The synthesis of qualitative evidence-based learning by design model to improve TPACK of prospective mathematics teacher

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Abstract. Teachers in the 21st century are required to have the ability to integrate technology for content knowledge and teaching strategies known as TPACK. 21st-century teachers must have the knowledge and skills to use various technological tools, both traditional and modern, to facilitate learning and improve learning outcomes. For this reason, it is necessary to prepare prospective teachers who have the knowledge and skills to integrate technology into education. This research aims to design a learning model to develop TPACK of prospective elementary teachers in mathematics learning. This literature study is based on related articles or books and analyzed to formulate applicable learning models. The results showed that The synthesis of qualitative evidence-based learning by design could improve the TPACK of prospective teachers. Because it provides an authentic context to learn about educational technology by starting from the difficulties of students. Also, it enhances prospective teachers’ self-regulated learning and collaboration.

1. Introduction

The increasing role of technology makes the ability of TPACK teachers need attention among educators to maximize the potential of technology. A teacher with good content knowledge, effective teaching strategies, and integrating technology will encourage students to be actively involved and self-motivated to learn [1]. For this reason, it is necessary to prepare prospective teachers who have the knowledge and skills to integrate technology into the learning [2].

Teaching is a complex activity involving different types of knowledge. Teaching activities are based on learning about the material to be taught (content knowledge), how to teach a material (pedagogical knowledge), and knowledge about the use of various technologies (technological knowledge) which all three have a contact to be able to support one among others [3].

Learning in the 21st century integrates various technological devices in conducting a complete series of interaction processes between students and teachers with learning resources in a learning environment. Technology plays an active role as a tool, process, and at the same time, a resource for learning and implementing learning [4]. Therefore, students and teachers in the 21st century must have adequate technological literacy [5]. Moreover, future teachers must have good technology knowledge, skills, and competencies to integrate technology in learning effectively and efficiently [6].

Answering the challenges of 21st-century education, prospective teachers need to be prepared in the knowledge and skills of using technology to facilitate students’ learning. This research aims to develop the ability of TPACK prospective teachers in mathematics learning for elementary school students...
through SQD based Learning for Design (SQD-LD model). Through this research, prospective teachers will analyze students' learning difficulties in mathematics, then design learning media based on computer technology, practice, and reflection. Thus, prospective teachers created learning media and practice to teach students. Then prospective teachers revise based on students’ responses. This model will be effective for developing TPACK prospective teachers.

Several studies have been carried out in the development of TPACK prospective teachers. Examined the effectiveness of TPACK in teacher education by applying the Web-based IRIS Module in classroom action research [7]. The results showed that the use of TPACK in teacher education helped prospective teachers build a higher foundation of knowledge and skills. But research focuses on the role of TPACK on literacy and characteristics of students with special needs.

Concluded that the application of TPACK with an integrated approach develops the TPACK skills of prospective teachers from recognition to exploration [8]. They were applying an integrated pedagogical approach to investigate the impact on the knowledge and skills of TPACK participants. This integrated approach juxtaposes educational technology courses with method courses and field experience through careful instructional design. The findings revealed that participants experienced significant gains in all TPACK constructions. The results have implications for teacher education programs and researchers interested in developing and assessing preserving teachers' knowledge of teaching with technology. But this research was conducted on English subjects rather than on mathematics.

Furthermore, examined the development of TPACK for prospective teachers in science through the integration of Microcomputer Based Learning (MBL) in physics learning [9]. The study concludes that MBL allows the transfer of effective design and practice to prepare teacher candidates for science teaching. However, the findings of this study can only be applied to universities that have sophisticated laboratory infrastructure and require high computer skills. Explored strategies to prepare TPACK for prospective teachers through Synthesis of Qualitative Evidence (SQD) [10]. They argue that the SQD strategy can increase the TPACK of pre-service teachers. But they have a downside in the lack of concrete examples of how content and technology knowledge can relate to one another. Therefore, they suggest that pre-service teacher technology learning experiences should be related to their discipline and pedagogical knowledge. This is because teachers do not feel sufficiently ready to integrate technology effectively into the material they teach. They recommend that further research explore SQD strategies to accommodate certain types of technology (TK) in certain subject areas (CK) and specific pedagogical approaches (PK) in certain contexts.

Unlike the previous TPACK development research, this study developed TPACK through SQD based Learning for Design (SQD-LD model) for prospective teachers. SQD-LD model modifies the SQD model [10] with Learning by Design [11]. This research was conducted in the Mathematics Learning course in primary school, which examines the content and pedagogy of mathematics. At the same time, this research is a continuation of the study of Tondeur et al. because this model is applied to subjects related to the discipline of science and pedagogical knowledge.

2. Method
This method of the study is a literature review. The literature review was conducted by analyzing some literature, arrange them to interrelated ideas to develop the central issue [11]. To obtain the purpose of the study, we collected journals and books related to HOTS, Flipped Classroom, and Problem Based Learning. Then we analyze and synthesize to design Problem Based Learning Flipped Classroom learning model.

3. Results and Discussion
3.1. TPACK
TPACK was adapted from the PCK model [12]. The Technological Pedagogical Content Knowledge (TPCK) model is a framework that treats technology integration in education "as a way of thinking about knowledge [that] teachers need to understand how to effectively integrate technology in their
classrooms” [3]. TPACK consists of knowledge about content, pedagogy, and technology, as well as skills to use the interactions among these components [3].

Also, a similar opinion was conveyed that TPACK is an extension of PCK which functions as a support in the learning process integrated with PCK [13]. Furthermore, Hulya and Aysen stated that TPACK provides a lot of insight into how technology is related to other educational components so that the learning process is quality. TPACK was formed by a combination of 3 types of basic knowledge, namely Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK) [3]. The combination of 3 basic knowledge results, resulting in 4 new knowledge, including Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK). The image above clearly shows the interrelation between 3 basic knowledge that produces 4 knowledge.

![Figure 1. The components of the TPACK framework reproduced by permission of the publisher.](Image)

Technological knowledge (TK) or technological knowledge is the knowledge of various types of technology as tools, processes, and sources. Pedagogical knowledge (PK) or pedagogic knowledge is knowledge of theory and practice in planning, processing, and evaluation of learning. Content knowledge (CK) is knowledge of content or subject matter that must be learned by the teacher and taught to students.

Pedagogical content knowledge (PCK) is pedagogic knowledge related to special content (Shulman, 1986). Technological content knowledge (TCK) is the knowledge of reciprocity between technology and content. Technological pedagogical knowledge (TPK) is the knowledge of various technologies can be used to facilitate learning and learning.

Technological Pedagogical Content Knowledge (TPACK) or pedagogical technology knowledge and content is the knowledge of the proper use of technology on the appropriate pedagogic to teach a content well. The seven knowledge needs to be mastered by future teachers who will teach in a learning environment filled with various technological instruments. So that teachers can use the right technology on pedagogics that are appropriate for specific content well.

3.2. *The SQD based Learning by Design Approach*

The SQD based Learning by Design Approach is combination of The Synthesize Qualitative Evidence (SQD) System Model and Learning by Design Approach. SQD initiated by Tondeur [14]. The SQD model has 6 aspects, namely: (1) the teacher as a model, (2) reflection, (3) instructional design, (4) collaboration, (5) authentic experience, and (6) feedback (Figure 2).

The first step, the existence of lecturers as role models, in the first strategy in the inner circle of the SQD model, emphasizes the need for teacher educators to provide good practices. Prospective teacher also need to reflect on the role of technology in education (Step 2). This strategy involves discussing and reflecting on TPACK and the use of technology applications in education.
In step 3, the use of the collaborative design of curriculum materials to encourage the development of TPACK. Teachers need to design curriculum materials related to TPACK collaboratively (Step 4). As a fifth step, the pre-service teacher must also apply their TPACK in authentic settings. Finally, feedback, which is useful for developing pre-service teacher abilities to realize TPACK.

Meanwhile, [3] proposed the development of TPACK abilities using the learning by design approach. A learning-by-design approach to TPACK development and argues that, for teachers, one of the best ways to learn about educational technology is to design educational technology. Learning-by-design enables teachers to work in design teams with individuals with varying levels of expertise in content, pedagogy, and technology, and develop solutions to authentic pedagogical problems using technology. Argue that educational technology design provides teachers with an authentic context for learning about educational technology [3]. Design experience helps teachers design instructional media that are directly related to specific teaching materials and instructional objectives. Students participate in creating, designing, and implementing in learning. So that it can be seen later the suitability between learning components such as learning theory, application, students, implementation, meaning. Learning by Design was adapted to design courses around four principles: (1) problem-centered design assignments; (2) skills are developed through learning technology with an instructional design approach; (3) PTs work collaboratively and (4) PTs are involved in reflective practice[11].

Between the SQD model and Learning based design there is a similarity that is to create instructional design collaboratively. Also prospective teachers apply learning technology that has been restored to students.

3.3. SQD based Learning by Design Framework
Based on SQD theory and Learning by design, it can be argue that the TPACK development model framework for prospective teachers in Mathematics in Figure 3. Aspects of learning by design are implemented in the form of analysis of problems or difficulties learning mathematics students. Students' learning problems and difficulties are overcome with the development of learning technology. The application of SQD based learning by design begins with educators displaying the learning concept process using learning technology including using video, PPT and animation (role model). Learning technology plays a role in delivering how to align conceptual or procedural knowledge from a concept. In the learning process, proper and appropriate learning tools are used to achieve learning goals. Role model provide prospective teachers experience on pedagogical content knowledge. They have opportunity to learn the proper learning strategies in teaching and learning mathematics. Beside role model contribute prospective teacher self regulated learning [15]. Learning paradigm was change. Learner is not assimilating knowledge passively, but the are challenge to learn
different way. They live in internet environment and the get information in many ways, they able to analyze, criticize learning material.

![Figure 3. The SQD based learning design model.](image)

The second stage, reflection. Reflection refers students looking back what they did and analyzed their performance. In other word, reflection Reflection provides prospective teacher to compare and clarify their understanding to with educators and peers. Reflection connected to articulation which is prospective teachers verbalized their knowledge and reasoning. Educator invites prospective teachers to make reflections of the learning technology that has just been demonstrated. Reflection refers to the effectiveness and efficiency of learning technology. It's not limited to its advantages and disadvantages. Prospective teachers are also challenged to provide a better alternative.

The third stage, Student's mathematics instructional design project. This stage addresses students' problems in learning mathematics or students' learning difficulties. At this stage educators need to provide related references because prospective teachers have not taught and their knowledge is very little in this regard. The problem of students learning mathematics is then discussed and sought solutions based on mathematical learning theories obtained from books or research articles. The fourth stage, collaborative instructional design. Based on the solution, prospective teachers create a project to create instructional design and realize it in the form of learning technology. Prospective teachers collaborate in small groups.

The fifth stage, feedback. Each group presents a learning technology project. The same concept can be solved in different ways by each group. Educators provide feedback and prospective teachers can also provide opinions and suggestions for improvement if needed. The sixth stage, authentic experience. Learning technology is applied to elementary school students. The learning process is recorded and reported to educators. Prospective teachers make reflections on the effectiveness and efficiency of their projects. The SQD based learning model has advantages in developing learning technology based on students' problems in learning a concept. Students' problems in learning mathematics are almost found in all mathematical concepts. Helping students on basic issues will reduce students' problems on relevant concepts.

4. Conclusion
Based on the findings of the study can be concluded SQD based learning design effective to improve TPACK prospective teachers. The SQD based learning model phase are: 1) role model; 2) Reflection, 3) Students Mathematics Problem/difficulty; 4) collaborative instructional design project; 5) feedback; 6) Authentic experience.
SQD based learning by design gives prospective teachers the opportunity to learn from models, create collaborative projects and observe students’ response to instructional learning. The experience is very contextual and improve PCK dan TPACK of prospective teachers.

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