of teachers’ TPACK. The result of the survey on teachers’ TPACK revealed that in general teachers use ICT in their mathematics classes. Only two out of the 27 mathematics teachers reported their difficulty in integrating ICT into their instructional strategies. Figure 1 shows the software or application which were used by the teachers in their mathematics classrooms (note: in the survey teachers were allowed to choose more than one applications). Nevertheless, it is revealed that most teachers used ICT simply for presenting learning materials or, at most, demonstrating learning materials. For example, teachers use PowerPoint to present the material to improve time efficiency. In short, such practice indicates that
the use of ICT is seen from the perspective of general classroom management instead of content and learning management. Only 25% of teachers who could describe the use of ICT to develop students’ critical thinking. Similar situation was also found for the use of ICT to develop students’ collaboration skills. This finding suggests rooms for improvement regarding teachers’ TPACK.

![Teachers' Use of Application](image)

**Figure 1.** Teachers’ use of ICT software or application for learning mathematics

After acquiring information about teachers’ TPACK, the next step is to investigate into detail the roles of teachers. With respect to teachers’ role in the digital era, the present paper suggests three important areas, i.e. preparation, classroom management, and assessment (see Figure 2). Preparation covers designing lesson plan and designing or preparing appropriate mathematics tasks. Classroom management includes the way teachers implement their instructional activities and provide scaffolding to support students’ learning process. Lastly, the assessment area deals with accessibility and efficiency.

![Three areas of teachers’ roles](image)

**Figure 2.** Three areas of teachers’ roles

*Task design or task preparation*

The integration of ICT into mathematics tasks or activities is not just as an attention getter or even a ‘brain replacement’. Instead, ICT is a powerful exploratory tool that can be used to trigger and develop students’ critical thinking. In this study, ICT-based exploratory tasks were reported. The first task (see Figure 3) is about re-constructing a broken plate into its original form and size, which is mathematically about constructing a circle from a given circular segment. This task was given to first year of undergraduate students. In this task, Geogebra is used as a tool to explore various ways to construct a circle. Geogebra provides features to construct a circle, e.g. ‘Circle with Center through
point’ and Circle through 3 points. Therefore, to trigger students’ mathematical thinking, students are required to give mathematical explanation for their strategies.

![Image of Geogebra](image1.png)

**Figure 3.** Using Geogebra to explore various solution to real-world problem

The second task (see Figure 4) is about exploring number relation. The task is aimed for third graders. The task contains simple number operations – i.e. addition, subtraction, and multiplication – that involve only two numbers. Although the tasks are about number operation, the main thinking process required to solve the tasks are not the arithmetical operations. Instead, students have to think about number relation. For example, for the first question is “2 + 4” students have to find numbers that can replace the 4. Various answers are available such as “4 is 2 and 2 or 4 = 2 + 2”, “4 is 1 and 3 or 4 = 1 + 3”, and “4 is 5 minus 1 or 4 = 5 – 1”.

![Image of Calculator](image2.png)

**Figure 4.** Using calculator to explore number relation

Classroom management: Scaffolding

To help students come up with mathematical ideas cannot be simply done by providing them mathematics tasks only. During classroom activities teachers still play an important role to support students grab mathematical understanding. Developing students’ higher order thinking skills such as mathematical modelling or application skills require more than *explain-example-exercise ritual* [12]. Keeping a balance between providing guidance and fostering students’ independence is a key aspect. With this respect, teachers should guide students to construct knowledge or identify mathematics concepts actively and independently by using their prior knowledge and experiences [13]. One of the strategies that can be used by teachers is metacognitive instruction that can stimulate students to reflect on their own understanding of a problem and on how they solve the problem. Metacognitive instruction can be implemented in the form of questioning. Good questioning can be used to: focus students’ thinking on mathematics concepts; help students extend their thinking from concrete and
factual knowledge to analytical aspect; help students find connections between different mathematics concepts or between mathematics and daily life situation [14].

In the second study summarized in this paper (note: see the method section), two types of questioning were used to help students do mathematical exploration. At the first stage, the question type “can you find other strategies?” can be used to trigger students explore various strategies. The study revealed that this question could direct students to explore strategies. Indeed, some students’ strategies might be unsystematic or do not have clear mathematical basis. For example, students changed their solution strategies to solve the broken plate problem (see Figure 3) from using ‘circle through 3 points’ feature to using a semi-circle and reflect it to construct a full circle. In this respect, the question is effective to stimulate students to find various strategies. However, many students could not give mathematical explanation. The questioning ‘can you find other strategies’ might not be specific enough to direct students to think of mathematical concept. Therefore, further questioning is required. A “what if” questioning is posed to direct students to move from strategy exploration to mathematical exploration. Students who solved the broken plate problem with GeoGebra was asked the question “what could we do if we use compass instead of GeoGebra?” A particular example was for the case is ‘circle through three points’ feature. Students were asked how they could construct a circle by using a compass when they were given three non-collinear points. After group discussion, students noticed that three points on the arc of the broken circle could be seen as a triangle. In this situation, students grabbed the idea that the circle they need was a circumscribed circle (see Figure 5).

Figure 5. A shift towards mathematical exploration as a result of ‘what if’ question

Assessment

One of the important benefits of technology for assessment is its accessibility and portability. As mentioned by several researchers, the use of technology for assessment can enhance the way students operate in responding to the task and simplify the process of generating and accumulating evidences of students’ works. A simple example presented in this paper is the use of desmos.com for accessing students’ modelling competence. A total of 24 graduate students were asked to work on a web-based
modelling activity at desmos.com, i.e. the Water Line task (see Figure 6). The students directly worked on the Desmos platform.

![Figure 6. Web-based modelling activity](image)

In terms of assessing students’ competence and works, desmos.com offers a dashboard for teacher to not only administer activity but also to monitor and assess students’ works. Students’ works are shown in the teacher’s dashboard (see Figure 7). This system improves the efficiency and accessibility of assessment because teacher can access and assess students’ works anytime and anywhere through the internet.

![Figure 7. A dashboard showing students’ works](image)

There are new possibilities for the ways in which tasks are selected for use in assessments, in the way they are presented to students, in the ways that students operate while responding to the task, in the ways in which evidence generated by students is identified, and how evidence is accumulated across tasks [15].

4. Conclusions
The present study presents the role of mathematics teacher in the digital area. Three key areas of teachers’ areas are highlighted in the study, i.e. preparation, classroom management, and assessment. With respect to the preparation stage, the study focuses on task design for which examples of technology-related mathematics tasks are described. The important characteristic of the tasks is not simply on the use of technology to present and represent the tasks, but on the use of technology to explore strategies and trigger students’ critical thinking. Such task characteristics are important to develop students’ creative and critical thinking skills, which are considered as important skills in the digital era [16]. Mathematics task is not a standalone aspect contributing to students’ learning. Good
mathematics tasks still need to be accompanied by proper instructional practice [13]. Therefore, in terms of classroom management teachers in digital era need to be able to select and give proper scaffolding to support their students. The present study suggests the use of metacognitive questioning to guide students towards mathematical exploration and various problem-solving strategies. In relation to teaching in digital era, metacognitive questioning could improve students’ self-directed learning which is considered as an early phase towards lifelong learning. The last of concern with respect to teachers in digital era is assessment for which the present study highlight the potential of technology to improve the accessibility and efficiency of assessment process and results. To conclude, teachers’ roles in the digital era are aimed to develop crucial skills students need to cope with the demand of modern life.

5. Acknowledgment
The teacher survey and the calculator-related mathematics tasks were parts of an umbrella study supported by Casio for Education. The author would like to express gratitude to Casio for Education and its team (Mutia Munawar and Pientha Glenys Amanti) and Casio Researchers (Heri Retnawati, Wahid Yunianto, and Pastitta Ayu Laksni) for all supports and contribution.

References
[1] European Commision, “Recommendation on key competences for lifelong learning.” 2006.
[2] M. Spante, S. S. Hashemi, M. Lundin, and A. Algers 2018 Cogent Educ., 5 1.
[3] A. Clark-Wilson, O. Robutti, and N. Sinclair, “Introduction,” in The Mathematics Teacher in the Digital Era, A. Clark-Wilson, O. Robutti, and N. Sinclair, Eds. New York: Springer, 2014, pp. 1–10.
[4] J. van den Akker 2004 Curriculum perspectives: An introduction Curriculum landscapes and trend eds Jan van den Akker, W. Kuiper, and U. Hameyer (Dordrecht: Springer) pp. 1–10.
[5] D. A. Grouws and K. J. Cebulla 2000 Improving student achievement in mathematics (Brussels: International Academy of Education).
[6] J. Hiebert and D. A. Grouws 2007 The effects of classroom mathematics teaching on students’ learning Second handbook of research on mathematics teaching and learning ed F. Lester (Charlotte: Information Age Publishing) pp. 371–404.
[7] N. Bretscher 2014 Exploring the Quantitative and Qualitative Gap Between Expectation and Implementation: A Survey of English Mathematics Teachers’ Uses of ICT The Mathematics Teacher in the Digital Era eds A. Clark-Wilson, O. Robutti, and N. Sinclair (New York: Springer) pp. 43–70.
[8] J.-B. Lagrange and E. O. Erdogan 2008 Educ. Stud. Math. 71 65.
[9] C. Harrison, C. Comber, T. Fisher, K. Haw, C. Lewin, and et al. 2003 ImpaCT2: The impact of information and communication technologies on pupil learning and attainment (Coventry: Becta).
[10] Ofsted 2008 Mathematics – understanding the score (London: Ofsted).
[11] K. Stacey and D. Wiliam 2013 Technology and Assessment in Mathematics Third International Handbook of Mathematics Education eds M. A. (Ken) Clements, A. J. Bishop, C. Keitel, J. Kilpatrick, and F. K. S. Leung (New York: Springer) pp. 721–752.
[12] S. Antonius, C. Haines, T. H. Jensen, M. Niss, and H. Burkhardt 2007 Classroom activities and the teacher Modelling and Applications in Mathematics Education: The 14th ICMI Study eds W. Blum, P. L. Galbraith, H.-W. Henn, and M. Niss (New York: Springer) pp. 295–308.
[13] W. Blum 2011 Can modelling be taught and learnt? Some answers from empirical research Trends in teaching and learning of mathematical modelling eds G. Kaiser, W. Blum, R. B. Ferri, and G. Stillman (New York: Springer) pp. 15–30.
[14] M. Swan and D. Pead, “Professional development resources. Bowland Maths Key Stage 3, Bowland Charitable Trust,” 2008. [Online]. Available: http://www.bowlandmaths.org. [Accessed: 03-Sep-2016].
[15] R. G. Almond, L. S. Steinberg, and R. J. Mislevy 2003 *A four-process architecture for assessment delivery, with connections to assessment design* (Los Angeles: UCLA CRESST).

[16] Partnership for 21st Century Learning Skills and P. for 21st Century, “Framework for 21st Century Learning,” *Partnersh. 21st Century Ski.*, pp. 1–2, 2011.