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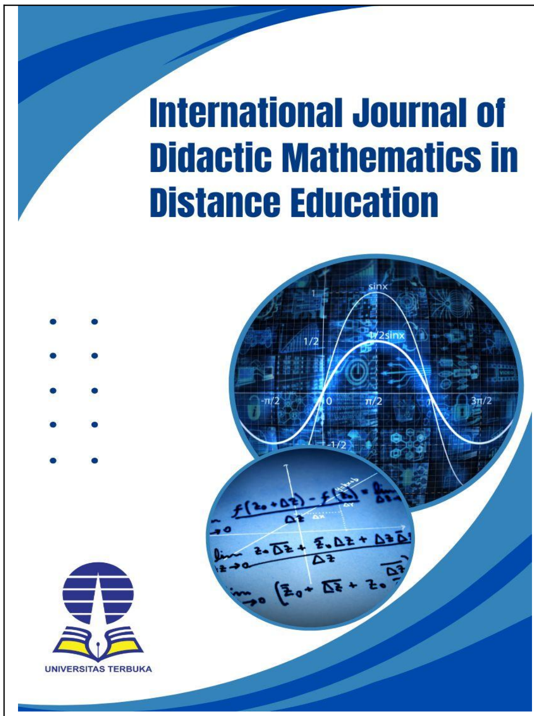

Implementation of a hybrid mathematics module to minimize students' learning obstacles when interpreting fractions

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Implementation of a hybrid mathematics module to minimize students' learning obstacles when interpreting fractions

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Abstract
The COVID-19 pandemic forced a sudden shift to emergency remote teaching—commonly referred to as panic-gogy—which exacerbated students' learning challenges, particularly in mathematics. This study addresses the urgent need for responsive instructional designs by integrating parental insights into the learning process. Framed within the didactical design research (DDR) methodology, this study aimed to develop an alternative learning approach to reduce obstacles in students' understanding of fractions during panic-gogy. Participants included 56 junior high school students (aged 13–18) and 71 parents (aged 35–50) from a school in Indonesia. Data were collected using a fraction concept test, semi-structured interviews, a hybrid mathematics module, and documentation analysis. Thematic qualitative analysis was conducted with the aid of NVivo 12. Results revealed that students struggled with interpreting the meaning of fractions, often due to inadequate teacher explanations. Parental feedback emphasized a strong preference for face-to-face instruction, even when delivered via online platforms. The hybrid mathematics module, designed in response to these findings, successfully integrated contextual problem situations to support the construction of fractional meaning and reduce learning barriers. This study contributes to the body of knowledge by highlighting the value of involving parents in instructional design and demonstrating how hybrid modules can mediate learning in crisis contexts. The findings have implications for developing resilient educational strategies in future disruptions.

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1. Introduction

The educational systems were threatened by the COVID-19 pandemic (Engelbrecht et al., 2020; Karahisar & Unluer, 2022; Wildemeersch & Jütte, 2017), thereby causing learning to evolve from face-to-face into distance learning (DL), including mathematics learning (Borba et al., 2020; Clark-Wilson et al., 2020; Engelbrecht et al., 2022). Also, classrooms normally bustling with student interactions became quiet as learning activities were conducted virtually. Mathematics teachers, who rarely interacted with the digital world while learning, were forced to harness different digital learning platforms, such as Zoom Meetings, Google Meet, and Moodle, to maintain the continuity of teaching and learning (Asad et al., 2021; Cevikbas & Kaiser, 2020; Marfuah et al., 2022; Reimers et al., 2020). Similarly, social media platforms, which were typically used for interactions among friends or co-workers (Bencivenga, 2017; Omeh & Olelewe, 2021; Zhou et al., 2022) , evolved into a place for teachers to share materials and give assignments to students (Chirinda et al., 2021). These changes led to a panic-based phenomenon called 'panic-gogy' (Kamanetz, 2020).

Panic-gogy causes a variety of issues in learning, particularly in mathematics. Therefore, researchers are using various methods to analyze the phenomenon of distance learning of mathematics (DLM), which includes the panic-gogy that currently occurs in mathematics classes. In Indonesia, a cross-sectional questionnaire with a quantitative method was employed to identify the obstacles that middle school mathematics teachers experienced during the panic-gogy in mathematics learning. The difficulties experienced included limited smartphones, internet connection problems, and inadequate student skills in using digital learning platforms (Mailizar et al., 2020) . In South Africa, a descriptive qualitative study combined with an experimental method revealed how high school mathematics teachers responded to panic in mathematics learning. The results showed that teachers learned from various communities accustomed to facing obstacles during the panic-gogy in mathematics learning, such as the widely used digital learning platforms or media (Prabowo et al., 2022). It is the reason Chirinda et al. (2021) explained that WhatsApp had been a space for mathematics teachers to facilitate learning activities. In Australia, a qualitative descriptive method was used to describe elementary teachers' challenges during the panic-gogy in mathematics learning. It was discovered that teachers were not accustomed to using digital learning platforms. Also, the interaction between the teachers and students and the one among students tended to be lacking. The teachers' feedback was not optimal, and they faced challenges in assessing and facilitating the differences in student learning abilities (Kalogeropoulos et al., 2021) . Other studies also revealed the problems students experienced from the teacher's perspective (Akar & Erden, 2021; Barlovits et al., 2021; Chirinda et al., 2021; Hadriana et al., 2021).

Most of the studies focused on mathematics teachers as subjects (participants) and also analyzed the obstacles experienced during the panic-gogy in mathematics learning. Moreover, only a few discussed the solutions to this problem and considered the students and parents as participants. For example, Diana et al. (2021) and Gann & Carpenter (2017a, 2017b) considered parents as the primary companions or impromptu teachers during the panic-gogy in mathematics learning. Only a limited number of junior high school education levels were considered in those studies (Engelbrecht, et al., 2020) . These are the levels where children are in their formal operational stage, which is critical to developing students' formal mathematical understanding. Apart from that, not many previous studies used didactical design research (DDR). In fact, DDR is quite relevant to use as a research design, especially when the research aims to find alternative solutions in mathematics learning (Sukarma et al., 2024) . Therefore, this study aims to look for alternative solutions to minimize obstacles to students' mathematics learning during panic-gogy. The focus of this research is learning the meaning of fractions during the panic-gogy.

Scope of Fractions in School Mathematics

Regarding the concept of fractions, countries from various parts of the world have their own approaches or curricula. For example, Japan uses a visual and concrete approach, such as the use of area models and line numbers in introducing fractions (Watanabe, 2006). Elementary mathematics teachers in Japan introduce the fraction concept as a quantity less than one and as a number similar to other numbers with a position on the number line, such as a meter stick (Watanabe, 2007). In line with Japan, Singapore uses bar models (Low et al., 2020) to make it easier for students to learn fractions. The same goes for countries in

North America. The USA utilizes various forms of manipulation starting with the concept of unit fractions, such as area models, in introducing fractions (NCTM, 2014; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) . Steffe & Olive (2010) outlined children's fraction concepts with counting schemes, part-whole schemes, partitive and iterative schemes, and units-of-units schemes. In Europe, Australia, and Africa, it is almost the same. Countries on these continents use various forms of illustration models in teaching fractions. In general, the strategy used in introducing fractions is almost the same as in Indonesia, namely using the area model. In fact, in Indonesia, students are also introduced to the concept of fractions using number lines (BSKAP, 2022; Isnawan, 2023).

Barriers in Learning Fractions

At least three types of illustration models are commonly used in learning fractions, namely the area model, number lines, and collections of objects (Isnawan et al., 2022). The area models used also vary, ranging from rectangles, squares, circles, and other relevant two-dimensional shapes. Basically, the use of various forms of illustration models is expected to minimize learning barriers experienced by students when learning about the concept of fractions. Learning barriers are learning difficulties experienced by students due to factors outside the student, such as teachers or learning design (Sukarma et al., 2024; Suryadi, 2019b). There are three types of learning barriers that students usually experience when learning mathematics, including learning fractions: epistemological, didactic, and ontogenic (Hendriyanto et al., 2024). Epistemological barriers relate to learning barriers that arise due to a lack of context, situation, or illustrative models used by teachers during learning. Didactic barriers refer to learning barriers experienced by students due to a lack of understanding of mathematics teachers regarding the content of the material, curriculum, or errors in the sequence of learning. Ontogenic barriers are learning barriers caused by students' unpreparedness when participating in learning. This unpreparedness is related to the teacher's actions that are less than optimal in preparing students before or during the initial learning activities (Prabowo et al., 2022; Sukarma et al., 2024).

The Role of Parents in Learning

To minimize the occurrence of learning obstacles in students, parents play an important role. Parents cannot completely hand over the improvement of student competence to teachers alone, especially during panic-gogy. In this context, parents play a crucial role because they are the main companions of students in learning (Diana et al., 2021) . Additionally, parents are responsible for providing all the devices and necessities needed while studying at home (Gann & Carpenter, 2017a; Isnawan et al., 2022). Parents do not need to fully master the mathematics material but should act as companions to their children in learning. They can contact teachers when they encounter obstacles during panic-gogy.

Framing of Research Questions

By knowing the types of learning barriers, teachers can easily identify the factors that cause students to experience learning barriers. By knowing these causal factors, teachers can easily compile a learning design. Learning designs that are compiled by utilizing the results of learning barrier analysis as one of the considerations in compiling designs are called didactic designs. There are various types of didactic designs, one of which is a module. Based on how they are used, modules are divided into several types, one of which is a hybrid mathematics module. A hybrid mathematics module is a module that can be used for offline learning, online learning, or a combination of offline and online. To achieve the previous learning objectives, several research questions are proposed by the researcher. The questions formulated to achieve the objectives include:

a) What are the obstacles to student learning in mathematics during panic-gogy?

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b) What solutions do parents seek to overcome mathematics learning challenges during panic-gogy?
c) What is the description of the form of mathematics learning design during panic-gogy?
d) How is the implementation of mathematics learning design during panic-gogy?
e) What are the obstacles to students' mathematics learning after implementing the learning design during panic-gogy?

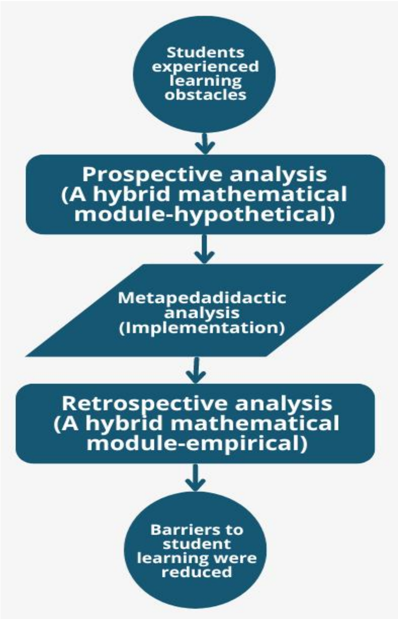
2. Method

In this section, first, we outline the research design for this study. Second, we describe the research participants. Third, we exlain the research tool. Finally, we discuss the analysis and interpretation of the data.

2.1 Research Design

A qualitative approach with a DDR-type research design was used in this research. The design was chosen because it examined an individual's experience regarding a phenomenon (Creswell & Creswell, 2018; Palacios & Simons, 2021; Stolz, 2020) and tried to provide alternative solutions by considering this phenomenon as a basis for developing learning designs. It is important to mention that the phenomenon considered in this study was panic-gogy during the COVID-19 pandemic. The procedure in this study then followed the steps of DDR, namely prospective, metapedadidactic, and retrospective analysis (Marfuah et al., 2022; Suryadi, 2019b) . During the prospective analysis, researchers developed a learning design in the form of a hybrid mathematics module that considered the factors that caused students to experience obstacles in learning mathematics during the panic-gogy. This step was used to answer the first three research questions. After the hybrid mathematics module was completed, the researcher implemented the module during the panic-gogy. This implementation process was referred to as metapedagogic analysis. The final research step was a retrospective analysis. This step was used to answer the fourth research question. In this step, researchers analyzed whether the learning obstacles experienced by students still appeared or not after the implementation. This step was used to answer the final research question (Sukarma et al., 2024) . In summary, the research procedure can be seen in Figure 1.

Figure 1
Research procedure



2.2 Research Participants

The participants of this study were: (a) 29 students who had studied fractions in junior high school (aged 14–18 years); (b) parents of seventh-grade junior high school students, totaling 71 people; and (c) 27 students who had not studied fractions in junior high school (aged 13–15 years old). The term "parents" in point (b) refers to all student parents, including the ones mentioned in point (a). Initially, all student parents were targeted as participants in the research. However, only 71 parents filled out the questionnaire. Additionally, we selected parents of students as one of the participant groups, as they served as their primary companions during the COVID-19 study period at home. The research was conducted from July 2021 to June 2022. As the main companion for students, it was appropriate to use parental information as one of the bases in preparing learning designs for students. This was because parents knew very well what students experienced while studying at home. Study ethics, including informed consent, anonymity, and confidentiality, were the primary considerations in selecting participants. Furthermore, this study (a) conveyed the purpose of having the instrument completed by parents, (b) did not force parents to fill it out, and (c) did not include parents' names for anonymity when filling out the form. Based on the ethics of informed consent and voluntary participation (Esposito, 2012; Roberts & Allen, 2015) , only 71 of the 332 parents who were the target participants voluntarily filled out the Google forms. Of the 71 participants, 57 were male and 14 were female, with ages ranging from 35 to 50 years. Most participants, totaling 37, were traders, entrepreneurs, or workers; 14 worked as civil servants, police, or the army, and the rest as drivers or construction workers.

2.3 Instrument of the Study

The researcher was the main instrument in this research, along with several additional instruments. Data were collected using: (a) fraction meaning tests and student answer sheets to identify students' learning barriers in understanding fractions; and (b) in-depth interview guides for students to confirm student answers when working on test questions. The main purpose of these guidelines was to identify the types of learning barriers in students from the perspective of the factors that cause these barriers; (c) semi-structured interview guides with open-ended questions to ensure diversity in the various answers provided by parents; (d) a hybrid mathematical module; and (e) study documentation in the form of online learning video recordings. The questions went through the expert judgment stage with the "essential" category and were valid as instruments (Lawshe, 1975). Researchers asked approximately nine experts to assess the instrument. In this study, triangulation of data sources and data collection techniques was used to strengthen trustworthiness (Morrison et al., 2019).

2.4 Analysis and Interpretation

Then, the data obtained from student answer sheets and the distributed Google forms were entered into the NVivo-12 software to simplify data management and coding. NVivo-12 was selected because it (a) was more systematic and followed thematic analysis characteristics; (b) was easy to use; (c) accepted various data types; and (d) provided results in various displays (Dalkin et al., 2020; Paulus et al., 2015) . In the context of this research, NVivo-12 was used to make it easier for researchers to carry out the coding process, not as an analysis technique.

Furthermore, the existing data in the NVivo-12 software was analyzed using thematic analysis. The several steps of thematic analysis conducted included (a) familiarizing oneself with the data by reading them repeatedly; (b) forming the initial code (IC) from the available data; (c) forming a theme from several initial codes with the same characteristics; (d) naming and defining the theme; and (e) compiling the reports (Finkelstein et al., 2019; Scharp & Sanders, 2018) . It is important to note that the theme referred to parents' experiences regarding alternative strategies concerning panic-gogy when learning mathematics. In the NVivo-12, references were the leading criteria during the coding process, which means a code or theme was as important as how much it had been referenced. These references referred to the number of data sources consisting of an initial code or theme. Meanwhile, data originating from student answer sheets, hybrid mathematical modules, and learning video recordings were analyzed using qualitative data analysis. The stages of this analysis were data reduction (where the researcher eliminated data that was not relevant to the research question), data display (where the researcher displayed data in various forms of representation), and drawing conclusions (where conclusions were made related to the answers to the research question) (Miles et al., 2014).

3. Results and Discussion

First, we present the results of the analysis of the data from the different sources, aligned with the research questions. Then, we discuss these results by interpreting them in the context of relevant theories and findings of other studies.

3.1 Results

3.1.1 Prospective Analysis

a. What are the obstacles to student learning in mathematics during panic-gogy?

Based on the results of the thematic analysis of student answer sheets, students experienced learning obstacles during panic-gogy. Students had a limited understanding of interpreting fractions. There were at least four themes of the meaning of fractions expressed by participants, namely *fractions as rational numbers*, *fractions as part of a whole*, *fractions as a tool*, and *fractions as whole numbers*. If we consider the true meaning of fractions, we find only two proper meanings: as rational numbers and as parts of a whole. To ascertain the factors causing students to experience limitations in understanding the meaning of fractions during the panic-gogy, researchers conducted interviews with several students and their mathematics teacher. The mathematics teacher explained the meaning of fractions during the interviews, but not too frequently during the learning process.

The results of the student interviews turned out to be in line with what the mathematics teacher expressed. The mathematics teacher revealed that she had explained the meaning of fractions to students. However, the meaning of the fractions conveyed also had limitations. Mathematics teachers were only able to interpret fractions as a tool. For example, when giving the case of dividing pizza, the teacher considered fractions in that context as a tool, not as a result of division. Excerpts from the results of researchers' interviews with mathematics teachers can be seen in Table 1.

Table 1
Excerpts of Mathematics Teachers Interview Results Regarding the Meaning of Fractions During Panic-gogy

Researcher Questions	Answers by Mathematics Teachers
What do you think fractions mean?	*For an everyday example, fractions make it easier for people to divide things. For example, when buying pizza and then sharing the pizza,*
Is there any other meaning?	*What is it? This is also the case, sir; because of COVID, we don't have time to teach fractions optimally to students.*

b. What solutions are parents seeking to overcome mathematics learning challenges during panic-gogy?

After analyzing the IC characteristics, eight themes emerged from the parents' perspectives about overcoming challenges of mathematics learning during the panic-gogy.

These themes have been presented with descriptions in Table 2. The thematic results showed that most parents stated that the primary solution to panic-gogy in mathematics learning (T-1) is to conduct face-to-face learning. The T-1 consisted of 30 ICs, namely IC-1 to IC-30, and the analysis showed that parents offered three types of face-to-face learning as alternative solutions, namely (a) full face-to-face meetings at school, (b) limited face-to-face learning by implementing strict health protocols, and (c) home-visit by mathematics teachers to students' homes or specific gathering points.

Regarding T-2, parents suggested that mathematics teachers need to provide students with more detailed explanations in the learning materials. This theme was formed from 12 ICs, ranging from IC-31 to IC-41 and IC-69. A more detailed explanation, in this case, was that the teachers are expected to explain the mathematical material in detail and provide examples before giving the students exercises or assignments. T-3 was formed from 11 ICs, ranging from IC-42 to IC-52, and it entails parents' anticipation for mathematics teachers to make online learning more effective. In this aspect, parents believed it is possible to perform several activities to make online learning more practical, such as sharing materials through WhatsApp Groups, using Zoom Meeting as a face-to-face tool with students, and improving educational videos on material explanations.

In T-4, parents expected the mathematics teacher to prepare teaching materials for DLM, such as 1) compiling mathematics modules in hard-copy form, 2) procuring student worksheets, and 3) explaining the material in written form only. It is important to note that an IC in T-4 contradicts the one in T-3, namely, an explanation in writing instead of a video. Also, the T-5 contained several ICs related to 1) teachers checking students' assignments regularly, 2) not giving too many difficult assignments, and 3) giving more assignments. T-5 was formed from 7 ICs, which include IC-63 to IC-70. However, some conflicting ICs were observed. Some parents expect students to be given more assignments and vice versa.

Table 2
Parents' Perspectives for Solution in Overcoming Children's Mathematics Learning Challenges Formed from IC

Theme Code	Description of concepts in themes	Number of Parents Who Submitted Descriptions
T-1	Learning needs to be conducted face-to-face.	30
T-2	The teacher gives a more detailed explanation to the students.	12
T-3	Teachers make online learning effective.	11
T-4	Preparation of teaching materials for DLM.	3
T-5	A series of activities related to student assignments.	7
T-6	Students become intelligent children.	1
T-7	General advice regarding health protocols and dependence on smartphones.	3
T-8	The school's strategy is good enough.	4

Furthermore, the T-7 included parents' general advice regarding health protocols and student smartphone dependence. It was observed from the IC that parents said the Covid-19 pandemic is ending soon, asked students to wear masks and maintain social distancing when leaving the house, and also advised them not to hold their cellphones too often. The T-8 relates to the parent's opinion about the school's strategies, treatments, and attitudes during panic-gogy, which were considered good. Therefore, no suggestion was made on alternative solutions to panic-gogy. These alternative solution themes are called T-6, which describes students becoming intelligent children.

The information obtained from Table 2 showed eight themes regarding the solutions to panic-gogy. However, not all are relevant as alternative solutions, such as T-6/7/8, because

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they are general and unrelated to panic-gogy activities. It simply means that only five alternative solutions were relevant for the implementation, namely 1) learning needs to be conducted face-to-face, 2) the teachers are expected to provide a more detailed explanation to students, 3) streamlines online learning, 4) teaching materials have to be prepared for panic-gogy, and 5) organizing series of activities that are related to student assignments. These five potential solutions for overcoming challenges of panic-gogy are liked with a hybrid mode of learning, that incorporates demands of face-to-face learning, detailed explanation in the learning materials, and enhanced learning through online videos and offline learning materials.

c. What is the description of the form of mathematics learning design during panic-gogy?

Based on the previously formed themes from parents' perspectives, the hybrid learning mode was one of the desired solutions for parents. The hybrid mathematics module was one of the forms of instructional design that could be used during the panic-gogy. The hybrid module was chosen because it facilitated both in-person and online face-to-face learning, as well as direct classroom interaction or home visits (Sukarma et al., 2024). In other words, this module could be used in various learning modes, such as face-to-face learning in class, home- visits, online learning, and a combination of face-to-face and online learning. The hybrid mathematics module in this research also referred to student, teacher, and parent modules. The student module contained all the activities that students had to do. The teacher module contained all the student modules but with the addition of an answer key with a description of how to implement the student modules. Meanwhile, the parent module contained assistance procedures that parents had to carry out during their children's learning and completing assignments. Additionally, the hybrid mathematics module was capable of facilitating students to learn independently.

In general, the hybrid module consisted of three activities: the initial activity, the core activity, and the concluding activity. The initial activities included two activities: *Let's Guess* and *Let's Read*. Both of these activities aimed sequentially to unearth the prerequisite abilities that students possessed and to ignite students' motivation to learn. Figure 2 provided an example excerpt of the hybrid mathematics module for the *Let's Guess* activity. The core activities encompassed several tasks: *Let's Search*, *Let's Tell a Story*, and *Let's Conclude.* All three of these activities aimed at facilitating students in discovering the meaning of fractions. Figure 3 presents an excerpt of the hybrid mathematics module for the *Let's Search* activity. The concluding activities comprised the *Let's Practice* and *My Reflection* tasks. *Let's Practice* aimed to facilitate students in applying the concepts or formulas of fractions they had acquired in different contexts or situations. On the other hand, the *My Reflection* activity aimed to assess whether the concept of fractions that the students possessed was correct or not. Furthermore, these activities also aimed to ensure the positive feelings or traits that students acquired after the learning activities took place. Figure 4 provided an example of the *Let's Practice* activity. For more details regarding the hybrid mathematics module, it can be accessed on the following page: https://rb.gy/pgxel.

Figure 2
Excerpt from the Let's Guess activity

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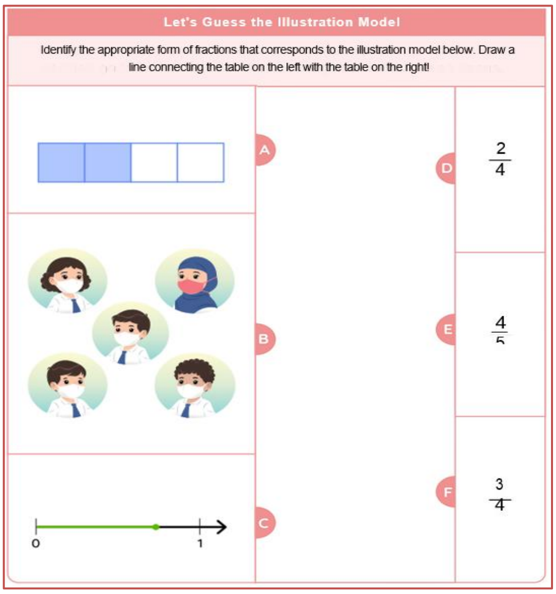
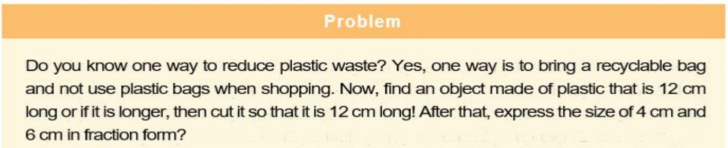


Figure 3

Excerpt from the Let's Search activity

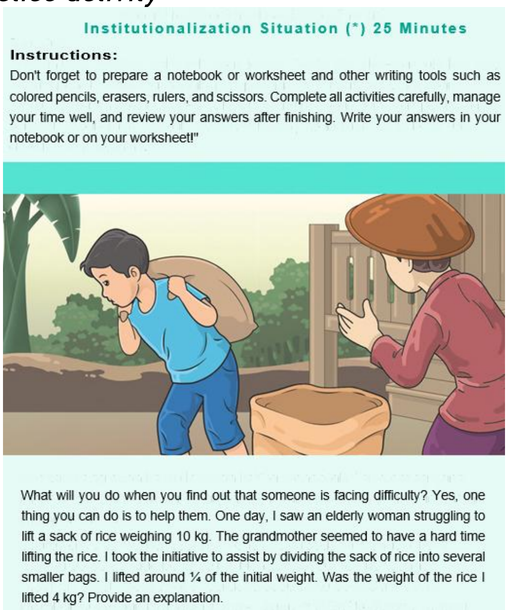


Problem

Do you know one way to reduce plastic waste? Yes, one way is to bring a recyclable bag and not use plastic bags when shopping. Now, find an object made of plastic that is 12 cm long or if it is longer, then cut it so that it is 12 cm long! After that, express the size of 4 cm and 6 cm in fraction form?

Figure 4

Excerpt from the Let's Practice activity



3.1.2 Metapedadidactic Analysis

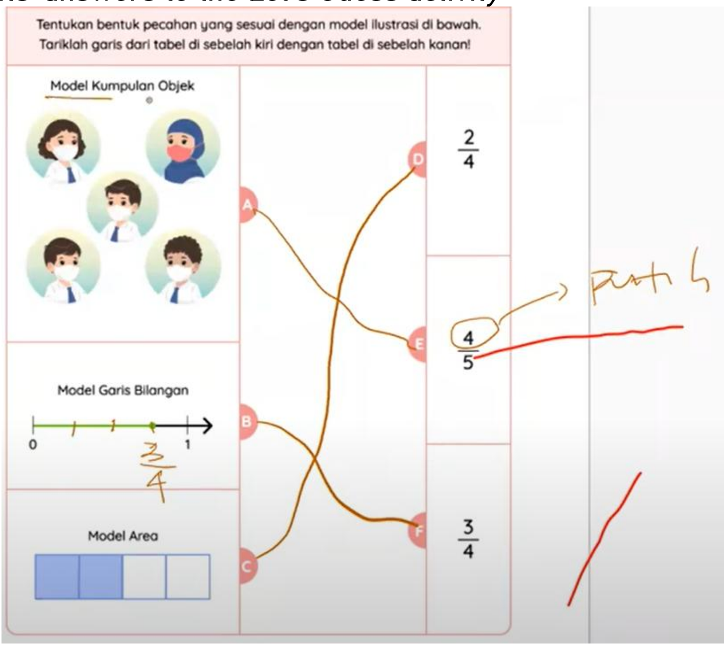
a. How is the implementation of mathematics learning design during panic-gogy?

Because learning was carried out during panic-gogy, teaching, and learning were conducted online. The platform used was Zoom Meeting. In the initial activity, the researcher opened the learning activity with greetings and an opening prayer. After that, the researcher checked student attendance and asked students to activate the video to ensure there were no students who were not ready to learn. The researcher then conveyed the learning objectives to the students and asked them to open the hybrid mathematics module that had been distributed to each student. The process of distributing hybrid mathematics modules was carried out by visiting each student's home while maintaining health protocols.

The activity continued with Let's Guess. In this activity, several students asked about how to do it. When guessing the illustration model, students were able to match the fraction value with the appropriate illustration model. Students could already provide correct reasons. However, when matching the number line, students seemed to have difficulty matching and giving reasons. Evidence of student answers can be seen in Figure 5. The next activity was Let's Read. In this activity, students were asked to read a motivational story and then look for messages or information from the story regarding the benefits of mathematics in life, more specifically about the uses of fractions in daily life. One of the students with the initials, ZA, read the story. After ZA finished reading, the teacher asked other students to provide opinions regarding the message conveyed in the story. Students revealed that fractional forms or values were often found in everyday life, especially when trading or farming.

Figure 5

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



The next activity was *Let's Search*. In this activity, students were asked to solve problems in groups. Problems were discussed in the breakout room (BOR). During the discussion at BOR, problems were found in group 2. Not a single student wanted to be a note-taker. The teacher then appointed one of the students as a note-taker. Meanwhile, for the other group, the researchers asked students to discuss by following the instructions in the hybrid mathematics module. The researcher directed students to try to solve the problem first by searching for each one. However, when students encountered problems, they were expected to use alternative methods provided in the hybrid mathematics module.

A few minutes later, groups 1 and 2 had succeeded in solving the problem (Figure 3). The teacher asked the two groups to determine the students who would present. In contrast to the two previous groups, Group 3 had not resolved the problem. In response to this, the teacher asked group 3 to solve the problem using alternative methods contained in the module. After all groups had finished working, the teacher asked each group to present their results. Group 1 appointed one group member to present the results. Group 1 used the second alternative method. And so on, groups 2 and 3 took turns presenting their results. Excerpts of each group's answers can be seen in Figure 6.

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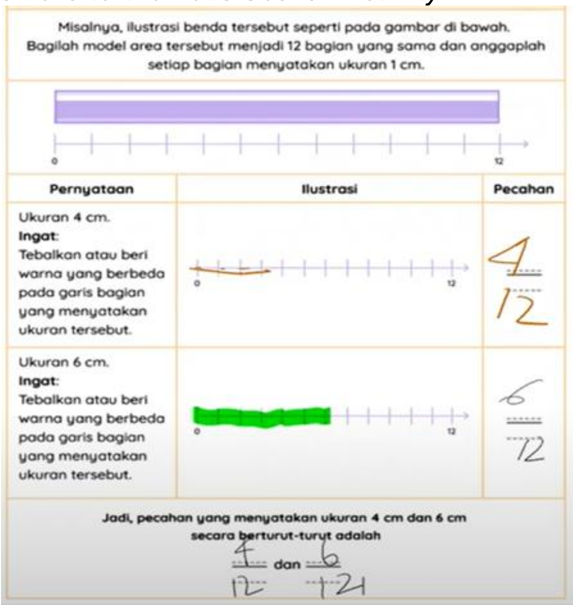
Figure 6
Excerpts of students' answers to the Let's Search Activity



Because all students' answers were correct, students were asked to conclude the meaning of fractions from the activities carried out previously. Most students concluded that fractions have meaning as part of a whole and a ratio. The next activity was *Let's Practice*. In this activity, students were only able to solve problem 1 (Figure 4). Meanwhile, problem 2 (Figure 7) was solved together with the teacher. A snippet of student answers can be seen in Figure 8. At the end of the lesson, namely the *My Reflection* activity, most of the students felt happy with the learning carried out at the meeting and were able to correctly reflect that fractions have meaning as part of a whole and a ratio.

Figure 7
Problem 2 in the Let's Practice activity

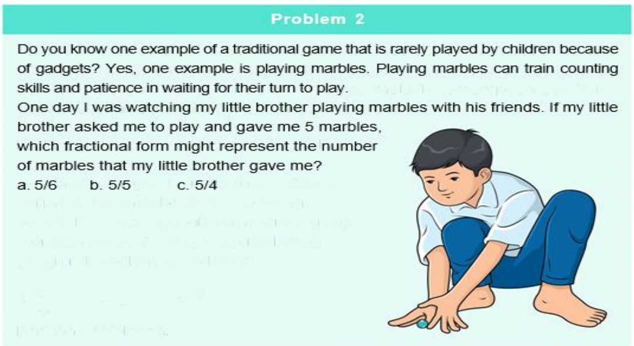
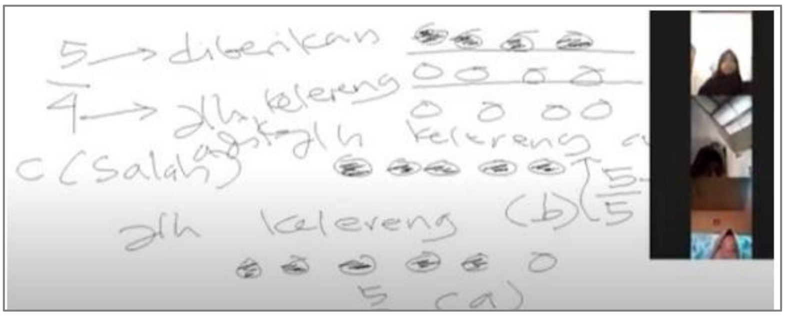


Figure 8
Excerpts of students' answers to the Let's Practice activity (Problem 2)



3.1.3 Retrospective Analysis

a. What are the obstacles to students' mathematics learning after implementing the learning design during panic-gogy?

After implementing the hybrid mathematics module, information was obtained that students had more understanding of the meaning of fractions than before. Although some students still expressed the meaning of fractions incorrectly, there were a variety of meanings expressed by students. A complete description of the meaning of fractions after implementing the hybrid mathematics module can be seen in Table 3. According to the results in Table 3, students could express all of the fractional meanings. However, there were still some incorrect meanings of fractions. After conducting interviews with several students who made mistakes, information was obtained that the students had not had any indication of experiencing learning obstacles. This was because students were still mistaken in interpreting fractions, not because of external factors, but due to factors from within the students themselves. Before the exam, students did not study enough at home, so their preparation for the exam was lacking. This had an impact on students' mistakes in interpreting fractions. Therefore, students did not experience problems due to external factors and indicated no experience of learning obstacles after implementing the hybrid mathematics module. Excerpts of the results of the researcher's interview with the student can be seen in Table 4.

Table 3
Meaning of Fractions After Implementing the Hybrid Mathematics Module

Description of the Meaning of Fractions by Students	Note
Fraction as a ratio.	Correct
Fractions as a measure.	Correct
Fractions as operators.	Correct
Fractions as a tool.	Wrong
Fractions as parts of a whole.	Correct
Fractions as a quotient.	Correct
Other meanings.	Wrong
Fractions as a whole.	Wrong
Fractions as objects.	Wrong

Table 4
Excerpts of Interview Results After Implementing the Hybrid Mathematics Module

Researcher Questions	Student Answers
Didn't you have enough study time yesterday before the exam?	M3: *No.*
Why?	M3: *There are lots of other subject materials, sir.*
What subjects?	M3: *English memorization and language note-taking.*

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Isn't there enough time to study while at home?	M4: *I can learn half, sir.*
Why?	M4: *There are physical education and Indonesian language assignments.*

3.2 Discussion

Based on the results, it can be concluded that students are experiencing learning obstacles during panic-gogy. Math teachers who do not fully understand the meaning of fractions are to blame for this problem. If related to theories related to learning obstacles (Brousseau, 2002; Siagian et al., 2022; Suryadi, 2019b), students are indicated to experience learning obstacles with the type of didactical obstacle. This is because mathematics teachers do not have good enough knowledge of interpreting fractions (Bosch et al., 2021). At least, mathematics teachers must know the meaning of fractions as part of a whole, quotient, measure, operator, and ratio (Isnawan et al, 2022). In other words, mathematics teachers have not yet reached the scholarly knowledge stage. Good scholarly knowledge is the first knowledge that mathematics teachers must have when transposing knowledge. Knowledge of mathematical content is one of the three main competencies that teachers must have, apart from pedagogical competence and mastery of technology (Açıkgül & Aslaner, 2020). In this sense, the obstacle due to a lack of proper knowledge of the meaning of fractions can be attributed to an epistemological obstacle (Hendriyanto et al., 2024).

As discussed above, most parents suggested face-to-face learning, which is divided into three categories: entire face-to-face learning at school, limited face-to-face learning, and home visits. Several previous studies supported these results, but from other participants' perspectives, a mathematics teacher expected that at least most learning activities during the Covid-19 Pandemic were not done online (Araya & Gormaz, 2021; Kalogeropoulos et al., 2021). Offline learning is expected to favor more interactions between teachers and students. During panic-gogy, students typically needed face-to-face time with the teacher to optimally discuss learning problems (Araya & Gormaz, 2021; Barlovits et al., 2021).

However, of the three face-to-face learning types suggested by the parents, not all alternative solutions were relevant to the COVID-19 pandemic, such as complete face-to-face learning in schools. For example, it was impossible to conduct real learning as it would violate the health and safety protocols implemented by the Indonesian government. Similarly, home visits tended not to be optimal since the ratio of mathematics teachers in the school did not match the students' numbers. Students' homes are also far apart from one another. The strategy that was quite relevant was the limited face-to-face learning, which could still be combined with online learning. In other words, blended learning was relevant as an alternative strategy during panic-gogy (Borba, et al., 2020; Engelbrecht et al., 2020; Engelbrecht et al., 2020; Isnawan et al., 2022; Isnawan & Alsulami, 2024; Kuswara et al., 2024).

Providing students with a more detailed explanation was the next alternative offered by parents. This result is also consistent with the study revealing that teachers must give brief and simple explanations to students during panic-gogy. It was also revealed that teachers must provide feedback on student work during DL (Moreira et al., 2017). In making panic-gogy effective when learning mathematics, parents expressed that 1) WhatsApp Group needs to be employed as a means of sharing information or subject matter with students, 2) Zoom Meeting has to be used as an online face-to-face tool, and 3) teachers are expected to increase the production of other learning videos. This result is also in line with several previous studies revealing that mathematics teachers are supposed to use social media, digital learning platforms, and YouTube as a forum to maintain the existence and quality of mathematics learning during the Covid-19 Pandemic (Chirinda et al., 2021;

Engelbrecht et al., 2020). According to Bergdahl & Nouri (2021), video learning is a tool that plays a significant role during panic-gogy in mathematics learning because students can play and study the materials repeatedly without having to interact directly with the teacher.

Another alternative solution that was relevant for the teachers was the T-4 or teaching materials for panic-gogy in mathematics learning. The result was consistent with Reimers et al. (2020) that the government, through schools, needs to develop digital-based unique teaching materials for maintaining learning quality during panic-gogy in mathematics learning. According to Pepin (2021), the teaching materials must be prepared based on the connectivity principle between all learning components and adapted to the environmental conditions of the Covid-19 pandemic. Regarding the last theme, one activity, which included checking students' assignments regularly, was the focus. Several previous studies supported this result as the action was crucial during panic-gogy in mathematics learning. These activities entailed checking the results of students' work or assignments, providing feedback, and evaluating the implementation of DLM in general (Aslam & Khan, 2021; Barlovits et al., 2021; Clark-Wilson et al., 2020; Hadriana et al., 2021) . However, checking student assignments, especially during panic-gogy, took work as several obstacles were encountered, including slow student or teacher responses. For example, when the teacher provided materials or assignments, students did not immediately respond due to quota limitations or internet signal constraints.

Conversely, the teachers were likely to be delayed before giving feedback when students responded because of difficulty checking online. In some scenarios, the responses could be printed; not all teachers had printers at home (Akar & Erden, 2021). Other tasks, such as giving more assignments to students, were considered less relevant. Meanwhile, reducing the tasks' number was considered a relevant alternative, as several previous studies have discovered that task allocation needs to be qualitative rather than quantitative. It means that the number of assignments is not always directly proportional to the student's mathematics learning achievement. In other words, mathematics assignments are expected to be quality-focused and problem-solving-based. It is in line with Jackson (2007) and Özcan & Erktin (2015) a conclusion that assigning a challenging but difficult task was an alternative solution to be applied during panic-gogy in mathematics learning.

This current study generally showed that parents expected face-to-face learning during panic-gogy in mathematics learning. In other words, panic-gogy in mathematics learning implemented in schools had transformed into face-to-face learning. However, due to various considerations, namely health protocols and the location of students' homes, which were distant apart, the most relevant alternative strategy was implementing limited face-to-face learning combined with online learning. For example, the alternative strategy was blended learning (Luo et al., 2022) , which had to be facilitated by providing unique teaching materials developed with the principle of connectivity, adapted to environmental conditions due to the pandemic, and owned by all students. It is important to note that the teaching materials owned by students can be in digital or hard-copy form. Mathematics teachers need to optimally use social media, e.g., WhatsApp Groups, as a forum to share all information related to implementing learning and teaching materials with students. Also, they are expected to take advantage of Zoom Meetings to meet students face-to-face. Mathematics teachers need to do live streaming via YouTube to increase educational videos, as this is likely to help students understand the material better.

As previously described, the hybrid mathematical module consisted of three activities: the introductory, core, and concluding activities. These three activities were organized based on a theory that a module should have at least three activities: preparatory, lecture, and evaluation (Aylward, 2012; Dio, 2022; The Learning Centres, 2013) . The Let's Guess activity aimed to ensure that students understand the prerequisite material well. The prerequisite material referred to in this context were the values of LCM and GCD, as a basis for learning fraction operations (Sutarto et al., 2021). Both of these materials are commonly used prerequisites in fraction learning. The Let's Tell a Story activity used stories to motivate students by explaining the practical applications of fractions in everyday life (Abramovich et al., 2019; Arthur et al., 2022).

The Let's Search activity was developed by presenting problems for students to solve. This approach was based on several theories and previous research (Abramovich et al., 2019; Arthur et al., 2022; Hartmann et al., 2021) that revealed the positive impact of problem-based learning on students' competency development. The Let's Search, Let's Tell a Story, Let's Summarize, and Let's Practice activities were then designed based on the theory of didactical situation (TDS), which divides the learning activities into action, formulation, validation, and institutionalization situations (Brousseau, 2002) . TDS was also employed based on previous research findings (Margolinas & Drijvers, 2015; Modestou & Gagatsis, 2013; Suryadi, 2019b, 2019a) that indicated students' competencies could optimally develop through various didactic situations in mathematics learning. The My Reflection activity became quite intriguing and was expected to facilitate the application of the assessment-as-learning principle. Assessment as learning was anticipated to help students become accustomed to reflecting on and improving their learning in subsequent activities (Ghorbanpour et al., 2021; Yang & Xin, 2022).

In general, the implementation of the hybrid mathematics module went according to the study plan. It proved that learning activities were interrelated and could be run systematically from beginning to end; all learning activities went well, providing students complete learning experience, and learning activities were flexible in terms of responsibility for solving problems. If linked to metapedadidactic theory (Suryadi, 2019b, 2019a), then the implementation of learning in this research was classified as good learning, from the viewpoints of students. Apart from that, the results of this study were also in line with several previous studies (Mettis & Väljataga, 2021; Sukiman et al., 2022), which revealed that hybrid learning design had a positive influence on students' affective abilities, such as feelings, interest, or motivation during learning. This was because the hybrid learning design was able to utilize the ICT in helping students construct mathematical concepts (Bennett et al., 2020; Mettis & Väljataga, 2021).

Although some students made mistakes in interpreting fractions, there were no indications that students experienced learning obstacles during the implementation of the hybrid module, though they had expressed epistemological and didactical obstacles during the early stage before the implementation of the module. This was because students' factors were to blame for their mistakes (Suryadi, 2019b). If it is related to the concept of learning barriers (Brousseau, 2002; Suryadi, 2019b), then this factor is not classified as a learning barrier. A difficulty experienced by a student in learning is categorized as a learning obstacle when the difficulty is caused by external factors of the student, especially those related to learning and the teacher. Therefore, it can be concluded that the hybrid mathematics module can minimize the learning obstacles that students experience. These results are in line with previous research, which reveals that students' learning barriers can be reduced by implementing didactic design in learning (Bergström et al., 2019; Prihandhika et al., 2022; Prihandika & Perbowo, 2024; Rønning, 2021; Rudi et al., 2020;).

Limitations

There are several limitations in this research, one of which is that the hybrid mathematics module was implemented during the pandemic or panic-gogy period, so there is no empirical evidence for post-pandemic implementation. Therefore, there needs to be further research related to the results of implementing hybrid mathematics modules for post-pandemic learning. Apart from that, future research still opens up opportunities to adapt activities in hybrid mathematics modules for high-level mathematics material, such as mathematics material for lecturers. Finally, the implementation of a hybrid mathematics module grants students full access to both the printed and electronic versions of the module. The intention is for students to concentrate on their learning rather than excessively focusing on module provision. In addition, the teacher's understanding of the module's use and content, along with their skills in class facilitation and ICT mastery, are crucial considerations during the learning process. Another notable limitation of the study is the generalizability of findings due to the limited sample and scope of study in a school. Hence, future studies are recommended to overcome these limitations by expanding the scope of study to several school districts or jurisdictions in Indonesia and possibly other economies.

4. Conclusion

This study concludes that the hybrid mathematics module offers a viable alternative for minimizing learning obstacles encountered by students during panic-gogy, particularly in understanding fractions. Developed in response to parental input and identified learning barriers, the module facilitates meaningful engagement with mathematical concepts by supporting students in constructing their own understanding of fractions. Mastery of fractional meaning not only enhances students' ability to solve advanced mathematical problems but also equips them with transferable skills relevant across disciplines—fostering values such as fairness and sharing. Crucially, the module is grounded in epistemic didactical situations, allowing it to establish a structured epistemic learning pattern. This approach provides a replicable model for mathematics teachers seeking to address learning disruptions and improve students' conceptual understanding. The findings suggest that involving parents in the instructional design process and using hybrid models that integrate real-world contexts can lead to more effective mathematics learning, even under crisis conditions. Future research should explore the long-term impact of epistemic learning patterns on student achievement and adaptability across various mathematical domains. Additionally, studies involving broader demographic and institutional contexts could validate the scalability and sustainability of the hybrid module, offering insights for resilient mathematics education in both normal and emergency learning environments.

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Author Contribution

Author 1: Conceptualization, Writing - Original Draft, Editing, and Visualization;
Author 2: Writing - Review & Editing, Formal analysis, and Methodology;
Author 3: Validation & Supervision.

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Conflict of Interest

The authors declare no conflict of interest.
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