Students' Epistemological Obstacles in Statistical Problems

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ABSTRACT

Learning difficulties often appear as obstacles that inhibit students from properly understanding concepts and solving problems. These obstacles are called epistemological obstacles, referring to scientific knowledge that can cause stagnation, even decline one's level of knowledge as shown by response errors in answering questions. This study analyzed the students' epistemological obstacles in statistics. This descriptive qualitative study included students of SMPN 12 Surakarta as subjects. Subject selection criteria included students who experienced epistemological obstacles and excluded students who did not experience epistemological obstacles. Data collection instruments in the forms of test questions and interview guidelines were validated by a statistical content expert, expert of research method, and teacher. Validators suggested to sequentially present the problems according to the level of difficulty. The data in this study were analyzed through three stages; data reduction, data presentation and conclusion drawing. conceptual obstacle is inability to determine the proper formula, procedural obstacle where the subject did not include the term "Suppose" for objects in problems involving variables and technical operational obstacle was less thorough in carrying out addition operations to subtraction when moving segments. The results of this study will be useful insights for further researchers in designing teaching materials that can minimize epistemological obstacles through the Didactical Design Research (DDR).

Keywords: *Conceptual Obstacles, Procedural Obstacles, Operational Technical Obstacles, Statistics*

1. INTRODUCTION

Mathematics and learning are two integrated domains since learning capability determines mathematic comprehension of students at high school and colleges [1]. Mathematics has been a subject avoided by many students as they perceive it difficult [2]. This avoidance lead to unsatisfactory grades [2]. The average national exam score for mathematics in 2017 was 52,69, which score then decreased by 46,56 points to 6,13 in 2019 [3]. The fact challenges mathematics teacher to make betterment in mathematics education.

Most students tend to find it difficult in applying mathematics in everyday life [4]. Mathematics is closely related to human daily activities, yet it is rarely used as the main tool to explain various phenomena, solve problems and the starting point to various human activities [5]. Interestingly, not only students with low abilities who experience the problems, but those with adequate abilities also experience similar problems. The low mathematic achievement might be caused by learning obstacles experienced by students regardless of the level of their abilities. These obstacles need to be identified in order to propose solutions and establish strategies to address them [6]. In this case, teachers need to be creative in developing their teaching materials [7].

Learning activities that are focused more on achieving the learning goals might put problems related to learning diversity, obstacles and learning styles in lower priorities of the evaluation [8]. Teachers should develop learning materials that adjust with students' needs. Every teaching material has its own characteristics depending on the material to be discussed and it needs to address students' learning obstacles and learning path [2]. Teaching materials are components

that support the learning process in didactic situations to anticipate problems that arise during the learning process which illustrate the efforts to facilitate students' cross-learning paths [9].

If the learning developed focuses more on achieving goals, then the substance of the evaluation also focuses on goals, so that problems related to learning diversity, barriers, and student learning paths may not be the main substance of evaluation [7]. Therefore, the subjects used by teachers must be based on the needs of students, each teaching material has its own characteristics based on the material to be discussed, teaching materials must be based on several things that become barriers to learning experienced by students and the learning path [2]. Teaching materials are one of the components to support the learning process in didactic situations to anticipate problems that arise during the learning process which illustrates the existence of efforts to facilitate cross-learning of children's learning paths [8].

Learning barriers are categorized into three types, namely ontogenic barriers, didactic barriers and epistemological barriers [9]. Ontogenic barriers are related to students' mental readiness to learn, didactic barriers caused by the teacher's teaching process and epistemological barriers related to students' knowledge which has a limited application context [8]. Epistemological barriers can be interpreted as wrong ways of thinking but such a perspective ignores its importance, developmental needs and productivity in a particular setting [10]. The focus of this study is epistemological barriers, because epistemological barriers are the most common obstacles experienced by students, obstacles that are often experienced by students when given problems in the form of questions. This is in line with the findings of experts who stated that the epistemological obstacle was seen from the presence of errors in the responses or responses of students in answering questions or teacher assignments [11]. Epistemological barriers to scientific knowledge can cause stagnation and even a decrease in one's knowledge [12].

Statistics is a core material in education curriculum that should be mastered by every student. However, students' mathematics mastery has been considered low. As stated in prior studies, students' difficulties in solving statistical problems were in the indicator in determining the average value of a data with an error percentage of 80% and 83% for data analysis, all of which were categorized high [13]. To address this gap, this study was conducted analyze the epistemological obstacles in statistics. The results of this study can be fruitful insights for researchers to conduct research involving wider subjects. Therefore, future researchers are recommended to develop teaching materials and mathematics learning designs to address epistemological obstacles.

2. METHOD

In this descriptive qualitative study, non-statistical data analysis or other means of quantification were performed [12]. Data were collected from students' written tests and interviews about their learning difficulties. The results were then described in objective manner without any manipulation [14]. Subjects were students who experienced learning obstacles. The obstacles referred to as are epistemological obstacles that occur descriptively, including conceptual obstacles, procedural obstacles and operational technical obstacles. It was found that several students experienced epistemological obstacles, however, in this study, only data from three students were explained since these three subjects already represented all students with constant comparative method [15].

Qualitative data analysis stages in case study design were employed. Data collected in this study were grouped based on the similarity of answers and errors. Data reduction was then carried out to select only relevant data to be explained and drawn into conclusions. Data collection instruments have been validated by an expert in statistics, content expert, expert in research methods, and teachers. Validators suggested that materials should be presented sequentially according to the level of difficulty. The mathematical problems used to explore students' epistemological obstacles are presented in Figure 1.

Data centering issue
Students' average score in mathematics was 6. Four students from other classes obtained average scores of 8. If the total average score of all class was 7. Therefore, the number of students before those average scores were combined was …
Information :   The average mathematics score was 6   Four students from other class obtained average scores of 8   If those scores are combined, they make an average score of 7
Question :   How many students are there in the class before their average scores combined ?

Figure 1 Test instrument.

3. RESULTS AND DISCUSSION

The following description describes students' epistemological obstacles in solving statistical problems supported by some interview results based on the indicators of epistemological obstacles.

3.1. S-1 Subjects with Conceptual Obstacles

Comprehension upon mathematical concept becomes an important part of learning because it is the foundation in the knowledge construction [16]. Therefore, it is important to analyze the conceptual obstacles that occur in learning process, especially in learning statistics. The most frequent conceptual obstacle experienced by students in solving questions on mean scores is inability to determine the proper formula.

The following is the answer for S-1 to the questions given:

Figure 2 The answer sheet of S-1 with conceptual obstacle.

In-depth interview was also conducted to the student who experienced conceptual obstacles while solving the question as follows.

Researcher : *Do you think your answer is correct?*
S-1 : *I do not know, Ma'am. I am confused with questions like this.*
Researcher : *Do you understand the concept of this question?*
S-1 : *I have not yet understood the concept and how to solve questions like this, Ma'am.*
Researcher : *Oh, I see. We can learn again about it.*
S-1 : *Yes, Ma'am. Thank you.*

The results of the tests and interviews showed that S-1 did not understand the concept of the question and was less careful in understanding the question. S-1 did not write down the formula and also used wrong formula. Factors causing difficulties experienced by students in solving problems mostly come from internal factors, namely difficulty understanding the concepts [17]. Understanding the concept of certain mathematical materials is an important part in minimizing the obstacles in learning [18]. Understanding the concept is a condition that allows ones to determine proper solution to the problem [19].

The indicators of conceptual obstacles showed that many students experienced such obstacles due to inability to develop proper mind set in applying the concept of questions [20]. Students have difficulties in understanding mathematics variables because they tend to rely on forms that are already known [21]. The problem occurs due to inability to develop the concept of the questions given [21]. Many students also do not write down formulas because they are not used to it, leading them to experience epistemological obstacles [21]. Such obstacle will not occur if students do not stick to existing problems and are able to develop a mindset to work on a new problem [21]. The obstacle was found in formula determination errors, discrepancies in the use of theorems or definitions and formulas, theorems unwritten which hindered subjects being able to analyze the concept of the questions given and they were reluctant to write formulas, theorems and even definitions [22].

3.2. S-2 Subject Experiencing Procedural Obstacle

S-2 experienced procedural obstacle as seen from the answers where the subject did not include the term "Suppose" for objects in problems involving variables and the steps in the completion process. The following are the answers of S-2 to the questions given:

Figure 3 The answer of S-2 that reflects procedural obstacle.

The researcher also conducted an in-depth interview to further analyze the problem.

Researcher : *For this particular question, how do you suppose it?*
S-2 : *This is it, Ma'am. I wrote "students before the combination = x"*
Researcher : *Oh, I see. Why did you not write down the word "suppose"?*
S-2 : *Oh right, I am sorry. I forgot about it because I was in hurry.*

The results of the tests and interviews indicated that S-2 was in a hurry and did not re-check the answers. Inability to include the meaning of the variable is also included in procedural obstacle. For instance, if equal sign is used, it means that there are many objects [20]. Difficulty in determining the proper terms and symbols is also one of the obstacles that occur to students in solving algebra problems [23]. Accuracy in carrying out procedures and re-checking the answers mark the presence of procedural obstacles [20]. Errors in solving mathematical procedures occur due to students' inaccuracy in using algebraic rules [24].

Similar pattern of procedural obstacle is found related to mistakes in carrying out mathematical completion procedures and not re-checking the answers made [22]. The inaccuracy of the process, for example the objects contained in problems involving variables, errors in carrying out the elimination and substitution method procedures, and not carrying out procedures for re-checking the solutions are signs of procedural obstacles [22]. Procedural obstacle is found when compiling steps and symbols in answering a problem due to inability to recognize the conditions of a concept [24]. Such mistake is not tolerated in mathematics learning process since symbols have important meaning [25].

3.3. S-3 Subject with Technical Operational Obstacle

S-3 experienced technical operational obstacle as seen from the answers provided. The obstacle occurred as S-3 was less thorough in carrying out addition operations to subtraction when moving segments and made errors in calculations. The following are the answers made by S-2 to the questions given:
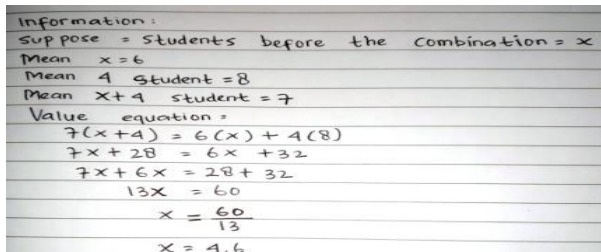

Figure 4 The answer of S-3 reflecting technical operational obstacle.

The researcher also performed an in-depth interview with S-3 to further analyze the problem.

Researcher : Is the calculation operation that you did correct?
S-3   : Yes, Ma'am. (re-reading the answer)
Researcher : If the "+" sign from the right side moves to the left. Doesn't "+" change to "−"?
S-3   : Right, Ma'am, it should be. So I did it wrong.
Researcher : Of course, it is wrong. How come?
S-3   : I was reckless.

Based on the results of the tests and interviews, S-3 was not careful in working on the questions that the calculation operation was wrong and the mark "+" moved to the left side remained "+". Supposed $7x+28=6x+32$ if grouped and moved side will be $7x-6x=32-28$ and the final result will also be 4 instead of 4.6. Mistakes related to symbols lead to wrong answer and inaccuracies in performing basic operations such as addition, subtraction, multiplication and division which are included in operational technical obstacles [22]. The wrong writing of the "+" sign (in addition operations) which should be a subtraction operation is a pattern of operational obstacles [26]. Students are often less careful in using basic operations [27].

Operational technical obstacles arise from the results of the study are limitations in determining correct arithmetic operations to fit the selected elimination method. Such problem mostly occurs due to students' inaccuracy in doing calculations, leading to wrong results [22]. Students' inaccuracy in performing calculations should be addressed even though the overall procedures, stages and completion steps are correct since wrong calculations will lead to wrong final answers [28]. This problem also occurs because many students still stick on the examples provided by teachers while the example might be different types of questions.

Students have not been able to develop a mindset to answer questions, which makes them experience epistemological obstacles as shown in technical obstacles indicators [20]. It is said that operational technical obstacles occur because students do not carefully read the questions [29].

4. CONCLUSION

In this study, three epistemological obstacles were identified. First, conceptual obstacle that occurs due to failure in understanding the concept of the problem, recklessness in understanding the questions, not writing down the formula or incorrect use of formula. Second, procedural obstacle due to rush and not re-checking the answer, which make students forget to include the term "supposed" in questions related to mathematical variables. The third obstacle is the operational technical obstacle that occurs due to lack of accuracy in performing addition operations into subtraction when moving segments and wrong calculations.

Further research is needed to determine whether epistemological obstacles are associated with ontogenic and didactic obstacles to make the findings of the study feasible to be used as theoretical basis. Future researchers are encouraged to focus on designing teaching materials that can be minimize the obstacles.

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