The implementation of tpack framework in mathematics mobile edugame design: basic multiplication and division concept

Y Rahayu\(^{1}\), H A Ahmad \(^{1}\), and I M Alamsyah\(^{2}\)

\(^{1}\)Faculty of Art and Design, Institut Teknologi Bandung, Jl. Ganesha no. 10, Bandung 40132, Indonesia
\(^{2}\)Faculty of Mathematics and Natural Science, Institut Teknologi Bandung, Jl. Ganesha no. 10, Bandung 40132, Indonesia

*ayu_yuniarti@students.itb.ac.id

Abstract. Mobile edugames were popular and has grown rapidly due to their ease of access, affordability, and interactivity. There have been numerous arithmetic related mobile edugames developed and available online. However, there are not so many mathematics mobile edugames existed which emphasize the basic concepts in accordance with Indonesia available curriculum and optimalize specific learning methods that suitable for targeted learner have been developed, particularly in basic division and multiplication materials. Through this study, the design of mathematics mobile edugame about basic division and multiplication with repetitive addition and subtraction concept will be discussed using TPACK framework that generates design recommendation and its application in mathematics mobile edugame with discovery-based learning model as an outcome. It uses specific TPACK plot from PCK to TPACK. The result shows in optimization used of technology in mathematics mobile edugame design user cognitive psychology development, gameplay and applied learning method are the most important aspect that then generates an adventure-puzzle mathematics mobile edugame which utilizes storytelling as final result.

1. Introduction

In the last 21\textsuperscript{st} century, technology have been growth rapidly and massively used in various field of life. It includes educational field that can be seen from the numerous educational games have been developed and available online. Mathematics is one of school subjects that often considered as challenging, difficult or even disliked by students in any school levels [1-3] that also become one of the subjects that widely used as educational game content especially in basic arithmetic for kindergarten and elementary students ages as targeted audience consider it is as basic but essential materials, the needs of practice in mastery\(^{1}\) and potential used by the targeted audience\(^{2}\). However, the available games which emphasize the basic concept in accordance with the latest Indonesia curriculum and applies specific learning method that suitable for targeted users have not been much developed notably in basic multiplication and division with repetitive addition and subtraction concept. Meanwhile media that support mathematic conceptual

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\(^{1}\) The Norwegian University of Science and Technology (NTNU) 2013 *No math gene: Learning mathematics takes practice*

\(^{2}\) The Asian Parent Insights 2014 *Mobile Device Usage Among Young Kids: A Southeast Asia Study*
understanding is needed considering PISA\(^3\) and Indonesian Student Competency Assessment (AKSI)\(^4\) survey that shows mathematical abilities of Indonesian students are still below average specifically in basic concept understanding, the use of most advanced technology also does not guarantee better learning outcomes if it is not balanced with any appropriate learning methods or models [4, 5]. Therefore, the development of mathematics mobile edugames that emphasize multiplication and division basic concept that not only focuses on its content and technology but also its pedagogy-related aspect is needed.

2. Method
This research uses Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra and Koehler’s as Shulman’s pedagogical content theory expansion which integrates technology, pedagogy, and content aspects as the basis of good teaching and optimal learning instruction development [6, 7] in this case is mathematics mobile edugame development about basic multiplication and division concept. There are three main components of knowledge that become the foundation of this framework and four components that show the three main components interact each other with TPACK as a result of all the components (see Figure 1).

![Figure 1. Technological Pedagogical Content Knowledge (TPACK) Framework](source: [6, 7])

The path of TPACK framework implementation in this research is PCK to TPACK where the process begins with selection of content knowledge which determine specific users followed by learning methods and appropriate technology selections respectively. After three aspects decided, discussion will begin with the blend of content and pedagogy aspects (PCK) followed by the implementation of PCK in the appropriate technology selected (see Figure 2).

![Figure 2. The path of TPACK framework from PCK to TPACK](source: [6, 7])

3. Result and Discussion

\(^3\) OECD 2016 Programme for International Student Assessment

\(^4\) Kementrian Pendidikan dan Kebudayaan 2017 Asesmen Kompetensi Siswa Indonesia (AKSI)
3.1. Basic Multiplication and Division as Content Knowledge (CK)

According to Indonesian latest curriculum, multiplication and division material is part of mathematic school subjects that begin to be learned in 2nd grade (around 6-9 years old) of elementary school level. The multiplication material begins with an introduction of repetitive addition concept where questions normally presented by asking all the multiplication components through iconic representative in order to generate students understanding of which numbers are multipliers or multiplied. The questions will be presented with more symbolic representations and tend to ask the result afterwards. After completing the multiplication learning, students will begin to learn division materials. The same learning process is applied, but the division material emphasizes repetitive subtraction. All the materials will be limited to natural numbers whose results are from 1 to 100 which means multiplication and division of 1 to 10 corresponding with basic competencies in curriculum. The overall content aspect can be seen in Figure 3.

![Figure 3. Content Knowledge (CK) details.](image)

3.2. Discovery Based Learning as Pedagogical Knowledge (PK)

Pedagogical knowledge consists of certain learning methods or models that influence learner understanding towards the material taught. Considering the contents, the age of learner, and existing curriculum that emphasize constructive-active learning with student-centered approach to generate meaningful learning, discovery-based learning is chosen to be used with guided type in specific since it is a recommended instructional event for concept understanding as a learning outcome. Discovery-based learning is a learning model where the learning process encourage learners to actively searching or finding the knowledge and information with their prior knowledge through assimilation and accommodation. The material also not presented in final form in order to provide opportunities for learners to do some explorations in problem-solving situations. There are principles and syntax of learning methods that will be considered in the implementation. There are five principles in discovery-based learning that referred in this study which are intellectual development, interaction, questioning, thinking and openness. Besides the model principles there is also a syntax or an application procedure that needs to be followed in discovery-based learning process that consist of stimulations, problem statement, data collection, data processing, verification and generalization. The overall pedagogical aspect can be seen in Figure 4.

![Figure 4. Pedagogical Knowledge (PK) details.](image)

3.3. Pedagogical-Content Knowledge (PCK)

After deciding particular content and pedagogical aspects that will be used, the blend of those knowledges will be discussed that will involve target user aspect with their cognitive development for consideration during the development process. Refer to Brunner theory, the 2nd grade students that usually in range of age between 6-8 years old is between the development of iconic and symbolic

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5 Kementrian Pendidikan dan Kebudayaan 2014 Kurikulum 2013
representations [14] which means they still need an iconic representative involvement and already balanced by the symbolic representative gradually. According to Piaget theory, 2nd grade students is in the beginning of concrete operational stage where the object representation involves concrete things [15, 16]. Consider Brunner and Piaget theory, manipulative mathematics widely used in mathematics learning as a tool to explain abstract mathematical concepts and proven to have a significant effect on student learning outcomes [17-19]. The overall pedagogical-content aspect can be seen in Figure 5.

**Figure 5.** Pedagogical-Content Knowledge (PCK) details.

PCK part in this study will discuss the mathematics learning activities that implement each point in discovery-based learning syntax that is showed on Table 1.

| Syntax            | Activities                                                                 |
|-------------------|-----------------------------------------------------------------------------|
| Stimulations      | Teacher/facilitator tells a story that stimulate student imaginations which leads to a problem situation. |
| Problem Statement | Teacher/facilitator explains specific problem that need to be solved by involving mathematics skill. In this case is multiplication and division. |
| Data Collection   | Student collects certain relevant information that can help them find the answers or solutions to the problem. The data is presented with the involvement of manipulative mathematics. |
| Data Processing   | Student thinking processes in assimilating and accommodating data obtained with their knowledge. |
| Verification      | Student checks answers based on the results of existing data and information processing. |
| Generalization    | Student draws conclusions about their findings based on the evidence of previous data in general. In this case they can write the form of repetitive addition and subtraction based on the mathematics question. |

**Table 1.** Discovery-based learning syntax implementation in math learning

3.4. *Mobile Edugame as Technological Knowledge (TK)*

Considering media ease of access, affordability, and interactivity mobile edugame is chosen as the technological knowledge. Edugame is a game that focuses on learning while still fun and entertaining [20]. In designing a game there are four fundamental elements that collaborate and rely on each other's presence which are mechanic, aesthetic, story and technology [21]. The overall technological aspect can be seen in Figure 6.

**Figure 6.** Technological Knowledge (TK) details.
3.5. Pedagogical Content Knowledge (PCK) to Technological Pedagogical Content Knowledge (TPACK)

According to the math as a content and discover-based learning as the method applied, there are several things that need to be considered supporting a better way of materials delivering such as curriculum. Then, considering the characteristic of 2nd grade elementary students, according their cognitive psychology development easy to learn by involving concrete objects, have begun to be able to carry out operational processes on the count and think logically (reasoning) where symbolic representative (language) is also starting to be involved to reach understanding of abstract concepts. It also could be supported by using manipulative mathematic, a concrete object that can be touched and moved with hands that can help classification, patterns, calculations, equations, and mathematical tasks. Story also can be used to make the stimulations in math problem. Another aspect is content and technology aspect where to support story in stimulation stage process, adventure puzzle genre could be applied considered it prioritizing exploration and problem solving where the puzzle tends to involve more thought processes than other genres than can present the learning content applied well. [21, 22] Fantasy theme seems suitable since the user is a 2nd grade of elementary student. [23] Moreover, discovery-based learning syntax in learning could be adjusted with the game feature as the blend of pedagogy & technology aspect that shows in Table 2. The whole discussion using the tpack framework can be briefly seen in Figure 7.

| Syntax | Activities |
|--------|------------|
| Stimulation | Prologue Video |
| Problem Statement | Instruction in each stage that have different gameplay with mathematics-related problem. |
| Data Collection | Visual asset contained in game environments. |
| Data Processing | Interaction that occurs with the user with the design elements contained in the game environment. |
| Verification | Button to do the answer validation (non-automatic response). |
| Generalization | A session in the game that displays the conclusions of learning from the activities that have been carried out by players in the main game. |

Table 2. Discovery-based learning syntax adjusted with game features

![Figure 7. TPACK framework correlation.](image)

3.6. Game Design Recommendations
Build upon previous discussion using TPACK framework, math mobile edugame design recommendations are generated as in Table 3.

| Aspects                  | Details                                                                 |
|--------------------------|--------------------------------------------------------------------------|
| Cognitive Psychology     | · Math problem presented with both iconic and symbolic representative    |
| Development              | · The iconic representative used in math problem should be countable and clear
   (not confusing by represent something that already a representative).  |
|                          | · Manipulative mathematic is recommended to be used.                      |
|                          | · The use of language that simple, clear and easy to be understood especially in
   the instructions provided to stimulates the user.                      |
| Gameplay                 | · Math problems contained in the game made unified in gameplay.          |
|                          | · Provide math problems with multiple answers but avoid the ambiguous choice
   that can lead to the other math topics.                                  |
|                          | · Provide clear game instructions without reveal the main topic that will be
   learned because user need to discover it by themselves.                  |
|                          | · Recommended to use adventure-puzzle genre while the learning process could
   be optimized in puzzle.                                                 |
| Learning Method          | · Discovery-based learning syntax should be applied in order.            |
|                          | · The role of facilitator in learning process can be applied into the hint feature,
   pop-up board, instructions or even vibrate without set aside the in-formation
   presented in the form of question that can stimulates user.              |
|                          | · Emphasize in the process while the math question is not always asking for the
   result of the multiplication operation but all the components.            |

3.7. Game Result

According to the discussion in previous sections, here are the output of the adventure-puzzle mathematics mobile edugame with the title ‘Hunt of magic Potions’. When students enter the game, they will be provided with the prologue video that shows the main problem which is a chaotic palace caused by a bad wizard that makes players have to find potions as the main goal. This is a part of stimulation phase. Then, an adventure begins when player needs to go to the dragon cave where the first mathematics problem will be faced. A short video will appear that shows an instruction a specific mission which is a part of problem statement phase. The most interesting here is the main gameplay that show on the Figure 8.

Students will be exposed in scene with data that consist of both iconic (countable berries) and symbolic representative that can be used to solve the problem and reach the goals as the phase of data collection. When player begin to move the visual asset in the cave, it is called data processing phase. Student needs to click the ‘makan’ button to check the answer which also part the verification phase. If the answer is correct, the student will be entering the generalization scene both repetitive addition and multiplication form with several questions as a guide. Guide, hint and feedback in this game are mostly shown in the form of questions. After completing the multiplication game, division session in fairy forest will be unlocked.
Figure 9. Division gameplay preview.

The gameplay on the Figure 9 is a little different because of the repetitive subtraction concept. Overall the game uses a simple but clear language, uses iconic and symbolic representatives in proportional way, involves manipulative mathematics, utilizes the technology feature such as sound, music and vibration effect, also presenting mathematics problem that unified with gameplay.

4. Conclusion
Technology used with considering both content and pedagogical aspect could avoid an ineffective use of technology in math mobile edugame development. In the development process, several points related with target user cognitive psychology development, gameplay and applied learning method need to be considered. Type of game that utilize storytelling, presenting mathematical problems that unified with gameplay and involves both iconic and symbolic representative in proportional way are potentially to be developed further for better educational game development. Application of discovery-based learning model covers all its syntax and principles that can be seen from gameplay, visual, facilitator role that spread into several game elements such as hint or feedback, stimulation and feedback in the form of questions and non-automatic mathematics operation result.

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