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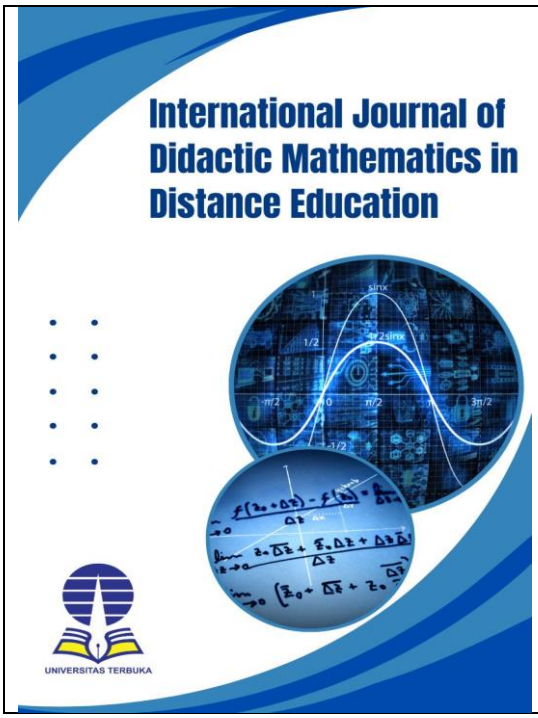

Didactical design for online learning in ordering fractions

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Abstract
During COVID-19, various obstacles were experienced during learning, including in learning mathematics. Learning had to be carried out online. Therefore, learning designs were also attempted to be made online. The learning design in this research was prepared using didactical design research. Participants in this research were 29 students at one of the junior high schools in Indonesia. The researcher was the main instrument in this research, along with several additional instruments, such as the fraction sequence test, interview guide, and online learning design. The data were analyzed using thematic analysis and qualitative analysis. The research results revealed that the factor that caused students to experience obstacles in ordering fractions was due to students' low prerequisite knowledge regarding LCM (conceptual ontogenic obstacle). The online learning design offered then facilitated students to solidify their understanding of LCM before entering the core learning activities. Online learning design was also developed using the theory of didactical situations. After implementation, information was obtained that the learning obstacles experienced by students had no longer reappeared. Therefore, learning in schools should ensure that students have a good understanding of the prerequisites before starting the core learning activities.

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1. Introduction

Fractions are one of the basic concepts in mathematics (Isnawan et al., 2022b; Wahyu, 2021). Fractions have quite a lot of benefits, not only when studying mathematics itself but also in other scientific disciplines and everyday life (Isnawan et al., 2022a, 2023; Lee & Shin, 2015; Zhang et al., 2014). Ideally, learning fractions should not be a problem for students. Learning fractions has become a problem, including fraction order material. For example, participants tend to consider fractions with larger numerator and denominator values as fractions with larger values (Isnawan, 2022). In normal learning, fractions are already a problem. Even more so during COVID-19. All learning has to be done online, so this research attempts to develop an online learning design for sorting fractions.

Several studies have studied the order of fractions. Sunariah & Rijal's (2017) research uses a descriptive qualitative design to determine students' learning difficulties in understanding fractions and their order at a school in Serang, Indonesia. The results of the study reveal that 83% of students have difficulty ordering fractions

with different denominators. Fitriani et al. (2022) use a research design to produce learning trajectories to help students sort fractions through discovery learning at a junior high school in Tasikmalaya, Indonesia. The results of this research reveal that the learning trajectory for fraction sequences starts with understanding decimals, percents, and vice versa; changing fractions to other forms; discovering how to compare improper fractions; discovering how to compare fractions; and finding out how to order fractions. Laurens (2016) uses mixed research methods in studying ethnomathematics in Maluku, Indonesia. The results of this research reveal that the sale of *embal* and *sagu lempeng* can be embedded in the concepts of fractions, equal fractions, and the order of fractions.

In contrast to several previous studies, this research tries to examine learning designs that can minimize students' learning barriers, especially in fraction sequence material. Learning designs are prepared online so that they can be used during the COVID-19 period. To make this study easier, researchers use didactical design research (DDR). DDR is used because it can produce designs that suit student characteristics and tends to minimize barriers to student learning (Sukarma et al., 2024). Several research questions will be answered in this study, including:

a) What are the factors that cause students to experience learning obstacles in ordering fractions?
b) What is the form of didactic design for online learning for fraction sequence material?
c) How is the implementation of didactic design for online learning for fraction sequence material?
d) What are the conditions of learning barriers after implementing online learning design?

2. Method

2.1 Design

The research design used in this research was DDR. DDR was chosen because this design was able to produce learning designs that suited student characteristics (Marfuah et al., 2022; Sukarma et al., 2024; Suryadi, 2019a). This was because the learning design developed was based on factors that caused students to experience learning obstacles. This learning design was called didactic design (Suryadi, 2019a, 2019b). DDR consisted of three research steps: prospective analysis, metapedadidactic analysis, and retrospective analysis. Prospective analysis was an analysis in which researchers attempted to analyze the factors that caused students to experience learning obstacles. The output of this analysis was a didactic design. The online learning design was the output of this step. This analysis was used to answer research questions 1 and 2. Metapedadidactic analysis was an analysis carried out when implementing a didactic design. This step aimed to identify student responses during online learning. This analysis was used to answer research question 3. Retrospective analysis is an analysis in which researchers reflect on the results and processes during implementation. Retrospective analysis in this study involved discussing the methodology and findings (Isnawan et al., 2023; Sukarma et al., 2024). One example of output was the revision of the learning design or the identification of learning obstacles experienced by students after implementing online

learning. This step was used to answer research question 4. The DDR research procedure can be seen in Figure 1.

2.2 Research Participants

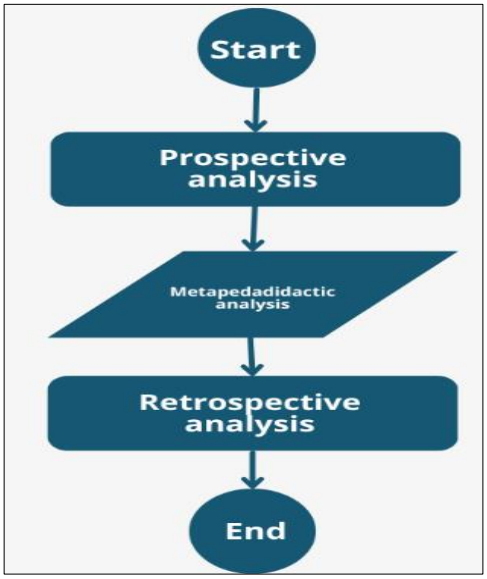
Participants in this research were 29 students who had studied fractions at the junior high school level. Participants' ages ranged from 14 to 18 years; they came from three ethnic groups, namely Sasak, Balinese, and Javanese; and they came from parents' professional backgrounds as entrepreneurs, farmers, builders, farm workers, civil servants, and police.

2.3 Research Instruments

The main instrument in this research was the researcher, with several additional instruments, such as a fraction understanding test, a semi-structured interview guide, an online learning design, and a documentation study. Fraction comprehension tests and semi-structured interview guides were used to obtain data related to factors that caused students to experience learning obstacles. Online learning design was used to obtain data related to the online learning process. Meanwhile, documentation studies were used to obtain data related to students' unique responses during online learning.

Figure 1

Research procedure



2.4 Analyzing of Data

To find out the factors that caused students to experience learning obstacles, researchers analyzed related data using thematic analysis. The stages of thematic analysis carried out were familiarizing oneself with the data (reading the data repeatedly), compiling initial codes, determining themes, reviewing themes, and naming or defining themes (Nowell et al., 2017; Sasidharan & Kareem, 2023). Meanwhile, to understand the process of learning, researchers used qualitative data analysis with several stages, such as data reduction, displaying data, and drawing conclusions related to research questions (Miles et al., 2014).

3. Results and Discussion

3.1 Results

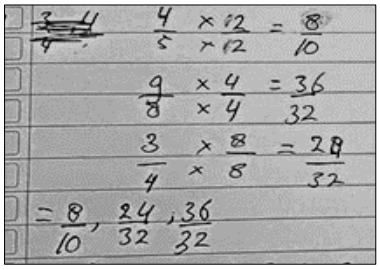
Prospective Analysis

3.1.1. What are the factors that cause students to experience learning obstacles in ordering fractions?

Based on the results of the analysis of student answer sheets, information was obtained that some students were not able to order fractions well. The method students used to order fractions was still incorrect. Although students seemed to be able to equate the denominators of several known fractions, Figure 2 shows a snapshot of students' answers when ordering fractions.

Figure 2

Excerpt of students' answers when ordering fractions



To confirm students' answers, researchers then conducted interviews to determine the factors that caused students to make mistakes when ordering fractions. Excerpts of student interviews can be seen in Table 1.

Table 1

Excerpts from Student Interview Results

Researcher	Informant
How? Is the first one possible or not?	*Can't find the LCM value, let's say it's 32, even if it's both 32 but it doesn't work, right?*
Sir, if you ask how much the LCM from 2 and 3, son?	*Mmm, no, don't know, don't know yet.*

Based on Table 1, information was obtained that one of the factors that caused students to make mistakes in ordering fractions was students' limited knowledge in determining the LCM value. Therefore, the solution offered in the learning design was to strengthen LCM material in the initial learning activities.

3.1.2. What is the form of didactic design for online learning for fraction sequence material?

Based on the previous description of causal factors, there were at least two alternative solutions offered in didactic design. First, strengthening related to the least common multiple (LCM) in initial learning activities. Second, the use of illustrative models makes it easier for students to sort fractions. Exemplary examples of strengthening the LCM and using illustrative models, respectively, could be seen in Figure 3 and Figure 4. Complete details regarding didactic design for online learning could be accessed on the following page: https://shorturl.at/knDJP. This didactic design was then used as a guide in carrying out online learning using *Zoom Meetings*.Figure 3

Footage of strengthening the value of the LCM

Ayo Menebak KPK	
Perhatikanlah beberapa barisan kelipatan bilangan di bawah. Kelipatan dari 2 adalah : 2, 4, 6, 8, 10, 12, ___ Kelipatan dari 5 adalah : 5, 10, 15, ___ Kelipatan dari 10 adalah : 10, 20, ___	
Jawablah pertanyaan di bawah dengan mengisi titik-titik.	
Berapakah nilai KPK dari 2 dan 5?	----------
Berapakah nilai KPK dari 2, 5, dan 10?	----------

Figure 4
Footage of the use of the illustration model

Alternatif cara ke-2		
Misalnya, ilustrasi makanan tersebut seperti pada gambar di samping. Buatlah ilustrasi banyaknya bagian pada gambar tersebut.		
Pernyataan	**Pecahan**	**Ilustrasi**
Bagian yang aku makan. **Ingat:** Arsir atau warnai bagian yang kamu makan.	$\frac{2}{10}$	
Bagian yang adik makan. **Ingat:** Arsir atau warnai bagian yang adik makan.	$\frac{1}{5}$	
Bagian yang kakak makan. **Ingat:** Arsir atau warnai bagian yang kakak makan.	$\frac{1}{2}$	
Siapakah yang memakan bagian yang sama?		----------
Siapakah yang memakan bagian yang paling banyak?		----------
Jadi, orang yang memakan bagian yang sama adalah ---------- dan yang memakan bagian yang paling banyak adalah ----------		

Metapedadidactic Analysis

3.1.3. How is the implementation of didactic design for online learning for fraction sequence material?

Once the online learning design was ready, learning was carried out according to the plan that had been prepared. After most of the students had entered, the lesson was opened by saying greetings and an opening prayer. The researcher then conveyed the learning objectives, namely comparing fractions, which were closely

related to ordering fractions. The activity continued with *Let's Guess.* After a few minutes, several students revealed that they had been able to guess the values of the LCM, FPB, and illustration models. However, because time had not yet ended for this activity, the researcher asked students who had finished to continue the *Let's Read* activity. After the specified time was over, a conversation took place between the researcher and the students regarding the LCM value. From this conversation, it was concluded that students were able to determine the LCM value from 2 and 5, namely 10, and provided reasons related to the process of obtaining the LCM value. Excerpts of conversations between researchers and students can be seen in Table 2.

Table 2

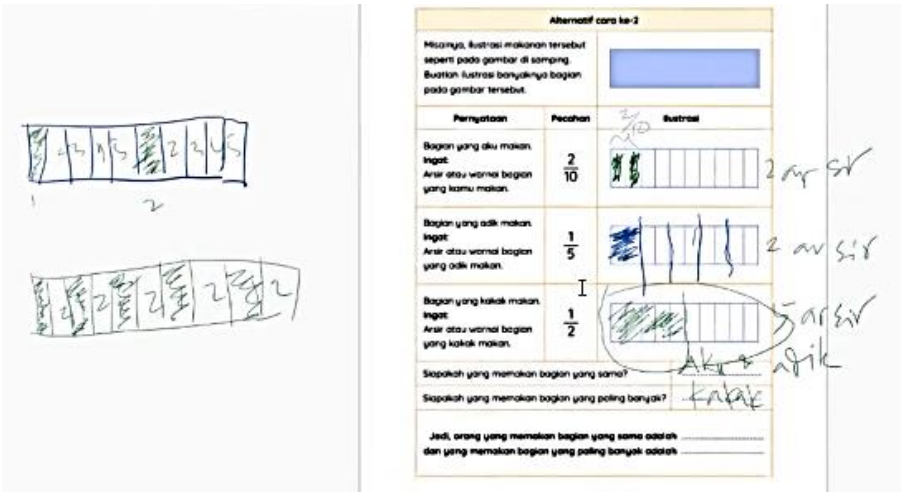
Excerpts of Student Conversations with Researchers for the Let's Guess Activity

Researcher	Student
What is the LCM of 2 and 5?	*Ten sir, ten.*
Why ten?	*Because the multiple of 2 and 5 that has the same result is 10.*
What is the LCM of 2, 5, and 10?	*Same thing, sir, ten.*
Why ten?	*Same sir, because the same number is also 10.*

From this conversation, information was obtained that the students were able to determine the LCM value of three numbers correctly. In other words, the learning obstacles previously experienced by students had been resolved. After the *Let's Guess* activity was discussed, the researcher continued the learning with the *Let's Read* activity. In this activity, students appeared to be able to read well and were able to convey the essence of the reading. The essence of this reading was that the context of watches involved fractions, and in ancient times, the concept of fractions was used for sharing and trading. The next activity was *Let's Look*. This activity was carried out in BOR. In BOR, student groups looked active in solving problems. Students appeared to be able to discuss well and were seen dividing tasks when solving problems. Students also determined which members were tasked with making the presentation. Excerpts of student answers for this activity can be seen in Figure 5.

Figure 5

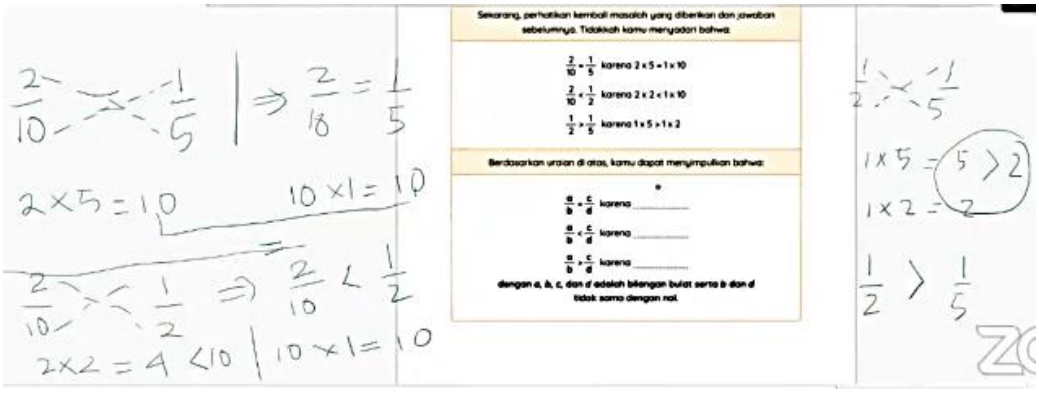
Excerpts of students' answers to the Let's Look activity



After solving the problem, the learning activity continued with *Let's Tell a Story.* In this activity, students appeared to be able to explain the solutions they obtained, and other students provided questions or responses. After all groups had their turn, the activity continued with *Let's Conclusion.* In this activity, it could be seen that students were able to compare fractions and find formulas for comparing fractions. Excerpts of student answers can be accessed in Figure 6.

Figure 6

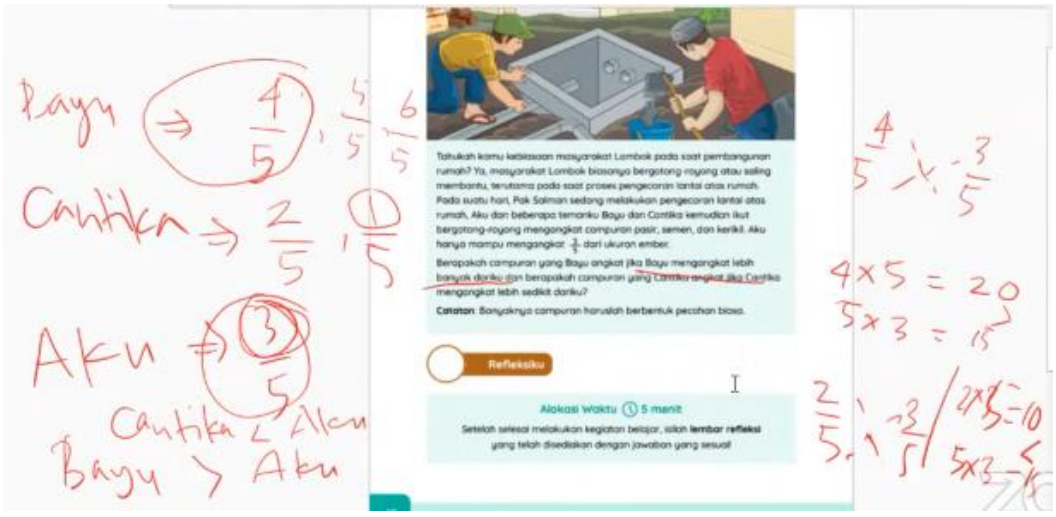
Excerpts of students' answers to the Let's Summarize activity



After students knew the formula for comparing or ordering fractions, the learning activity continued with *Let's Practice.* In this activity, students seemed able to solve the problems given with the help of several trigger questions from the researcher. Excerpts of students' answers to the *Let's Practice* activity can be seen in Figure 7.

Figure 7

Excerpts of students' answers to the Let's Practice activity



The last activity was *My Reflection*. In this activity, students seemed able to correctly conclude the order of fractions and expressed that they felt happy when learning to compare fractions. Students were also committed to continuing to share and help in various social and community activities, such as mutual cooperation.

Retrospective Analysis

3.1.4. What are the conditions of learning barriers after implementing online learning design?

After implementation, information was obtained that some students still experienced problems when sorting. To confirm this, researchers conducted interviews with students. From interviews with students, information was obtained that students did not study enough or their preparation before the exam was so inadequate that students could not answer during the exam. Likewise, for other students, the interview results also revealed the same information, namely that students had less time to study. This was what caused students to not be optimal when sorting fractions.

3.2 Discussion

Regarding the factors that cause students to experience learning obstacles, the following is an explanation: If related to theories related to learning obstacles (Brousseau, 2002; Suryadi, 2019b, 2019a), then the participants in this study experience learning obstacles with the conceptual type of ontogenic obstacle. This is because participants experience learning obstacles due to students' low knowledge of prerequisites. The prerequisite knowledge referred to in this context refers to the concept of LCM, which is the prerequisite material needed for ordering fractions. The results of this research are then in line with research by Aksoy and Yazlik (2017), which reveals that students indicate that they experience learning obstacles in ordering fractions. This obstacle is caused by students' limitations in creating illustrative models, so they tend to assume that fractions with larger numerators and denominators are fractions that have greater value (Malone & Fuchs, 2017). Several previous studies (Erol, 2021; Yang & Liu, 2013) also reveal that students experience obstacles in ordering fractions because they tend to be unable to find equivalent fractions. Regarding illustrative models, the learning design offered in this research attempts to use a variety of illustrative models to help students sort fractions. There are at least three models used, namely the area model, number line model, and object collection model (Isnawan et al., 2022a; Manhattan GMAT, 2012; Petit et al., 2010).

The didactical design for online learning used in this research uses didactical situation theory as a basis for preparing learning activities and steps. At least, this online learning contains situations of action-formulation, validation, and institutionalization (Arslan et al., 2011). This situation is used because it is epistemic, making it easier for students to construct concepts, including when ordering fractions. In action-formulation situations, students are asked to solve problems using mental and physical activities. Problem-solving activities are used as a situation for students to make it easier for them to find formulas for ordering fractions. A validation situation is when students present their solutions in front of the class and another group of students provides responses regarding the solutions presented by the previous group of students. This situation aims to enable students to conclude mathematical concepts or formulas that have been obtained through problem-solving activities. After finding a concept or formula, students then enter a situation of institutionalization. This is a situation when students use concepts or formulas that have been discovered in solving other problems (Sukarma et al., 2024). The action-formulation situation in this research uses the term *Let's Look,* the validation situation uses *Let's Tell* and *Let's Conclusion*, and the institutionalization

situation uses the term *Let's Practice*. Activities in this learning design are classified as epistemic learning patterns because they use didactic situations in composing learning activities. This didactic design also uses three phases in learning, namely initial, core, and closing activities, which refer to the theory that reveals that there are at least three phases in learning, namely preparatory, lecture, and evaluation (Aylward, 2012; The Learning Centers, 2013).

Problems are also used as situations because they tend to be able to ignite the potential that exists in students to use the competencies and experiences they previously had to solve problems and construct mathematical concepts or formulas. As previously described, the learning mode used in this research is online using Zoom Meeting. Zoom Meeting is used because it is commonly used by students for other online learning and tends to be easy to use when creating breakout rooms (BOR) (Prasetya & Mahmudah, 2021; Yanti, 2020).

During the implementation of the online learning design, there were no significant obstacles experienced by students during learning. It is proven that students can determine the LCM value well, students can construct formulas for ordering fractions through problem-solving, and students can use formulas that have been constructed in solving other non-routine problems. This is because the didactic design that is prepared is developed based on factors that cause students to experience learning obstacles (Prabowo et al., 2022; Sukarma et al., 2024). Didactical designs tend to be appropriate to students' developmental stages. The results of this research are then in line with several previous studies (Gantina & Herman, 2013; Miftah et al., 2019; Sulistiawati et al., 2015), which reveal that didactic design tends to get a positive response during learning and also a positive impact on the development of students' mathematical competence. This is because the didactic design is prepared using types of learning obstacles as a basis for compiling designs or alternative solutions to learning. In other words, the implementation of didactic design tends to minimize the learning obstacles that students experience in ordering fractions.

After implementing the online learning design, if it is linked to the theory of learning barriers, it can be concluded that students are not indicated to experience learning barriers. This is because students cannot answer questions due to external factors, but due to internal factors, such as not having enough time to study while at home. The results of this research are then in line with the research of Sukarma et al. (2024), which revealed that students did not indicate experiencing learning obstacles after implementing the didactic design.

4. Conclusion

The didactic design for online learning used in this research minimizes the learning obstacles that students experience when ordering fractions. This is because students' prerequisite abilities, especially the LCM concept, are quite good, and students can construct formulas for ordering fractions as well as use these formulas in solving other non-routine problems. Therefore, mathematics teachers should use didactic designs developed based on factors that cause students to experience learning obstacles as a basis for developing learning designs. Even though it minimizes students' learning barriers in ordering fractions, this research still has limitations, namely that the integration of technology is not yet optimal. For example,

in making illustrations, students still use manual methods. Therefore, future research is expected to be able to integrate a variety of more sophisticated technologies, especially in creating illustrations, such as https://www.mathsisfun.com/fractions.html.

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Author Contribution:
Author 1: Conceptualization, Writing - Original Draft, Editing and Visualization, Writing - Review & Editing, Formal analysis, and Methodology;
Author 2:Validation and Supervision.
Conflict of Interest:
The authors declare no conflict of interest.

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