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Obstacles to Relations and Functions Concepts Learning in Terms of Theory of Didactic Situations Criteria

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Abstract

Effective learning planning requires information on the obstacles to learning a given concept that students experience to create a learning flow that matches the students' characters, including in the learning of the concepts of relations and functions. The research aims to determine the learning obstacles (LOs) that students experience in learning the concepts of relations and functions as per the criteria of the theory of didactic situations (TDS). Employing the case study method, this qualitative research was conducted with subjects that included 19 prospective teacher students who had taken a diagnostic test and participated in in-depth interviews. An analysis was conducted based on three TDS criteria, namely action, formulation, and validation. The results revealed two types of LOs that students experienced in learning the concepts of relations and functions: 1) ontogenic obstacles and 2) epistemological obstacles. The first type of obstacles included 1a) the inability to properly understand the definition of the intersection of two relations, referred to as conceptual ontogenic obstacle, and 1b) the inability to relate the concept of relations in drawing a Hasse diagram, referred to as instrumental ontogenic obstacle. Meanwhile, the second type included 2a) the difficulty in expressing relations in the forms of mapping diagrams and graphs, 2b) the difficulty in determining the range of a function, 2c) the difficulty in identifying relations which are also functions, 2d) the inability to represent relations in the forms of mapping diagrams, and 2e) the inability to write a function as a set of ordered pairs. It is recommended that these LO findings be taken into consideration in designing learning tools.

Keywords: Learning Obstacle, Diagnostic Test, Relations and Functions, Ontogenic Obstacle, Epistemological Obstacle

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INTRODUCTION

Relations and functions are basic mathematical concepts important for learning calculus (Bardini et al., 2014; Larson & Pettersson, 2017; Umah, 2016). The concept of functions is central to most undergraduate mathematics courses, such as basic mathematics, introduction to mathematics, real analysis, and discrete mathematics, suggesting how important it is to master the concept of functions for the sustained mastery of other mathematical concepts (Restianim et al., 2020). In science development in the fields of engineering, technology, and informatics, applications of the concept of functions are commonplace (McCulloch et al., 2017).

Relations and functions meet numerous applications in everyday life (Handayani et al., 2020; Kartika & Hiltrimartin, 2019). Multitudes of everyday phenomena can be expressed as functions. Examples include the relationship between distance and travel time and the relationship between distance and velocity (Handayani et al., 2020; Khan et al., 2022). Relations and functions improve efficiency in the conduct of daily activities and help better understand the connection between two or more objects and make decisions (Setiyani et al., 2020). Given the pronounced importance and benefits of both concepts in everyday life, both are included in the curriculum for various courses.

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Many students experience difficulties in solving story questions on relations and functions (Hutagaol, Rejeki, Yopita, & Andau, 2022). Such difficulties that students encounter in the learning process bring about learning obstacles (Maatuk et al., 2022; Suryadi, 2018). Students find it difficult to define the concepts of relations and functions and lack the necessary understanding of the procedural stages involved in learning these concepts (Ats-Tsauri et al., 2021; Clem et al., 2021). In many cases it is difficult for them to draw a line between relations and functions and present functions in the correct forms, resulting in errors in problem-solving (Adelia et al., 2023; Cheah, 2020; Handayani et al., 2020; Raharjo & Christanti, 2020). In essence, functions is not an easy concept for students to understand (Akçakin, 2018). Students at every level of education, both in Indonesia and overseas, often stumble upon problems in learning this concept (Rahmi & Yulianti, 2022).

In light of such difficulties as described above, it can be inferred that problems in learning relations and functions are many. This of course creates learning obstacles for students in learning these concepts (Greefrath et al., 2022; Sandefur et al., 2022). It is important that lecturers analyze the obstacles faced by students in the learning process as part of their professionalism. Lecturers, in overcoming these obstacles, can provide didactic interventions which may also be the cause of difficulties or obstacles in the learning process (Sari et al., 2023).

As stated by Brousseau (Isnawan, 2023; Hajar et al., 2023), learning obstacles (LOs) that are experienced by students can be divided into three types by external factors: (1) ontogenic obstacles, which refer to learning obstacles caused by students' unpreparedness in participating in learning activities (Sidik et al., 2021); (2) epistemological obstacles, which refer to learning obstacles related to how students acquire knowledge (Kandaga et al., 2022); and (3) didactical obstacles, which refer to those obstacles to learning that are caused by didactic factors, such as lecturer's transposition errors during learning and mismatch between the learning flow used and the characteristics of the students (Prabowo et al., 2022), leading to the need to develop an appropriate didactical design that takes into account the students' obstacles to align the learning flow with the students' characteristics. A decision on how to best help students overcome obstacles will not come into existence unless the lecturer knows what the obstacles are. Therefore, it is necessary to identify LOs before creating a didactic design for implementation (Aziiza et al., 2022).

In view of the problems related to learning concepts, processes, and obstacles experienced by students described above, it is deemed important to carry out research aimed at studying in depth the LOs arising in learning the concepts of relations and functions in terms of the criteria of the theory of didactic situations.

METHODS

This didactic design research was carried out with a qualitative research approach and a case study method in three stages: 1) prospective analysis, 2) metapedadidactic analysis, and 3) retrospective analysis (Miftah et al., 2022; Noto et al., 2018; Ria et al., 2023; Suryadi, 2018). Learning obstacles identification belonged to the first stage. Researchers were employed in the qualitative research as the main instrument, and descriptive data were obtained in the forms of written or spoken words from research subjects.

The subjects comprised 19 prospective teacher students of a class at a private university in the city of Palembang, South Sumatra, to whom test questions on relations and functions were given. After the students' answers to these questions were analyzed, three students of different abilities were selected for in-depth interviews. Following data collection, data analysis was conducted using the model proposed by Miles & Hubermen, including stages of data reduction, data presentation, and conclusion drawing or verification (Abdussamad, 2021). The data reduction stage was carried out by focusing the data on important things according to the research objectives. Then, the data were presented narratively to make it easier to understand the data, and conclusions were drawn accordingto the formulation of the problems being studied. The flow of the research process is illustrated in Figure 1.

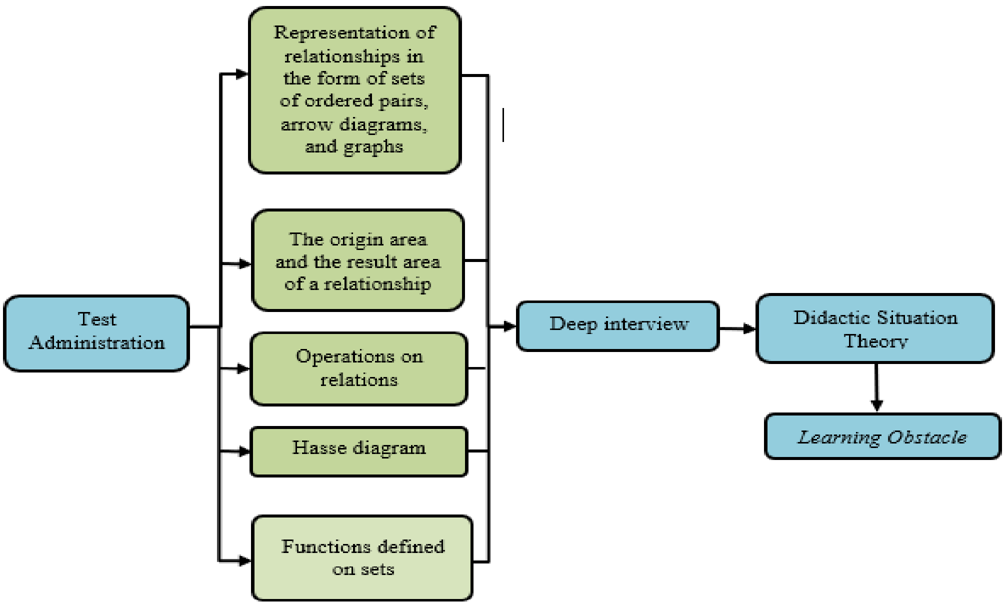


Figure 1. Research process

Toward the end of the research process, an LO analysis was carried out drawing on the theory of didactic situations (i.e., action situations, formulation situations, and validation situations) according to Brousseau (Pinheiro et al., 2022; Santiago et al., 2023; Utami et al., 2023). This theory comes with several criteria, which are described in Table 1.

Table 1. Criteria in the theory of didactic situations

Category	Criteria
Action	1. Answer questions 2. Write the answers even if they are wrong 3. Distinguish a function from a relation
Formulation	1. Describe a mapping diagram of a relation 2. Draw a Hasse diagram of a relation 3. Determine the range of a relation
Validation	1. Relate the concept of functions to the answers given 2. Relate the concept of relations to the answers given 3. Provide an explanation regarding the mapping diagram of a function

RESULTS AND DISCUSSION

In this research, data collection was carried out by administering a diagnostic test to 19 students of a private university in Palembang City who had studied the concepts of relations and functions. The questions posed in this test covered aspects as outlined in Table 2.

Table 2. Aspects covered in the diagnostic test problems

Questions	Visible Aspects	Concepts
1	Students are able to express relations in the forms of sets of ordered pairs, mapping diagrams, and graphs.	Representation of relations in the forms of sets of ordered pairs, mapping diagrams, and graphs
2	Students are able to determine the domain and range of known relations.	The domain and range of a relation
3	Students are able to determine relations which are functions from mapping diagrams provided.	Functions defined on sets
4	Students are able to represent relations in the forms of mapping diagrams.	Representation of relations in the forms of mapping diagrams
5	Students are able to write functions as sets of ordered pairs.	Functions defined on sets
6	Students are able to combine relations in the forms of combinations and intersections.	Operations on relations
7	Students are able to draw a Hasse diagram of a relations.	Hasse diagram

Table 2 provides a summary of the seven diagnostic test problems given to respondents to determine their learning obstacles in learning the concepts of relations and functions. These problems concerned relational representation, the domain and range of a relation, operations on relations, functions, and Hasse diagrams.

The data obtained from the diagnostic test answers of the students went through the stages of identification, analysis, and classification involving codes assignment based on the aspects that were observed. For example, one of the learning obstacles (LOs) explored through the diagnostic test was coded LO.TD.1 (short for learning obstacle diagnostic test problem number 1). A description of the identified learning obstacles from the diagnostic test is provided in Table 3.

Table 3. Diagnostic test analysis results

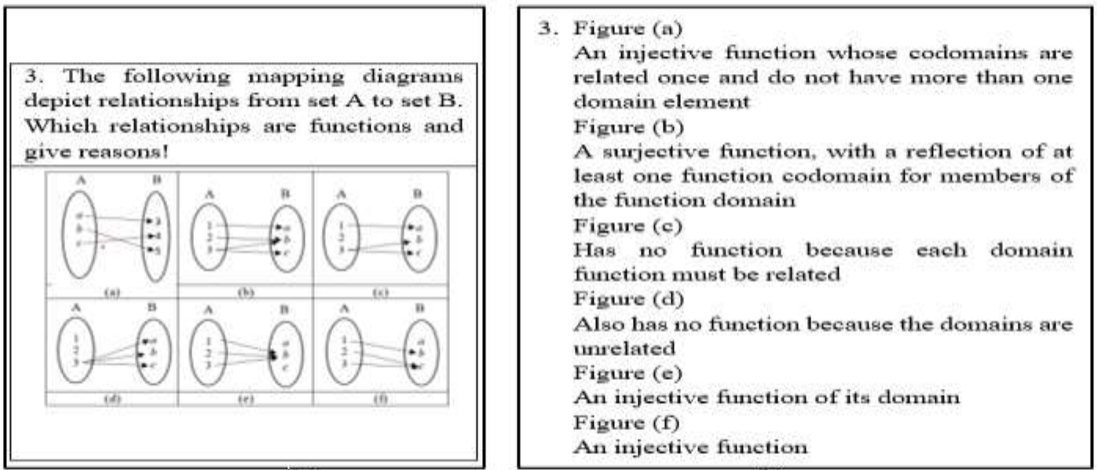
LO Code	Visible Aspect	LO Description	Amount	%
LO.TD.1	Students are able to express relations in the forms of sets of ordered pairs, mapping diagrams, and graphs	Students could express relations in the forms of sets of ordered pairs but could not express relations in the forms of mapping diagrams and graphs.	17	89.5
LO.TD.2	Students are able to determine the domain and range of a relation and draw mapping diagrams and graphs of relations.	Students could determine the domain but could not determine the range.	16	84.2
LO.TD.3	Students are able to determine relations which are functions from mapping diagrams provided.	Students could not demonstrate relations that are also functions from mapping diagrams provided.	11	57.9
LO.TD.4	Students are able to draw relations in the forms of mapping diagrams.	Students were not able to draw mapping diagrams correctly.	14	73.7
LO.TD.5	Students are able to write functions as sets of ordered pairs.	Students could not write functions as sets of ordered pairs.	18	94.7
LO.TD.6	Students are able to combine relations in the forms of combinations and intersections.	Students could look for combinations but could not find intersections correctly.	17	89.5
LO.TD.7	Students are able to draw a Hasse diagram of a relations.	Students could not draw a Hasse diagram of a relation with precision.	13	68.4

The results of the analysis of the diagnostic test data presented in Table 3 show that students experienced obstacles or problems in solving problems related to the concepts of relations and functions. These results are described in greater detail below.

A number of learning obstacles were identified from the analysis of the diagnostic test results derived from 19 students of a private university in Palembang City (Table 3). These students experienced the following learning obstacles: 1) 89.5% of students experienced a difficulty in expressing relations in mapping diagrams and graphs; 2) 84.2% of students could not determine the range of a function; 3) 57.9% of students experienced a difficulty in identifying relations which are also functions; 4) 73.7% of students were not able to represent relations in the forms of mapping diagrams; 5) 94.7% of students could not write a function as a set of ordered pairs; 6) 89.5% of students could not identify intersections correctly; and 7) 68.4% of students were inaccurate in drawing a Hasse diagram of a relation

To gain a deepert understanding of the learning obstacle experienced by students, interviews were conducted with three of the students who participated in the diagnostic test previously conducted (M1, M2, and M3). The test and interview results of the three students interviewed are described below.

In the case of LO.TD.3, 57.9% of students were not able to identify a relation which is also a function from a provided mapping diagram. Figure 2 is M1's answer to this problem.


3. The following mapping diagrams depict relationships from set A to set B. Which relationships are functions and give reasons!

3. Figure (a)
An injective function whose codomains are related once and do not have more than one domain element
Figure (b)
A surjective function, with a reflection of at least one function codomain for members of the function domain
Figure (c)
Has no function because each domain function must be related
Figure (d)
Also has no function because the domains are unrelated
Figure (e)
An injective function of its domain
Figure (f)
An injective function

(a) (b)

Figure 2. (a) Diagnostic test problem number 3, (b) M1's answer

The following is a translated excerpt of the in-depth interview with M1 regarding their answer to diagnostic test number 3.

Q : *In reference to figure b, why did you classify it as a surjective function?*

M1 : *Mmm, because the codomain area has at least one pair of domain members, Ma'am.*

Q : *Can you explain the difference between surjective, injective and bijective functions?*

M1 : *I'm only sure about injective functions, whereas about surjective and bijective functions I'm often mistaken, Ma'am.*

From the translated interview excerpt above, it can be seen that M1 had a correct understanding only of injective functions, but they were often mistaken in determining the other types of functions, which are surjective and bijective. In answering question number 3b, the student made a mistake in identifying relations which are also functions from provided mapping diagrams due to a lack of an understanding of the definition of a function. This error indicates the student's inability to define a function correctly (Ats-Tsauri et al., 2021; Clem et al., 2021). Two criteria of the theory of didactic situations, formulation and validation, were unmet. Therefore, the obstacles encountered by the student were categorized as epistemological (i.e., learning obstacles related to how the student acquired knowledge) (Kandaga et al., 2022).

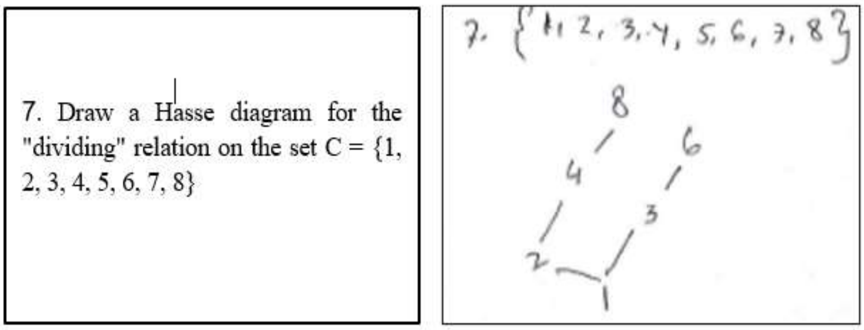
The interview results and learning obstacles experienced by M1 based on the criteria of the theory of didactic situations are outlined in Table 4 (note "✓" if the criterion had been met, "×" if the criterion had not been met).

Table 4. M1’s interview results

Question	Criteria			Type of Learning Obstacle
	Action	Formulation	Validation	
1	✓	×	✓	Instrumental ontogenic obstacle
2	✓	×	×	Epistemological obstacle
3	✓	×	×	Epistemological obstacle
4	✓	×	×	Epistemological obstacle
5	✓	×	×	Epistemological obstacle
6	✓	×	×	Epistemological obstacle
7	✓	×	×	Epistemological obstacle

Based on Table 4, M1 predominantly failed to meet the formulation and validation criteria of the theory of didactic situations. Thus, it can be concluded that the learning obstacles experienced by M1 were, according to Suryadi (2018), of the epistemological type (i.e., obstacles caused by an incomplete understanding of a context). For example, M1 had a difficulty solving diagnostic test problem number 3 regarding the definition of a function. Fitrianna & Rosjanuardi (2021) have previously reported that, since it was difficult for students to define the concepts of relations and functions, students experienced difficulties in understanding the procedural stages of solving problems on relations and functions.

In the case of LO.TD 7, 68.4% of students could not draw a Hasse diagram correctly. For example, M2's answer to this problem is presented in Figure 3.



(a) (b)

Figure 3. (a) Diagnostic test problem number 7, (b) M2's answer

To explore this answer, an in-depth interview with M2 was conducted. The following is a translated excerpt of the interview.

Q : Why didn't you include some members of the set C, 5 and 7, in the Hasse diagram?

M2 : Because, Ma'am, hmmm, because there are no numbers that can be divided by 5 and 7, Ma'am, so I didn't include them in the diagram.

As can be inferred from the translated interview except above, M2 did not write down the entire members of the set C; M2 left out 5 and 7 from the Hasse diagram. This suggests that the student did not understand the "dividing" relations. The student was unable to apply the concept of dividing relations when drawing the Hasse diagram. Since they had a difficulty linking the concepts of relations and functions, resulting in errors in drawing the Hasse diagram, the student was considered to have failed to satisfy the validation criterion of the theory of didactic situations.

The interview results and learning obstacles experienced by M2 based on the criteria of the theory of didactic situations are presented in Table 5 below (note "✓" if the criterion had been met, "×" if the criterion had not been met).

Table 5. M2's interview results

Questions	Criteria			Learning Obstacle Type
	Action	Formulation	Validation	
1	✓	✓	×	Conceptual ontogenetic obstacle
2	✓	×	✓	Instrumental ontogenetic obstacle
3	✓	✓	✓	-
4	✓	✓	✓	-
5	✓	×	×	Epistemological obstacle
6	✓	✓	×	Conceptual ontogenetic obstacle
7	✓	✓	×	Conceptual ontogenetic obstacle

Based on M2’s interview results outlined in Table 5, the most dominant criterion of the theory of didactic situations that M2 failed to meet was validation. Therefore, it was concluded that the student experienced conceptual ontogenic obstacles because of the inability to relate the concept of relations in drawing a Hasse diagram (Suryadi, 2018). Cahyani (2019) also reported the difficulty in making a Hasse diagram that students experienced. Since they had a poor understanding of how to make a Hasse diagram based on a given set of relations, the students were unable to determine the upper and lower limits of a Hasse diagram correctly.

In the case of LO.TD.6, 89.5% of students made mistakes in combining relations in the forms of unions and intersections. An example of this is provided in in Figure 4.

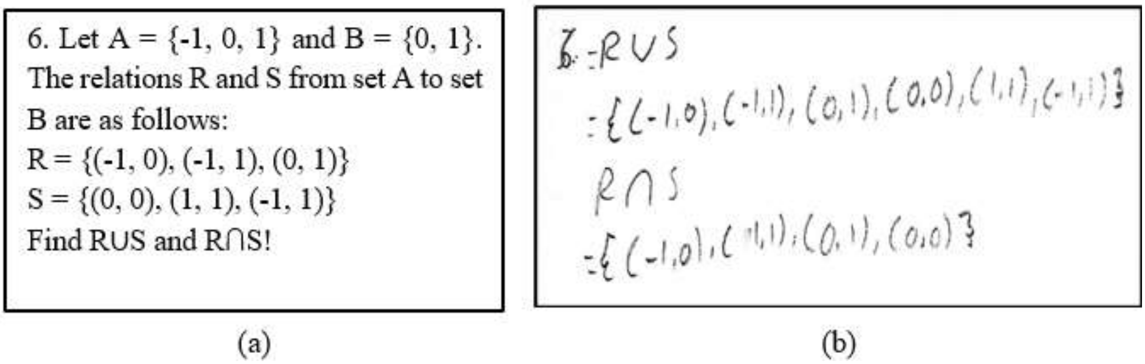


Figure 4. (a) Diagnostic test problem number 6, (b) M3’s answer

To explore M3's answer to diagnostic test problem number 6, an in-depth interview was conducted, and a translated excerpt of the interview is provided below.

Q : How did you determine the intersection of the relations R and S?

M3 : I wrote down the members of both relations that did not share commonality between relations.

M3 was able to determine the combination of two relations but was less precise in determining the intersection of two relations. To determine the intersection, M3 wrote down relation members that were distinct between the two relations R and S. However, M3's view of intersections was incorrect because intersections are sets whose members come from the overlap of one relation and another.

The interview results and learning obstacles experienced by M3 based on the criteria of the theory of didactic situations theory are presented in Table 6 below (note "✓" if the category had been met, "×" if the category had not been met).

Table 6. M3's interview results

Questions	Criteria			*Learning Obstacle Type*
	Action	Formulation	Validation	
1	✓	✓	✓	-
2	✓	×	✓	Instrumental ontogenetic obstacle
3	✓	×	×	Epistemological obstacle
4	✓	×	×	Epistemological obstacle
5	✓	×	✓	Instrumental ontogenetic obstacle
6	✓	×	✓	Instrumental ontogenetic obstacle
7	✓	✓	×	Conceptual ontogenetic obstacle

Based on M3's interview results as presented in Table 6, formulation was the theory of didactic situations criterion most frequently unsatisfied by M3. This indicates that the student experienced instrumental ontogenetic obstacles, especially in understanding the correct definition of an intersection (Suryadi, 2018).

The interview also revealed other learning obstacles that M3 encountered. Based on the interview results, M3 experienced instrumental ontogenetic obstacles in solving diagnostic test problems on the determination of the intersection and combination of two relations. M3 was able to determine the combination of two relations correctly but was less precise in determining the intersection of two relations. Janan & Hanafi (2022) in their study also discovered that students made errors in determining the intersection of two sets. These errors stemmed from the students' inability to understand how to determine the intersection of two sets correctly. This inability to determine the intersection of two sets led the students to experience a difficulty in determining the intersection of two relations.

According to the test and interview results as presented above, there were two types of learning obstacles that students encountered in learning the concepts of relations and functions, namely ontogenic obstacles and epistemological obstacles. This finding is in line with those of earlier research (Natalia et al., 2023; Puspita et al., 2023; Rayhan & Juandi, 2023). The former type of learning obstacles was divided into two sub-types: (1a) conceptual ontogenic obstacle, which refers to the students' inability to understand the definition of an intersection of two relations with precision, and (1b) instrumental ontogenic obstacle, which refers to the students' inability to relate the concept of relations in drawing a Hasse diagram. Meanwhile, the latter type included the difficulty in expressing relations in the forms of mapping diagrams and graphs, the difficulty in determining the range of a function, the difficulty in identifying relations that are also functions, the inability to represent relations in the forms of mapping diagrams, and the inability to write a function as a set of ordered pairs.

The LOs identified in this research can be used as considerations for designing learning activities (Aziiza et al., 2022) on relations and functions, as well as a basis for a preliminary analysis for the development of learning tools such as teaching modules, student worksheets, and evaluation instruments on the concepts of relations and functions.

CONCLUSION

From this research, two types of learning obstacles (LOs) in the learning of the concepts of relations and functions were found, namely 1) ontogenic obstacles and 2) epistemological obstacles. The ontogenic learning obstacles experienced by students were divided into 1a) conceptual ontogenic obstacle, that is the inability to understand the definition of an intersection of two relations precisely, and 1b) instrumental ontogenic obstacle, that is the inability to relate the concept of relations in drawing a Hasse diagram. As for the epistemological obstacles, the most dominant obstacles experienced by the students were 2a) the difficulty in expressing relations in the forms of mapping diagrams and graphs; 2b) the difficulty in determining the range of a function; 2c) the difficulty in identifying relations which are also functions; 2d) the inability to represent relations in the forms of mapping diagrams; and 2e) the inability to write a functions as set of ordered pairs.

The scope of this research was limited only to learning obstacles to learning the concepts of relations and functions. Therefore, the findings obtained from this research can be used as a consideration for a needs analysis to compile and develop learning tools on relations and functions. The research process can be emulated to find out obstacles to learning other mathematical concepts.

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