Gender bias on the students’ scheme in ratio and proportion solving problems

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Abstract. The research aims to describe the gender bias on the student’s schema in ratio and proportion problem solving. The schema means to represent the student’s concepts stored in his or her memory and used for ratio and proportion problem solving. The research was conducted at SMP Muhammadiyah Program Khusus Junior High School in Surakarta, Indonesia. It employed a qualitative approach. The data were collected by interview and students’ written works. The subjects amounted to 2 male and female students with the similar high mathematical ability. The data were analyzed by using an interactive model, including data collection, data reduction, data presentation, and conclusions. The results of the research show that (1) the students’ schema in ratio and proportion problem solving comprised the content schema, the formal schema, and the linguistic schema; (2) the male subject with high mathematical ability (SLT) used the unit rate strategy, the cross product strategy, and the equivalent class strategy in ratio and proportion problem solving; and (3) the female subject with high mathematical ability (SLT) employed the equivalent strategy, the unit rate strategy, and the build up strategy in ratio and proportion problem solving. The different strategies in problem solving indicates varying schema in solving problems related to ratio and proportion.

1. Introduction

Mathematics is a structured science in which mathematical concepts are arranged hierarchically, logically, and systematically beginning from undefined elements, defined elements, axioms or postulates to the theorem. Thus, learning mathematical concepts requires prerequisites as a basis of understanding the next concept. In relation to mathematics, Bell F stated that the characteristics of mathematics are to have an object of abstract study that relies on agreement, deductive thinking that pays attention to the universe of conversation and is consistent in its system [1]. Based on these characteristics, the basic objects of mathematics in the form of facts, concepts, operations or relationships, and principles are mental objects or mind objects [1]. Because of these, information process will occur and these mental objects will be stored in memory[2]. Sternberg stated that memory (long-term memory) is a place to store knowledge[3].

Regarding knowledge, Anderson stated that schema is a collection of prior knowledge that provides a context for interpreting new information [4]. Anderson also defined that, schema is as abstract knowledge structures that regulate some information to the system that is meaningful. So, it is a person's mental structure in which he or she intellectually adapts to his surroundings. Rumelhart stated that the basic elements by which information processes depend on: schemas are used in the process of sensory interpretation of data, repeating information, organizing actions, setting goals and directing processes in the system[5]. Furthermore, Rumelhart stated schema as data structures to express concepts stored in
memory (schemas represent knowledge). Thus, it can be stated that the schema is a structure concept stored in memory and helps to interpret new situation or information.

The schema can be developed through learning process. Students can form new schemas of new experiences and they can add new components to the old schema. They can complete and develop it if they face new experiences, problems, and thoughts. In the learning process, they face changes to the schema either by adding components, improving, developing or changing the old schema[6]. The schemas they have can be equipped and developed through problem solving. To sharpen students' abilities in mathematics, it is necessary to give a problem, where the problem is not a routine problem [7].

Ratio and proportion are mathematical materials as a learning outcome discussed by Elementary, Junior, and High School students. It is due to many daily problems solved by using the concept of ratios and proportions. However, students are difficult to employ ratio and proportion problem solving. The introductory research showed that the students don’t solve mathematical problems, due to lack of students in understanding them and low ability in computing. In addition, in a mathematical problem solving, students’ ability, accuracy, and skill are different from one another. As Maccoby and Jacklin stated, girls have greater verbal ability than boys and that boys excellent in visual spatial ability[8]. However, the male and female students are similar in their early acquisition of quantitative concepts and their mastery of arithmetic during the grade-school year, beginning at about age 12-13, but males’ mathematical skills increase faster than female’s ones[8].

The problem statements of the research include (1) what kind of the students’ strategies are used in ratio and proportion problem solving and how is the students’ schema in ratio and proportion problem solving based on gender? It is greatly essential because by understanding the students’ schema in ration and proportion solving problem will make easier for teachers to develop the students' knowledge based on their schema.

2. Methods
The type of research is an exploratory research with qualitative approach. The research was conducted at SMP Muhammadiyah Program Khusus Junior High School in Surakarta Indonesia. The subjects were two seventh grade students, namely (1) the subject (SLT) representing a male student and (2) the subject (SPT) representing a female student. Both of these subjects have the same mathematical ability. The instruments used in this study were the researchers to be the main instrument, the assignment sheet in the form of ratio and proportion problem solving, and audio visual recording equipment. As the main instruments, the researchers acted as as a planner, data collector, data analyzer, and data estimator. The task problem solving for the ratio and proportion materials are described as follows.

"Hidayat likes cats. He has 3 cats. He has fed 4 kg of cat foods to his three cats for days. Mr. Anwar, his uncle, bought 9 cats for him. In the same portions, how many kg of foods has he needed to feed all of his cats for a week?"

The data based on the results of assignment problem solving in writing, observations and results of interviews were analyzed by taking these stages: (1) transcribing all interview data from written records and recorded results, (2) reducing data by making abstractions, (3) arranging into units categorized by making coding, (4) analyzing the schema process based on mathematical and gender abilities, and (5) making a conclusion of the answer sheet and interview results, analyzed based on schema indicators in problem solving[9].

3. Results and Discussion
To find out the students’ schema in ratio and proportion problem solving, the subjects were given the questions. Their responses to the problem and interview results are presented as follows.

3.1. The male subject with high mathematical ability (SLT)
The results of the subject’s written answers are reported in Figure 1 below.
To find out SLT’s schema in problem ratio and proportion solving, it is necessary to interview the subject to clarify the written answers as presented below.

| Q*: Have you ever got a problem like this? | Q: What do 3 cats mean - 1 kg of food for one day? |
| SLT**: Never | SLT: It is for 3 cats - 4 kg of foods for 4 days. So, 3 cats need 1 kg of food for one day. |
| Q: Can you explain what is meant by the question? | Q: What do you mean by this? |
| SLT: Hidayat has 3 cats. He has fed 4 kg of cat foods for 4 days and now he has 12 cats. | SLT: 3 cats need 1 kg of foods. 12 cats need 4 kg of foods. |
| Q: What is the problem with the question or what is being asked? | Q: How to solve this problem? |
| SLT: The question is how many kg of foods needed by 12 cats for one week. | SLT: Calculating the foods needed by 3 cats for one day, 12 cats for one day, and 12 cats for one week. |
| Q: How to solve this problem? | Q: How many kg of foods are needed by 12 cats for one week? |
| SLT: 3 is multiplied by 4 = 12, then the denominator must also be multiplied by 4, so? = 4 | SLT: 4 x 7 = 28 kg of foods |

From the results of written answers and interviews with SLT, the phases in solving the problem of ratio and proportion can be described as follows.

**The preparation phase**
In the preparation phase, the subject (SLT) prepares for ratio and proportion problem solving. It is preceded by his activities by reading and understanding the questions. When understanding them, he takes the following activities, including 1) identifying the ratios of the problems, namely cats, food and days; 2) identifying the elements that build a ratio of cats to 3 cats and 12 cats: the elements for the day ratio are 4 days and 1 week and the elements for the food ratio are 4 kg and x kg; and (3) stating what the question of the problem is.

**The planning phase**
In this planning phase, the subject devises a plan for problem solving by determining (1) the foods needed by 3 cats for one day, (2) those needed by 12 cats for one day, (3) those needed by 12 cats for one week.

**The execution phase**
In this execution phase, he takes the completion steps as planned in the planning phase. In the first step, he calculates the foods needed by 3 cats for one day: 3 cats need 4 kg of foods for four days, so 3 cats need 4 kg divided by 4 = 1 kg of food for one day. In the second step, he calculates the foods needed by 12 cats for one day: 3 cats need 1 kg of food for one day, so the foods needed by 12 cats for one day are found. To find a value \( x \), 3 is multiplied by 4 = 12, so \( x \) equals to 1 multiplied by 4 equals to 4. 3) In the last step, he calculates the foods needed by 12 cats for one week (7 days). He said that 12 cats need 4 kg of foods for one day, so the foods they need (4 kg x 7) equal to 28 kg for 7 days.

Based on the results of interviews and data analysis of written work on the issue of contextual ratio and proportion, the subject’s schema in proportion problem solving is described as follows.

1) The content schema identifies (a) selected information from problems relevant to the prior knowledge by identifying ratios that arise from the problem; (b) the elements chosen to build a ratio based on the prior knowledge, namely the concepts of proportions, ratios and fractions; and (c) what the question of the problem is.

2) The formal schema includes (a) explaining the elements that have been chosen to build a mental model, (b) using the schemas of proportions, ratios, fractions, multiplication, and division to build the planning steps used to solve problems, and (c) taking the stages of the design that have been prepared to determine the weight of food needed by 12 cats for 1 week by using the unit rate strategy, the cross product strategy, and the equivalent class strategy[10].

3) The linguistic schema identifies terms and symbols from selected elements and the subject can use terms or symbols in building mental models, plans solutions, and implements the phase of the design prepared. For more details, the profiles of SLT’s schema in proportion problem solving are presented in Figure 2.

**Figure 2. SLT’s Schema in Ratio and Proportion Problem Solving**

**Explanation:**

| Content Scheme | Formal Scheme | Language Scheme |
|----------------|--------------|----------------|
| **D1** | **E1** | **D2** |
| Identifying the ratio to build proportion | Identifying the elements of cats, food and days that build proportions | Identifying many cat elements to build ratios |
| **D3** | **E2** | **D1** |
| Identifying the elements of the day to build a ratio | Calculating the food needed by 3 cats for one day | Calculating the food needed by or 12 cats for one day |

4
D4: Identifying the elements of food to build a ratio
E4: Calculating the food needed by 12 cats for one week
D5: Declaring what the question of the problem is
E5: Using the unit rate strategy to answer E2
C1: Expressing the elements of the ratio to form proportions
E6: Using the division concept to answer E2
C2: Planning to calculate the food needed by 3 cats for one day
E7: Using the cross product strategy to answer E3
C3: Planning to calculate the food needed by 12 cats for one day
E8: Using the multiplication concept to answer E3 and E4
E9: Using the equivalent class strategy to answer E4
C4: Planning to calculate the food needed by 12 cats for one week
F1: Using the symbol "..." to express ratio
Use the symbol "... = ..." to express proportion.

C5: Using the unit rate strategy to answer C2
F2: Using the symbol "..." to express "so", "need", and "duration/for"
C6: Using the cross product strategy to answer C3
F3: Using the symbol
C7: Using the equivalent strategy to answer C4
to express a x 4 = b

3.2. The female subject with high mathematical ability (SPT)

The results of the written answers are described in Figure 3 below.

Figure 3. Results of SPT’s Written Answers
Based on the results of written answers and interviews with SPT, the phases in ratio and proportion problem solving can be described as follows.

**The preparation phase**
In the preparation phase, the SPT performs the following activities. First, she identifies the ratios of the problems, including cats, food and days. Second, she identifies the elements that build a ratio, the ratio of cats to 3 cats and 12 cats: the elements for the day ratio are 4 days and 1 week and the elements for the food ratio are 4 kg and X kg. Third, she states what the question of the problem.

**The planning phase**
In this phase, the SPT develops a plan to solve the problem by determining the foods needed by 12 cats for four days, for one day, and for one week.

**The execution phase**
In the execution phase, SPT takes the completion steps as planned in the planning stage. These steps are calculating (1) the foods needed by 12 cats for four days: 3 cats need 4 kg of foods for 4 days, so 12 cats need 16 kg of food for 4 days; (2) those needed by 12 cats for one day: 12 cats need 16 kg of foods for 4 days, so the foods needed by 12 cats for one day amount to 16 kg divided by 4 = 4; (3) those needed by 12 cats for three days, namely 4 kg x 3 = 12 kg; and (4) those needed by 12 cats for one week: 12 cats for four days plus 12 cats for three days = 16 kg + 12 kg = 28 kg.

Based on the data analysis of the written work and interview of contextual problems, the subject’s schema in proportion problem solving can be described below.

(1) The content schema includes (a) explaining the selected information from the problems relevant to the prior knowledge by identifying the ratios of the problem, (b) describing the elements chosen to build a ratio based on the prior knowledge, including the concepts of proportions, ratios, and fractions, and (c) explaining what the problem of the problem is.

(2) The formal schema includes (a) describing the elements that have been chosen to build a mental model, (b) using the schemas of proportions, ratios, rapport, division, addition, and fractions to build the planning steps for problem solving, and (c) taking the stages of the design that have been prepared to determine the weight or portion of foods needed by 12 cats for 1 week using the equivalent class strategy, the unit rate strategy, and the build-up strategy[10].

(3) The linguistic schema means the subject’s ability to identify terms and symbols from selected elements and use them for building mental models, planning solutions, and implementing the stages of the design prepared.

3.3. **Discussion**
The schemas produced by SLT and SPT in proportion problem solving comprise content schema, formal schema, and linguistic schema [11][12]. The content schema in ratio and proportion problem solving includes (1) explaining the information selected from the problem in the form of identification of the ratio of cats, days, and food; (2) identifying the elements that build the ratios of cats, days, and food, and (3) explaining the questions in the problem. Thus, both SLT and SPT as a male and female subject have the same content schema in proportion problem solving. It is relevant to [12][11], stating that the content of the information of what happened and how the relationship of one event to another occurred are to build a logical relationship.

The formal schemas produced by SLT in proportion problem solving include (1) building a mental model in the form of planning steps by determining the foods needed by 3 cats for one day, 12 cats for one day, and 12 cats for one week and (2) implementing the completion steps as planned in the planning stage by using the unit rate strategy, the cross product strategy, and the equivalent class strategy. The formal schema produced by SPT in proportion problem solving covers (1) building a mental model in the form of planning steps by determining the foods needed by 12 cats for four days, for one day, for three days, and for one week and (2) taking the stages of the design that has been prepared to determine
the weight or portion of the foods needed by 12 cats for one week using the equivalent class strategy, the unit rate strategy, and the build-up strategy. The uses of the equivalent class strategy and the unit rate strategy are often used by the students in proportion problem solving [13]. Thus, the formal schema produced by SLT and SPT is a process of constructing and testing a problem based on the prior knowledge [11] [12]. Furthermore, formal schemas produced by SLT and SPT are different, both in planning steps and strategies used to solve problems. It is in line with the research by Zheng Zhu [14], stating that there are differences in a male and female student in problem solving.

The linguistic schema produced by SLT and SPT are identification terms and symbols of the elements that have been chosen and can use the terms or symbols for building mental models, planning solutions, and implementing the stages of the draft prepared. Because the planning and strategies used by SLT and SPT are different, so the linguistic schema in ratio and proportion problem solving for SLT and SPT are also different

4. Conclusion
Both the subjects’ (SLT and SPT) schemas in ratio and proportion problem solving the problem of ratio and proportions can be stated as follows.

(1) In the content schema, the subject describes information from the elements that have been selected relevant to prior knowledge. (2) In the formal schema, the subject can explain a mental model building based on the elements that have been selected from the problem and use the schemas for building the planning steps and implementing the planned completion steps. (3) In the linguistic schema, the subject identifies terms and symbols of the elements that have been chosen and can use the terms or symbols for building mental models, planning solutions, and implementing the stages of the draft prepared. (4) In proportion problem solving, SLT uses the unit rate strategy, the equivalent class strategy, and the cross product strategy while SPT uses the equivalent class strategy, the unit rate strategy, and the build-up strategy. (5) Different strategies in problem solving will produce different schemas.

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