Scientific Contexts in Pre-Service Elementary Teacher-Designed Mathematics Picture Books

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Abstract. Mathematical literacy is a key point of the PISA study, and students are expected to deal with mathematics in a variety of contexts. A scientific context is one among four areas that could challenge students to understand mathematics and link between mathematics and sciences. Therefore, this study aims to investigate the scientific contexts from two mathematics picture books (MPB1 and MPB2) designed by two groups of pre-service elementary teachers in 2015. The content analysis is used as a research method to evaluate the spectrum of the scientific contexts and how they relate to mathematics contents. The findings show that MPB1 is designed based on an environmental issue, go green, while MPB2 based on farm environment. While the mathematical content of MPB2 is more challenging than MPB1 because it requires students’ mathematical problem-solving.

1. Introduction
Program for International Student Assessment (PISA) is an international study that tests 15-year-old students’ competences in reading, mathematics, and science [1]. The study is designed to evaluate how well the students perform on those key subjects in order to be prepared for real-life situations. Therefore, the tasks are designed differently from standard national tests in many countries, including in Indonesia.

In mathematics, mathematical literacy is a key point of the PISA study. This means that the students are expected to have the capacity to formulate, employ and interpret mathematics in a variety of contexts; personal, occupational, societal, and scientific [1]. The personal context is a problem focusing on activities of one’s self, one’s family or one’s peer group such as food preparation, shopping, games, personal health, personal transportation, sports, travel, personal scheduling and personal finance. The occupational context is a problem centred on the world of work, such things as measuring, costing and ordering materials for building, payroll/accounting, quality control, scheduling/inventory, design/architecture and job-related decision making. The societal context is a problem focusing on one’s community (whether local, national or global), such things as voting systems, public transport, government, public policies, demographics, advertising, national statistics and economics. Finally, the scientific context is a problem relating to the application of mathematics to the natural world and issues and topics related to science and technology, such areas as weather or climate, ecology, medicine, space science, genetics, measurement and the world of mathematics itself.

In this study, the scientific contexts are examined from mathematics picture books written by pre-service elementary teachers from an elementary teacher education in an institution in Indonesia. The mathematics picture books are books that contain texts and pictures, where pictures have a very important role in communicating and providing understanding [2, 3]. While, mathematics is believed
to be difficult for students to learn [4, 5] and for teachers to teach [6, 10], so combining mathematical concepts in math picture books is an opportunity to help students understand mathematics in an interesting and easy way. The mathematics picture books could support students’ mathematical literacy. Thus, the main research question for this study is to examine what scientific contexts are presented in pre-service elementary teacher-designed mathematics picture books, and how those contexts are related to mathematical contents.

2. Methods
The present study applies content analysis as a research method to investigate scientific contexts in mathematics picture books designed by pre-service elementary teachers. The content analysis is a method aiming to investigate a broad spectrum of problems where the contents, communicated in mathematics picture books, act as a basis for conclusions [11]. The approach to content analysis is done carefully in determining the appropriate category and unit of analysis. Specifically, in this study, the scientific contexts are evaluated from titles, pictures, and stories of mathematical picture books, and then those are analysed based on the PISA framework such as whether the contexts related to weather or climate, ecology, medicine, space science, genetics, measurement, and other related topics. Then, the mathematical contents are analysed within the praxeological analysis: types of task, proposed techniques, technological discourses to justify those techniques, and possible theories to explain the technology [6 - 10, 12, 13].

Sixteen mathematics picture books were designed by second-year student teachers during their participation in the course of mathematics instruction for the upper-grade elementary school in 2015, but only two mathematics picture books were related to scientific contexts. Therefore, we only focus this case study to analyse the two mathematics picture books. The general information of those books are presented in table 1 as follows:

| General information | Mathematics picture book 1 (MPB1) | Mathematics picture book 2 (MPB2) |
|---------------------|----------------------------------|----------------------------------|
| Title               | Go green [14]                    | Brain teaser of Mr. Tono [15]    |
| Number of authors   | 4 female student teachers        | 5 female student teachers        |
| Page numbers        | 7 (not include the title)        | 7 (not include the title)        |

3. Results
The content analysis of the two mathematical picture books is presented separately into two subsections. In each subsection, we first present the scientific context and followed by the praxeological analysis of the mathematical aspects.

3.1. Scientific and praxeological analysis of MPB1
The scientific context is clearly presented in the title and drawing of the book cover (Figure 1a). The title “go green” indicates that the scientific context is about an environment, such as how students should care about greening. A tree, some flowers, and grass presented in the cover also provide some support to the environmental issue. While a female student, standing in the centre, may illustrate that students have to care about the environment issue around them.

Figure 1b and 1c illustrate the scenery of the conversations take place. The situation shows how green the areas are. For instance, two students meet and discuss the task given by the teacher in the school garden where a tree, a grass, and some flowers support the setting of the scientific context (Figure 1b).
The task giving to the students is presented in figure 1b. The teacher asks a student to plant 12 plant seedlings in three areas, in front of the classroom, in the school garden, and in front of the school canteen. This kind of task relates to science and mathematics. Then, it is followed by a situation where the student sits on the garden and thinks about how to solve that task, and then his friend comes and provides some help. In figure 1c, the two students discussed the task, and the background of the picture consists of some flowers that indicate the environmental setting of the conversation.

In relation to the mathematical praxeology, the task given to the students is presented in a contextual situation: the teacher asks the students to plant 12 plant seedlings in three areas. Mathematically, this task can be written as $12 \div 3$, and it belongs to the division of integers (the type of task). The technique to solve the task is presented in figure 1. First, each place gets one plant seedling, so three plant seedlings have been shared into three areas. The students follow this step until all plant seedlings equally shared in three places. Thus, the result is 4 plant seedlings be planted in each place. There is no technological-theoretical discourse presented in MPB1, but we can argue that the partitive division is part of the theoretical dimension used by the book authors to justify the mathematical practice.
3.2. Scientific and praxeological analysis of MPB2

The cover of MPB2 does not present a clear image, but we still can see the setting of the figure (Figure 3a). It shows several activities on a sunny day, such as two kids standing close to different types of animals like four ducks, a dog, and a rabbit. Yellow flowers are presented as the scenery of this cover. However, the title, “Brain teaser of Mr. Tono”, does not really present the scientific context of the book.

Figure 3b and 3c illustrate the scenery and the setting of the activities doing by the students. The story is about a group of students visiting a farm. In figure 3b, the students first get off the bus and then they enter the farm. The story tells “the students go around the farm and they see an elephant, chickens, ducks, goats, and other farm animals”. This explanation is supported by the drawings of some animals in the cages in figure 3a and 3b. In addition, the green scenery becomes the background of figure 3c. However, the elephant, categorised as a farm animal in MPB2, seems inappropriate because it is a wild animal, and it can only be seen in the zoo.

![Figure 3a. MBP2’s cover](image)

![Figure 3b. Students’ task](image)

![Figure 3c. Students’ discussion](image)

In figure 4a. The book authors present a mathematical situation based on the situation on the farm. It is a group of students finding a closed cage where they cannot see and count how many animals there. The farmer, a male drawing with a cone hat (figure 4a), explains the mathematical situation as follows:

“Inside of this cage, there are 10 animal heads and 26 animal legs, and some animals have 4 legs, and the others have 2 legs. How many animals have 4 legs and animal have 2 legs?”

The mathematical situation leads students into two questions (the below figure in figure 4a), and it is about how one can calculate the number of animals if the cage is closed. Mr. Tono, the farmer, argued that it is not necessary to open the cage to know the number of animals. This situation triggers the students to think mathematically about how to solve this type of mathematical task, and this task belongs to mathematical problem-solving.
Figure 4b presents a solution to the mathematical task proposed by a student who explains to the other five students. His explanation can be described as follows:

“…In the cage, there are 10 heads and 26 legs. Look at this, we first draw 10 heads. In each head, we add two legs, so 20 legs have been used, and 6 legs are still available. Then, we add 2 more legs to each of the 3 animals. Now, all those legs have been matched to all heads, so we can calculate how many four-legged animals and two-legged animals are.”

The mathematical technique presented can be categorised as an informal technique. It can be understood by the elementary school students because the drawing and the logical explanation provides an opportunity to mathematize the concrete situation into abstract mathematics [16]. Realistic mathematics becomes the technological-theoretical discourse to justify that technique.

MBP2 also proposes an alternative technique to solve the task (Figure 4c). This technique is more formal and based on the elimination and substitution method of solving systems of equations in two linear variables. The idea is to model the two animals with the variable $I$ and $K$, so the mathematical situation can be written as follows:

\[
I + K = 10 \quad (1) \\
2I + 4K = 26. \quad (2)
\]

To solve the equations, the mathematical technique is to multiply the first equation by 2 and then subtract it by the second equation, so $K$ equals 3. By substituting $K$ into (2), $I$ equals 7 (Figure 4). The formal procedure to solve the equations in two linear variables is the technological discourse to explain the technique, and linear algebra becomes the formal theory to explain this technology. But, this type of knowledge is not part of mathematics curriculum in elementary school, and the students may challenge to learn it.

4. Discussion and concluding remarks
The results of this study show difference scientific contexts presented in both MPBs. MPB1 are designed based on the idea of an environmental issue, go green, and it is clearly in the step of an example of scientific contexts on the PISA framework [16]. The drawings on MPB1 really support the scientific knowledge in which the students have to take care of their school environments. While, the scientific context in MPB2 is built upon a situation in a farm, but it provides misinterpretation between a farm and a zoo, because an example of animals, an elephant, and use of the cage, may not represent an appropriate situation in the farm.

The mathematical contents of the two MPBs are built upon difference praxeologies. MPB1 proposes a simple mathematical task, how to share 12 plant seedlings into three different areas, and this type of task is really appropriate for learning division in elementary school. MPB1 only proposes a single mathematical technique based on partitive division, while other potential techniques, such as
measurement and quotative division, could add some challenging and potential for the quality of MPB1. On the other hand, MPB2 presents a problem-solving task, and it also provides two alternative mathematical techniques, the informal technique and the elimination and substitution technique of solving systems of equations in two linear variables. This type of task and techniques could trigger elementary school students’ problem-solving skills, and those are totally different from Indonesian pre- and in-service teachers’ mathematical and didactical knowledge [16-10]. The teachers tend to instruct pupils based on direct instruction of formal mathematical techniques.

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