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A Didactical Design of Teaching Decimal Numbers for Fourth-Grade Elementary Students

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Abstract

Learning obstacles to decimal concepts at the elementary level can hinder students' mathematical development in subsequent grades. A common difficulty lies in interpreting decimal values, which requires a well-structured instructional design to minimize these barriers. This study aims to develop a didactic design for teaching decimals based on an analysis of learning barriers and learning trajectories. Using Didactical Design Research (DDR), this study was conducted through three stages: prospective analysis, metapedadidactic analysis, and retrospective analysis. Data were collected through interviews, tests, documentation, and video recordings. Initially, learning barriers in ontogenic, epistemological, and didactic aspects were identified in fifth-grade students who had already learned decimals. Based on these findings, a Hypothetical Learning Trajectory was developed and implemented with 19 fourth-grade students who had not yet learned decimals. The results showed that the didactic design significantly improved students' ability to interpret decimals and strengthened their understanding of decimal operations. These findings underscore the importance of addressing learning obstacles in instructional design and recommend the integration of the DDR approach in mathematics teaching to enhance conceptual understanding from an early stage.

Keywords: Decimal numbers, Hypothetical learning trajectory, Learning obstacles

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INTRODUCTION

Mathematics is a science that provides a universal logical framework for human thinking and is the foundation of knowledge for educational success, so mathematics is taught at every level of education, including primary school (Sopiyah, 2020; Sutopo, 2019). In mathematics learning in schools, mathematics learning is one of the main subjects taught in elementary school. Mathematics itself is learning about logic, forms, and interrelated ideas. One of the studies of mathematics learning is material on decimal numbers.

Decimal numbers are also called the basic system of ten because they use the ten basic numbers of calculation (Purnomo, 2015). The term decimal refers to a system of numbers consisting of ten main digits that are usually expressed by a decimal point sign. Decimal numbers use the number 10 as the basis for calculation (Yurniwati, 2015). Decimal numbers have diverse applications in daily life, such as Finance, Measurement, Technology, and Calculation in

Education (Kusuma, 2022). This app shows that decimal numbers are very important to teach students from an early age. However, many students experience difficulties related to the concept of decimal numbers.

Some of the results of this study show that students cannot compare the magnitude of values between decimal numbers because they do not understand the meaning of decimal numbers, one of which is by assuming that decimal numbers that have more numbers on the right have more values and do not know the meaning of the number of zeros on the left (Durkin & Rittle-Johnson, 2015; Pulungan, 2023). Research conducted by Pulungan (2023) on grade VI elementary school students in Sumedang Regency found that many students are unable to compare the magnitude of values between decimal numbers, one of which is by assuming that a longer decimal number means a larger number. In addition, research conducted by Rahman (2020) on grade V students of Ar-Rahman Integrated Islamic Elementary School stated that students still cannot memorize and calculate addition and multiplication of decimal numbers smoothly. When calculating the division of stacks, it is still not smooth, and for the multiplication of decimal numbers, students still use their fingers.

The results of the above research were also found by the researcher when carrying out initial observations at SD Negeri 2 Lais. Many students make mistakes in grouping decimal numbers so that students experience obstacles in performing decimal number calculation operations. Another finding is that textbooks only present decimal number counting operations with the same decimal number procedurally so that students do not understand counting operations with different decimal numbers. This shows that the mathematics learning process carried out by teachers and students has not been effective so that it still experiences obstacles. Learning can be said to be effective if teachers and students together become implementers of learning goals (Sopiyah, 2020).

In the teaching and learning process in schools, there are often several students who experience learning obstacles that need to be identified to find ways to overcome them and establish strategies that can reduce or minimize these obstacles (Fuadiah, 2016; Zulkarnain, 2020). In learning activities, teachers are required to be active and creative in delivering material (Agustianingsih et al., 2021). Learning management in the classroom needs to be managed properly so that learning succeeds optimally by creating a conducive learning atmosphere so that students can be motivated (Deswita, 2016; Oktariyani & Juwita, 2019; Rahman, 2020). When a person has good motivation, he will do his best to follow the learning process (Sari, Yana & Wulandari, 2021; Zuhriyah, 2022). So that teachers can be a source of learning and can overcome if there are learning obstacles in students.

In the process of learning mathematics, students often face various obstacles that can interfere with the understanding and mastery of concepts. Brousseau (2002) and Suryadi (2019) classified these learning barriers into three types, namely ontogenic, epistemological, and didactic barriers. Ontogenic barriers arise due to the lack of students' developmental readiness when participating in learning. Epistemological barriers occur when students' initial knowledge is not contextual enough to understand the concept being studied. Meanwhile, didactic obstacles come from the learning process carried out by teachers that are not in accordance with the characteristics or needs of students.

To overcome these obstacles, teachers need to design learning strategies that are adaptive and appropriate to students' cognitive development. One approach that can be used is Hypothetical Learning Trajectory (HLT), which is a learning plan that is prepared based on predictions of students' learning paths in achieving learning goals. The concept of HLT was first introduced by Simon (1995) and further developed by other researchers (Fuadiah, 2017; Hendrik, Ekowati & Samo, 2020). HLT consists of three main components, namely the learning objectives to be achieved, learning activities designed to support the achievement of these goals, and predictions of students' thinking processes based on the stages of thinking and learning context that are relevant to the student's character. HLT is an important tool for teachers in designing a learning process that is in harmony with the thinking patterns of students in the classroom. Understanding HLT allows teachers to develop more adaptive and effective learning strategies, paying attention to the unique characteristics of students (Baroody, 2022; Larson, 2017; Nuraida & Aman, 2019).

HLT It is a hypothesis that is flexible and can be developed through observation and reflection during the learning process (Adrews-Larson, Wawro & Zandieh, 2017; Lantakay, Senid, Blegus & Samo, 2023). By understanding HLT, teachers can design more effective learning strategies and pay attention to the unique characteristics of students in the classroom (Surya, 2016). In the context of decimal number learning, HLT is an important reference to anticipate learning obstacles experienced by students. The results of in-depth observation of the teaching and learning process at SD Negeri 2 Lais, South Sumatra, showed that students had difficulties in solving decimal number problems, so an appropriate HLT design was needed to help them understand the concept.

In addition to HLT, another approach that can be used is the Theory of Didactical Situation (TDS) introduced by Brousseau in 1986. This theory emphasizes the importance of interaction in a didactic triangle consisting of teachers, students, and learning materials. This interaction is the basis for creating an effective didactic situation in mathematics learning (Fuadiah, 2021). TDS divides didactic situations into four types, namely action, formulation, validation, and institutionalization situations. Action situations occur when students are encouraged to build their own understanding of a problem. Formulation situations allow students to combine understanding and strategy through discussion and collaboration. Validation situations involve the teacher's active role in reviewing and reinforcing students' strategies with relevant explanations and theories. Meanwhile, the institutionalization situation is a stage where students are able to reconstruct old knowledge into new knowledge with the help of direction from the teacher.

By combining HLT and TDS approaches, teachers can design learning that is more responsive to student needs. This effort aims to identify learning barriers in decimal number materials, design appropriate HLTs, and develop didactical designs that support an in-depth understanding of concepts. This approach not only helps students overcome learning difficulties but also encourages the creation of meaningful and sustainable mathematics learning.

This research was carried out within the framework of Didactical Design Research, research that is a research step in compiling a learning design based on learning trajectories and student needs. Although previous research has explored

Didactical Design Research (DDR) in relation to mathematics learning including decimal numbers, this study focuses on the analysis of fourth grade students, which has not been widely explored in the context of primary schools in Indonesia. Based on previous research, DDR is an effective alternative and can improve decimal learning for students. Therefore, this study aims to analyze how these factors are managed and contribute to the design of DDR in elementary schools.

RESEARCH METHODS

This study employed the Didactical Design Research (DDR) approach as it aligns with the objective of developing a didactical design for teaching decimal numbers aimed at minimizing students' learning obstacles. DDR was selected because it provides a systematic framework through three main stages: prospective analysis, metapedadidactic analysis, and retrospective analysis, which enable researchers to identify learning barriers, design instructional strategies, and comprehensively evaluate their effectiveness (Suryadi, 2019).

The research was conducted at SD Negeri 2 Lais, Kabupaten Musi Banyuasin, Sumatera Selatan, during the second semester of the 2024/2025 academic year. The participants consisted of 21 fourth-grade students selected through purposive sampling, as they had not yet formally studied decimal numbers, making them appropriate for the initial implementation of the didactical design. The classroom teacher was also involved through interviews to gather insights into the typical teaching practices used in the classroom.

The research followed the three DDR stages. In the prospective analysis stage, a prerequisite diagnostic test was administered to assess students' initial understanding, followed by a learning barriers diagnostic test to identify conceptual errors, semi-structured interviews with six students, and an analysis of students' prior work. Based on these findings, the researcher developed a Hypothetical Learning Trajectory (HLT) that outlined the sequence of learning activities, anticipated student responses, and recommended instructional strategies. In the metapedadidactic analysis stage, the didactical design was implemented in the classroom. Data were collected through classroom observations, video recordings, field notes, and a post-instruction diagnostic test to evaluate students' understanding after the implementation. The retrospective analysis stage involved comparing the results of the implementation with the initial HLT predictions to refine the didactical design.

The research instruments included a prerequisite diagnostic test, a learning barriers diagnostic test, semi-structured interviews, observation sheets, and a post-instruction diagnostic test. The prerequisite diagnostic test was used to determine students' initial readiness, while the learning barriers diagnostic test aimed to identify their difficulties in understanding decimal number concepts. Interviews were conducted to further explore the causes of these difficulties. Observation sheets and video recordings were used to document classroom interactions, while the post-instruction test was used to measure learning outcomes after the implementation of the didactical design. Data analysis followed the qualitative analysis model, which consists of three stages: data reduction, data display, and conclusion drawing (Miles, Huberman & Saldaña, 2014). During data reduction,

the researcher categorized data based on types of learning obstacles. In the data display stage, findings were presented in tables and concept maps to identify patterns more clearly. Finally, during the conclusion drawing stage, the data were verified through triangulation using test results, interviews, and classroom observations. To ensure the validity of the findings, the study employed credibility, transferability, dependability, and confirmability checks (Creswell & Poth, 2018).

RESULTS AND DISCUSSION

Prospective Analysis

The prospective analysis aims to formulate HLT and design a learning through the identification of learning obstacles in decimal number learning from didactic, oncogenic, and epistemological aspects. This stage is carried out through research on students' understanding of concepts, analyzing curriculum, textbooks and teaching materials, and analyzing learning carried out by teachers in decimal number learning. The first step taken by the researcher is to determine and analyze the material that will be the material in the research, followed by compiling a diagnostic test instrument and then validating it to three experts that two lecturers in their fields and one mathematics teacher.

The diagnostic test was in the form of 5 questions describing decimal number material given to class V of SD Negeri 2 Lais with a total of 21 students. From the diagnostic test, it was found that the learning obstacles experienced by the students were found. The learning obstacle results of the analysis of students' mistakes in doing the questions can be seen in Table 1.

Table 1. Diagnostic Test Analysis Results

Learning Obstacle	Presents
Students cannot write decimal numbers.	52%
Students cannot determine the place of decimal numbers.	76%
Students cannot sort decimal numbers.	95%
Students cannot determine the result of adding decimal numbers.	28%
Students cannot determine the result of decimal number subtraction.	19%

By conducting textbook analysis that used by the teacher, the following information was found: 1) textbooks do not present an explanation of how to express decimal numbers and directly present problems; 2) the presentation of the material is not clear, there are no examples of decimal number structure material and few practice questions; 3) in the textbook, only explain how to add and subtract for decimal numbers that have the same number of decimal numbers. There is no explanation of how to add and subtract to decimal numbers that have different decimal numbers.

Based on the results of interviews conducted by the researcher with the teacher, several findings were identified regarding students' learning difficulties in understanding decimal number material. First, the primary difficulty experienced by students lies in their low numeracy skills, particularly in understanding real

and common numbers, as well as performing addition and subtraction operations involving decimal numbers. Second, one of the main factors contributing to these difficulties is the nature of decimal numbers themselves. Decimal numbers use a comma (or point), and the digits following it are often misinterpreted by students. They tend to assume that the digits after the comma hold the same place value as whole numbers, such as hundreds or thousands, leading to misconceptions in understanding place value.

To address these challenges, the teacher have attempted to implement instructional methods that allow students to recognize numerical concepts without immediately relying on numerical symbols. The approach used is the concrete-to-abstract method, in which students are first introduced to tangible objects before progressing to the concept of decimal numbers. This method continues to be applied throughout the learning process. Once students grasp the foundational concepts, they are gradually introduced to decimal number material, and teachers clearly convey the learning objectives to ensure students understand the relevance of the topic.

Students' responses to learning methods involving games have been overwhelmingly positive. They express joy and enthusiasm during lessons. Nevertheless, it is important for teachers to evaluate the types of games used to ensure they are appropriate for elementary school students and aligned with the overall learning goals. On the other hand, when students struggle to understand decimal number material, they often exhibit signs of nervousness. Therefore, it is crucial for teachers to assess which students require additional attention and provide enrichment or extra time to help them better comprehend the material.

Hypothetical learning trajectory (HLT) in decimal numbers can be divided into three components, namely: the direction of learning objectives, learning activities, and predictions in the learning process so that there is an estimate of how students' thinking and understanding processes can develop during learning activities. The Hypothetical Learning Trajectory based on the Learning Obstacles that emerged in this study can be seen in Figure 1.

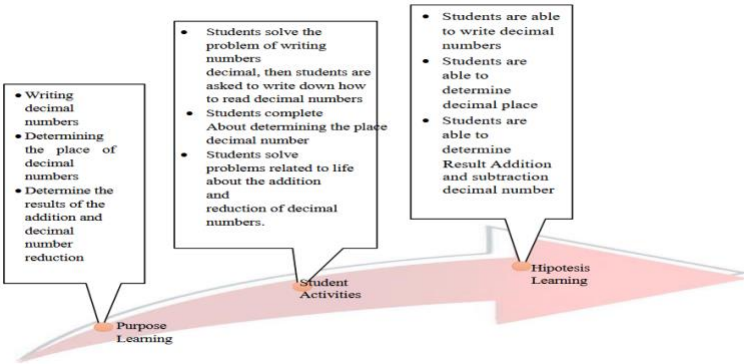

Figure 1. Hypothetical Learning Trajectory Decimal Number

The didactical design to overcome the difficulties experienced by students, a learning design is needed that pays attention to the needs of students, so that students can understand the concept of decimal number. The instructional design will be outlined in the Hypothetical Learning Trajectory (HLT) which is then developed into a didactic design. The stages in the implementation of didactic design are adaptation, action, formulation and validation. The learning process

will be created if the teacher can apply a model (Kuswidyanarko & Pratama, 2020, p. 154). The didactical design which also contains the alleged student response and the anticipation of student response to decimal number material can be seen in Table 2.

Table 2. The Didactical Design on Decimal Number

Learning Flow	Didactical Situation (Teachers Input)	Predicting Student Response	Anticipating Student Responses
Writing decimal numbers			
Adapts	Teachers provide perceptual, motivational and learning objectives activities to students	a. Students listen to the perceptions, motivations and learning objectives conveyed by the teacher b. Students do not listen to the perceptions, motivations and learning objectives conveyed by the teacher	a. Teachers give appreciation to students b. The teacher directs students to listen to the perceptions, motivations and learning objectives conveyed by the teacher
Action	The teacher gave a question about writing decimal numbers which consisted of: Write down the decimal number below and then write down how to read it a. 1,412 b. 7,201 c. 10,90	a. Students are able to write decimal numbers b. Students are unable to write decimal numbers	a. The teacher gave a different question b. Students are given a re-explanation of how to solve the problem
Formulate -on	The teacher asks students to discuss with their group friends about the right way to write.	a. Students can do the task and write the results on the board. b. Students cannot explain well	a. Students are appreciated by teachers b. Students are given a re-understanding of writing decimal numbers using whiteboard media
Validation	The teacher asks all	a. Students are able	a. The teacher

	students to answer the questions on the board together and students check their answers.	to work on problems related to writing decimal numbers b. Students cannot to work on problems related to writing decimal numbers	gave another assignment that one more difficult. b. Students are given a re-explanation of how to write decimal numbers
Determining the place of decimal numbers			
Action	The teacher uses the place value table to present decimal numbers, ranging from tenths, hundredths, and so on	a. Students are able to show the place value of decimal numbers b. Students are unable to work on problems related to decimal number places.	a. Students are appreciated by teachers b. Students are given stimulus in the form of examples of how to determine the place of decimal numbers
Formulas	The teacher invites students to engage in discussions with their peers regarding the methods to be applied for assessing the location of decimal numbers	a. Students are able to use the right strategies in determining the value of the place b. Students are not able to use the right strategy in determining the value of the place	a. Students are appreciated by teachers b. Students are given stimulus in the form of examples of how to write decimal numbers
Validation	The teacher asks one of the students to present the results of the discussion to the board and check the answer with the other students	a. Students are able to present the results of the discussion b. Students are unable to present the results of the discussion	a. Students are appreciated by teachers b. Students are given a new understanding of determining decimal numbers using Media Table Values
Determining the result of addition and subtraction of decimal numbers			
Adapts	Teachers provide perceptual, motivational and learning objectives	a. Students listen to the perceptions, motivations and learning objectives	a. Teachers give appreciation to students b. The teacher

	activities to students	conveyed by the teacher b. Students do not listen to the perceptions, motivations and learning objectives conveyed by the teacher	directs students to listen to the perceptions, motivations and learning objectives conveyed by the teacher
Action	The teacher presents problems related to daily life regarding the addition and subtraction of decimal numbers.	a. Students are able to work on problems related to daily life b. Students are unable to work on problems related to daily life	a. Students are appreciated by teachers b. Students are given stimulus in the form of examples of how to add and subtract decimal numbers
Formulas	The teacher asks students to discuss with their group friends about the strategies that will be used in solving the problem	a. Students are able to use the right strategies in solving problems b. Students are able to use the right strategies in solving problems	a. The teacher gave the problem solving one more level b. Students are given a re-explanation of how to solve the problem decimal number reduction
Validation	The teacher asked each group representative to answer the problem on the board and then explain the results of their presentation	a. Students are able to work on and explain the answers to the questions b. Students are able to work on and explain the answers to the questions	a. The teacher gave the enrichment problem solving task. b. Students are given a re-explanation of how to solve the problem

Metapedadidactic Analysis

The *metapedadidactic* analysis aims to analyze learning in the classroom using a didactic design of decimal number learning. Learning video recordings are very helpful for analysis to see and observe the interactions that occur between teachers – students – subject matter, teacher interventions, didactic and pedagogical actions

carried out by teachers in following up on didactical situations that develop during learning.

The *metapedadidactic* theory is divided into three integrated components: unity, flexibility, and coherence (Suryadi, 2019). Therefore, in designing or compiling a didactical design, the three components of the *metadadidatic* theory must be applied. The unit component is related to the teacher's competence in seeing the didactic triangle (teacher, student, and material) which is modified so that it is closely related and as a complete unit. The flexibility component is that teachers predict student responses and prepare their anticipations before learning activities take place. The coherence component is the teacher's ability to anticipate student responses that are not in accordance with the predictions of student responses that have been made during learning activities (Suryadi, 2019). This is in accordance with the view put forward by Sulistiawati (2015) that coherence is understood as a didactic situation that develops so that different situations arise, which must then be managed so that the change in the situation in the learning process runs smoothly and leads to the achievement of goals.

Based on the findings in the decimal number learning activity, some student responses occurred according to predictions, such as 1) when writing decimal numbers, it is found that the student response and the anticipation of the student response that occurs in the field are in accordance with the didactical design that has been prepared. The student response that occurs is that students can write decimal numbers. The anticipation of student responses that has been prepared is quite successful in overcoming the student responses that have emerged; 2) when determining the place of decimal numbers, the prediction of student response and the anticipation of student response are not in accordance with the didactical design that has been designed, because at the time of the implementation of the design, there are still two students who are confused in determining the place of decimal numbers, so the anticipation carried out by the researcher is to provide a brief explanation first about determining the place of decimal numbers, then use the value table as a medium of aid; 3) in determining the results of adding and subtracting decimal numbers, it was found that student responses and anticipation of student responses that occurred in the field were in accordance with the didactical design that had been prepared. The student response that occurs is that students can determine the results of adding and subtracting decimal numbers. The anticipation of student responses that has been prepared is quite successful in overcoming the student responses that have emerged.

Although students' responses are not entirely in accordance with the predictions in didactical design, the anticipation carried out by teachers using the right learning media is very helpful in overcoming the obstacles experienced by students (Muliaman, 2021). Student responses that are not present in the prediction such as students require a visual explanation of the learning process, so the actions taken by the teacher to make students understand the concept are like students using the medium of the table of values to determine decimal numbers, students are given the media of sticks to help understand the concept of addition and subtraction of decimal numbers.

After getting the application of the didactical design, students were given a post test to see the extent of students' ability and understanding after the application of the didactical design of decimal number material. The final

identification test will be carried out in fourth grade with a total of 19 students. The percentage of student final identification test results can be seen in Table 3.

Table 3. Learning Obstacle Students Based on Post Test

Learning Obstacle	Presents
Students cannot write decimal numbers.	0%
Students cannot determine the place of decimal numbers.	10%
Students cannot sort decimal numbers.	10%
Students cannot determine the result of adding decimal numbers.	0%
Students cannot determine the result of decimal number subtraction.	0%

Retrospective Analysis

Based on the results of the analysis of diagnostic tests before the implementation of the hypothetical didactic design, 5 learning obstacles experienced by students were found. After the implementation of the didactical design and the analysis of the final identification test was carried out, the Learning Obstacles experienced by students decreased. From the previous 5 Learning Obstacles after the implementation of the design to 2 Learning Obstacles and the two Learning Obstacles have decreased. Although the Learning Obstacles experienced by students have not been completely resolved, the Learning Obstacles experienced by students can at least be minimized, this is in accordance with the opinion of Sakinah et al (2019) that didactic design is part of efforts to minimize learning barriers. The results obtained from the two tests were related to learning obstacles. It can be seen in Table 4.

Table 4. Comparison of Diagnostic and Post Test of Learning Obstacle Results

Learning Obstacle	Presents of Diagnostics Test	Presents of Post Test	Information
Students cannot write decimal numbers	52%	0%	This incident was found in the diagnostic test questions and experienced a decrease in learning obstacles in the final identification test
Students cannot determine the place of decimal numbers	76%	10%	This incident was found in diagnostic test questions and experienced a decrease in learning obstacles in the identification test
Students can't sort decimal numbers	95%	10%	This incident was found in diagnostic test questions and experienced a decrease in learning obstacles in the identification test

Students can't determine the result of adding decimal numbers	28%	0%	This incident is found in diagnostic test questions and has decreased Learning obstacles on identification tests
Students cannot determine the result of decimal number subtraction	19%	0%	This incident was found in diagnostic test questions and experienced a decrease in learning obstacles in the identification test

Based on Table 4, after applying the didactical design that had been designed by the researcher, it was found that the Learning Obstacle that appeared in the diagnostic test with a high percentage decreased in the final identification test. This is in line with Nopriana, Rosita & Widiawati (2018) that Didactical Design Research (DDR) can be an effective tool in developing mathematics learning. Through the stages of analysis, implementation, and reflection, educators can design better learning according to the needs of educators.

CONCLUSION

The students grade 4th elementary school of SD Negeri 2 Lais face several learning obstacles in understanding decimal number concepts, which can be categorized into three types. First, oncogenic obstacles include low motivation and lack of readiness to learn mathematics, as well as insufficient mastery of prerequisite materials. Second, didactical obstacles arise from learning processes that strictly follow textbook sequences without considering students' actual needs and comprehension levels. Third, epistemological obstacles are evident in students' limited understanding of decimal concepts, inability to write decimal numbers, difficulty in identifying decimal places, and challenges in performing addition and subtraction with decimals. To address these issues, a Hypothetical Learning Trajectory (HLT) was employed as a framework for designing effective learning activities. The HLT for decimal numbers includes writing decimal numbers, identifying their place values, and calculating the results of addition and subtraction operations. The implementation of this didactical design has shown positive effects on student learning outcomes, as reflected in improved post-test scores compared to initial diagnostic assessments. Therefore, the HLT-based instructional design proves effective in reducing learning obstacles and can serve as a practical alternative for fourth-grade teachers in achieving the intended learning objectives.

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