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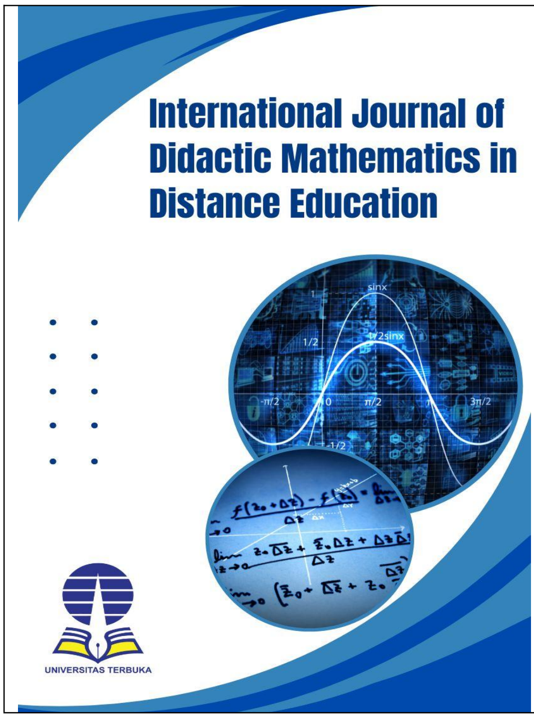

Online didactical design for subtraction fractions: a didactical design research through lesson study activities

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Online didactical design for subtraction fractions: A didactical design research through lesson study activities

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Abstract
The COVID-19 pandemic disrupted educational practices worldwide, posing significant challenges for students, particularly in mastering foundational mathematical concepts such as fraction subtraction. In response to the urgent need for effective remote learning strategies, this study aimed to develop and implement an online didactic design to reduce student learning obstacles. Employing a Didactical Design Research (DDR) approach, the design process was supported by lesson study activities at each developmental phase to ensure instructional quality. Participants included 56 students from grades VII and VIII (ages 13 to 18). The researcher served as the primary instrument, supported by additional tools including a fraction test, interview guide, documentation study, and the online didactic design itself. Thematic analysis was used to identify learning barriers, while qualitative analysis assessed the effectiveness of the design implementation. Findings revealed that during the pandemic, students experienced both ontogenic and epistemological learning obstacles in subtracting fractions. However, after the online didactic design was introduced and implemented, these learning barriers were no longer evident. Remaining difficulties were attributed to internal, non-instructional factors, such as limited personal study time, rather than issues related to instructional delivery. This study contributes to the field of mathematics education by providing an empirically grounded model for designing online instruction that addresses specific learning barriers. The findings underscore the importance of aligning didactic design with student learning needs, especially in crisis contexts, and highlight the potential of structured online approaches to support equitable mathematics learning.

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1. Introduction

Studying fractions is essential for advanced mathematics, other scientific disciplines, and daily life (Alsulami et al., 2023; Isnawan et al., 2022; Isnawan et al., 2023; 2023; Muhiban et al., 2023; Wahyu, 2021). For some people, fractions are a simple mathematical concept. However, for some people, fractions are a complicated mathematical concept (Zhang et al., 2014). Even in the context of learning mathematics, fractions are a problem for students even when learning mathematics. Under normal conditions, fractions are already a problem for students, especially during the COVID-19 pandemic. Various types of research study fractions, but not many are studying fractions during COVID-19 and using didactical design research as an alternative solution for learning fractions during COVID-19.

Jarrah et al. (2022) have conducted research using a qualitative descriptive method to examine junior high school students in the UAE's understanding of subtracting fractions. The research has revealed that subtracting fractions remains a problem for students. Different from previous research, Widiawati and Deniansyah (2022) have used research design to study learning to reduce fractions at a junior high school in Pagaralam, Indonesia. The research has revealed that the use of chaplet context has helped students discover the concept of subtracting fractions. Parwadi et al. (2020) have used a descriptive research design to identify types of student errors in subtracting fractions. The research has revealed that 42.4% of errors occur when students subtract fractions.

Different from previous research, this research uses didactical design research as a research design to help students carry out learning during COVID-19. This research proposes an alternative approach, which involves using an online didactic design to teach fraction reduction. In addition, this research uses lesson study activities to produce effective and efficient online didactic designs (Fitriati et al., 2023). Therefore, this research aims to minimize barriers to student learning through the implementation of online didactic design. To achieve the research objectives, we have formulated several research questions.

a) What are the types of student learning obstacles when learning to subtract similar mixed numbers?
b) What is the type of online didactic design for studying fraction subtraction?
c) How is the implementation of online didactic design for subtraction fractions?
d) What are the conditions of student learning barriers after implementing online didactic design in reducing fractions?

2. Method

2.1 Design

DDR was used as the design type in this research. DDR was chosen because it is based on an interpretive paradigm (Suryadi, 2019a), which sought to interpret the types of learning obstacles that students experienced and identify the factors that caused students to experience these obstacles. Apart from that, DDR was also used because DDR was based on a critical paradigm that sought to develop alternative learning designs that could be used to overcome students' learning obstacles (Sukarma et al., 2024; Suryadi, 2019b). Lesson study activities were then used in this research when researchers prepared learning designs, implemented them, and reflected on learning outcomes (Huang & Shimizu, 2016; Joubert et al., 2020). This was intended to make revisions to the didactic design better.

DDR research consisted of three research steps: analysis before learning (prospective), metapedadidactic analysis, and analysis after learning (retrospective) (Marfuah et al., 2022). Pre-learning analysis was intended to identify types of student learning barriers and determine the factors that caused students to experience learning barriers. Apart from that, this analysis also produced final results in the form of online didactic designs. The next step in DDR was metapedadidactic analysis. In this step, the researcher implemented an online didactic design to determine the connection, flexibility, and unity between didactic situations. The final step was learning. The lesson study team, apart from the model teacher, was an observer of online learning. In this step, the researcher revised, together with the lesson study team, the online didactic design based on the implementation results. Figure 1 shows the research procedure.

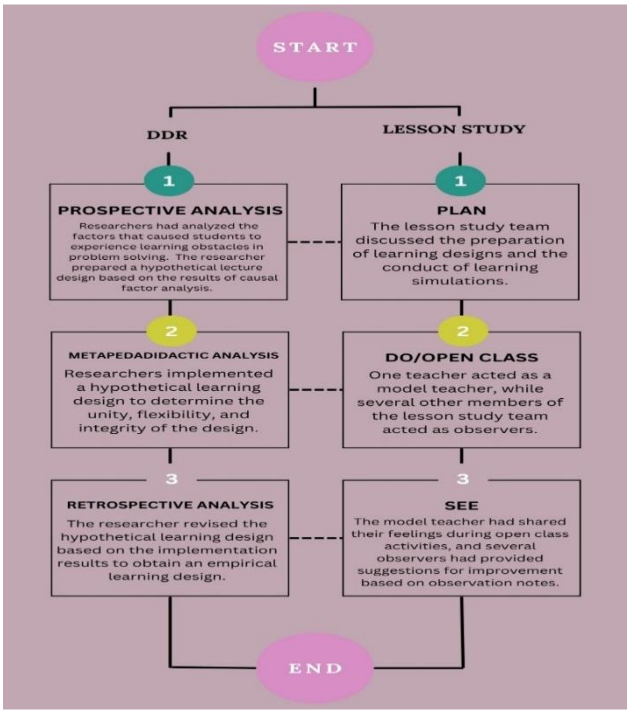
2.2 Research Participants

Participants in this research consisted of two groups of students. The first group was 27 students who had not studied fractions in middle school. Meanwhile, the second group consisted of 29 students who had studied fractions in junior high school. The age range of participants ranged from around 13 to 18 years.

2.3 Research instruments

Because this research used a qualitative approach, the researcher acted as the main instrument. To make it easier to obtain data, researchers used several additional instruments. Some of these additional instruments included online didactic designs, fraction tests, student answer sheets, interview guides, and learning video recordings.

Figure 1
Research procedure



2.4 Analyzing of Data

Miles et al. (2014) used qualitative analysis with data reduction steps, data display, and conclusion drawing to analyze the data resulting from the implementation of online didactic design. Meanwhile, we used thematic analysis to analyze the data related to learning barriers. The thematic analysis steps carried out included identifying initial codes, determining themes, reviewing themes, and naming or defining themes (Alhojailan & Ibrahim, 2012; Finkelstein et al., 2019; Nowell et al., 2017).

3. Results and Discussion

3.1 Results

3.1.1 Prospective Analysis

3.1.1.1 What are the types of student learning obstacles when learning to subtract similar mixed numbers?

Based on the results of the thematic analysis, information was obtained that the themes of learning obstacles experienced by students when subtracting similar fractions were divided into three themes, namely students who could not subtract similar fractions, students who could not understand the prerequisite material, and students who were able to subtract fractions kind of well. In connection with the prerequisite material, in this context, students tended not to be able to optimally convert mixed numbers into fractions. A complete description of the answer to this question can be seen in Table 1.

Table 1
Mixed Number Subtraction Theme

Initial Code	Theme	References
The final result is wrong and just write down the final result.	Can not do the procedure	20
Students add the denominator to the denominator and the numerator to the numerator.		
Students simply add denominator to denominator.		
Students are unable to convert mixed numbers into fractions.	Can not get prerequisite material	21
Students are unable to simplify fractions.		
Students are unable to perform integer subtraction operations.		
Student outcomes and procedures are appropriate.	Results and procedures correspond correctly	7

After conducting interviews, information was obtained that there were several reasons why students experienced learning obstacles. First, students were not careful when carrying out subtraction operations on whole numbers. Second, students had forgotten material related to fractions, including how to convert mixed numbers into improper fractions. Third, teachers' teaching methods tended to only provide material, then sample questions and practice questions during the COVID-19 pandemic.

3.1.1.2 What is the type of online didactic design for studying fraction subtraction?

Following up on the answer to the previous question, information was obtained that students were not careful in their work, the learning methods used by teachers tended to be conventional, and learning was not optimal due to COVID-19. Therefore, the solutions offered in online didactic design also contained several alternatives. First, the didactic design offered was used for online learning as a means to address learning concerns during the COVID-19 pandemic. Second, the online didactic design contained several learning instructions that acted as reminders for students not to be careless during learning. Third, the online didactic design was prepared based on didactic situation theory, which facilitated students in constructing concepts or formulas by solving mathematical problems to anticipate conventional learning methods used by previous teachers. One example of a snapshot of the use of problems in online didactic design can be seen in Figure 2.

Figure 2
A snapshot of the use of problems in online didactic design

3.1.2 Metapedadidactic Analysis

3.1.2.1 How is the implementation of online didactic design for subtraction fractions?

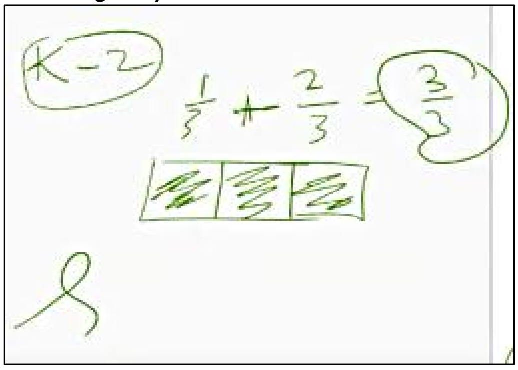
Like several other online learning courses, the implementation of online didactic design used Zoom meetings as a platform for carrying out learning. The learning activities began with greetings and opening prayers. The first activity was Let's Guess. In this activity, the researcher asked students to determine the KPK values of 5 and 10. Students appeared to be able to answer that the KPK value between 5 and 10 was 10. Students were then asked to find the KPK values of 5, 10, and 15. Students successfully provided the correct answer, which was 30. In relation to FPB, students also appeared to be able to determine the FPB value from 5 to 10, which was 5. Students also appeared to be able to provide an explanation regarding the process of finding the KPK and FPB values.

These results indicated that the students' prerequisite abilities were good and ready to continue learning in the next activity. The next activity was Let's Read. In this activity, students were able to read motivational stories well but were not yet able to express the essence of the story. Therefore, researchers revealed that fractions were quite useful in life, such as in the world of health, pharmacy, and art. The next activity was Let's Look. The Let's Search activity divided the students into breakout rooms (BOR). The BOR required students to solve problems. During this session, students engaged in discussions about problem-solving and divided presentations.

Once finished, the next activity was Let's Tell a Story. Students were required to present the results they had obtained in this activity. All groups were able to present the results well. Figure 3 displays footage of the students' work results.

Figure 3

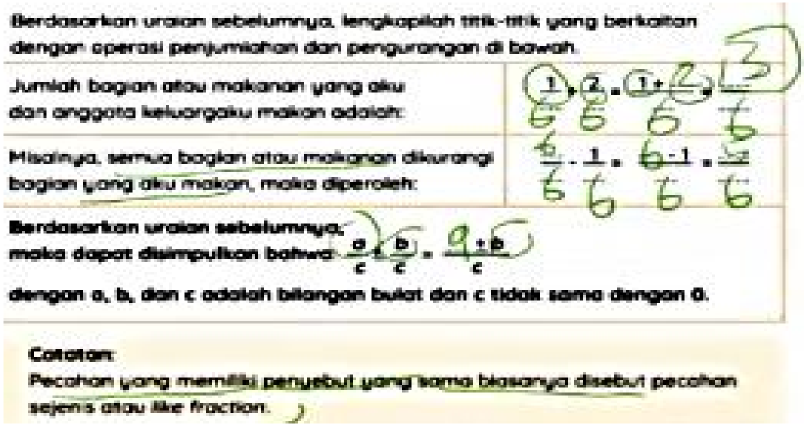
Excerpt from the answers of one group of students



Once finished, the learning activity continued with Come to Conclusion. In this activity, students appeared to be able to construct their own fraction subtraction formulas. Figure 4 shows excerpts of student answers.

Figure 4

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



Berdasarkan uraian sebelumnya, lengkapilah titik-titik yang berkaitan dengan operasi penjumlahan dan pengurangan di bawah.

Jumlah bagian atau makanan yang aku dan anggota keluargaku makan adalah:	$\frac{1}{6} + \frac{2}{6} = \frac{1+2}{6} = \frac{3}{6}$
Misalnya, semua bagian atau makanan dikurangi bagian yang aku makan, maka diperoleh:	$\frac{6}{6} - \frac{1}{6} = \frac{6-1}{6} = \frac{5}{6}$

Berdasarkan uraian sebelumnya, maka dapat disimpulkan bahwa: $\frac{a}{c} + \frac{b}{c} = \frac{a+b}{c}$

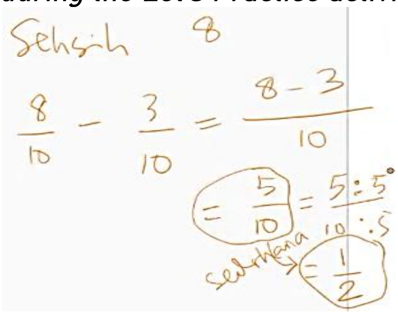
dengan a, b, dan c adalah bilangan bulat dan c tidak sama dengan 0.

Catatan:
Pecahan yang memiliki penyebut yang sama biasanya disebut pecahan sejenis atau like fraction.

The next activity was Let's Practice. In this activity, students seemed capable of solving problems well. Excerpts of student answers for this activity can be seen in Figure 5.

Figure 5

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



The last activity was my reflection. In this activity, students expressed that they felt happy participating in learning activities. Apart from that, students were also committed to walking and helping Mother complete homework. This commitment was related to the meaning of fractions, which taught us to help each other in everyday life. Video recordings made during the implementation of online didactic design could be accessed on the following page: https://www.youtube.com/watch?v=ZeRJx53ogFU.

3.1.3 Retrospective Analysis

3.1.3.1 What are the conditions of student learning barriers after implementing online didactic design in reducing fractions?

Following the completion of the lesson, the researcher collaborated with the lesson study team to pinpoint potential barriers to student learning. The analysis results revealed that students might be facing learning obstacles. The thematic analysis revealed several themes, including difficulty with the procedure, difficulty with the prerequisite material, and difficulty with completing the procedure and providing the correct answer. A complete description of the themes formed can be seen in Table 2.

Table 2 revealed that some students could solve fraction subtraction problems. However, further analysis revealed that some students also struggled to correctly solve fraction subtraction problems. Interviews with students revealed that some expressed a lack of preparation for the exam. This was because students had quite a lot of assignments to complete on the same day. These results then led to the conclusion that students were not indicated to experience learning obstacles because the problems experienced by students were due to students' factors, namely the lack of time allocated for studying.

Table 2

Mixed Number Subtraction Theme (After Implementation)

Initial Code	Theme	References
The final result is wrong and just write down the final result.	Can not do the procedure	7

Students add the denominator to the denominator and the numerator to the numerator.		
Students simply add denominator to denominator.		
Students are unable to convert mixed numbers into fractions.	Can not get prerequisite material	7
Students are unable to simplify fractions.		
Students are unable to perform integer subtraction operations.		
Student outcomes and procedures are appropriate.	Results and procedures correspond correctly	8

3.2 Discussion

Regarding the existence of barriers to learning during the COVID-19 pandemic, the results of this research are different from Rianasari and Julie (2018) which, in one of its conclusions, revealed that students were able to convert mixed numbers into fractions well. The results of this study are also different from Singh et al. (2021) which revealed that there were several students who were able to convert mixed fractions into improper fractions. The difference in research results seems to be due to the fact that during the COVID-19 pandemic, students were not studying optimally. In other words, when students were still in class VII, almost all of the students at this research location experienced lost learning, which had an impact on understanding the subject matter, including the concept of fractions. The results of this research are then in line with several studies that reveal that students experienced learning obstacles during the COVID-19 pandemic (Isnawan et al., 2022; Stewart et al., 2022; Zhou et al., 2020).

If linked to the theory regarding learning barriers (Brousseau, 2002; Suryadi, 2019b), it can be concluded that students are likely to experience several types of learning barriers. First, students experience learning obstacles with the type of psychological ontogenic obstacle because students tend to be less careful when doing their work. Second, students are indicated to experience learning obstacles with the type of epistemological obstacle because the learning methods used by teachers are less relevant to students. Third, students are indicated to experience learning obstacles with the instrumental ontogenic obstacle type because they are experiencing problems due to the COVID-19 pandemic.

As previously described, the online didactic design in this research uses didactic situation theory. This theory is used because it is able to facilitate students in constructing concepts or formulas in mathematics through the problem-solving process (Sukarma et al., 2024). The didactic situations contained in the online didactic design are divided into several situations, namely action-formulation, validation, and institutionalization situations. Action-formulation situations are situations when online didactic design presents problems for students to solve as a means of constructing concepts or formulas for reducing fractions. Validation situations are situations in online didactic design that facilitate students to present solutions to problems, with the final result being the discovery of a concept or formula for reducing fractions. Institutionalization situations are situations in didactic design that facilitate students using concepts or formulas to solve new problems (Arslan et al., 2011).

In general, the implementation of didactic design follows an epistemic learning pattern. Epistemic learning patterns facilitate learning from initial activities to final activities in learning (Sukarma et al., 2024). Apart from that, the implementation of online didactic design has also gone well because students are able to follow a series of didactic situations to form a complete lesson. The flexibility of online didactic design can also be seen in the fact that when students are unable to carry out an activity optimally, the teacher takes over the role by re-reading some of the trigger questions contained in the online didactic design so that students are finally able to do the activity. The results of this research are in line with several previous studies (Gantina & Herman, 2013; Rønning, 2021; Sollervall & Iglesia, 2016; Sukarma et al., 2024), which revealed that online didactic design can optimize student activities during learning.

The results of this research are then in line with several previous studies (Kasim, 2017; Sukarma et al., 2024; Sulistiawati et al., 2015), which revealed that didactic design was able to reduce the existence of barriers to student learning after implementation. This is because the didactic design is prepared using didactical situations that facilitate students to use physical and mental activities in solving problems. Through this problem-solving activity, students were able to discover the concept or formula for subtracting fractions, as well as use this concept or formula in solving other problems in different contexts or situations. Lesson study activities are quite helpful for students because researchers and a team of teachers can develop online didactic designs that are effective and efficient (Chen & Li, 2010; Huang & Shimizu, 2016; Isnawan & Fakhrina, 2023).

4. Conclusion

This study set out to investigate how an online didactic design could reduce learning obstacles in mathematics during the COVID-19 pandemic. The findings confirm that students faced multiple types of learning barriers—including psychological, instrumental, ontogenic, and epistemological obstacles—largely due to the disruptive learning environment and reliance on conventional instructional methods. To address these challenges, the research developed an online didactic design grounded in epistemic learning patterns and supported by lesson study activities. The results demonstrate that the implemented design effectively minimized learning obstacles. Students engaged more actively in the learning process, and post-implementation analysis showed no significant evidence of the previously identified barriers. These outcomes suggest that well-structured online didactic designs can facilitate meaningful mathematical understanding, even under constrained conditions. However, limitations remain, particularly regarding equitable access to online learning. Some students were unable to fully participate due to poor internet connectivity or lack of technological resources. To mitigate this, future implementations should ensure the availability of alternative learning modalities—such as recorded lessons on accessible platforms (e.g., YouTube) or offline support through printed materials and home visits. This research contributes to the growing body of knowledge on effective digital pedagogy in crisis contexts and offers practical implications for mathematics teachers seeking to overcome instructional barriers. Future studies should explore the long-term impact of such designs, examine student engagement across diverse socio-economic backgrounds, and refine strategies for inclusive, flexible learning environments in both emergency and post-pandemic education settings.

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Declarations

Author Contribution:

Author 1: Conceptualization, Writing - Original Draft, Writing - Review & Editing, Formal analysis, and Methodology;

Author 2: Editing, Visualization, Validation and Supervision.

Conflict of Interest:

The authors declare no conflict of interest.

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