

LEARNING TRAJECTORY FOR TEACHING 3D SHAPES USING PMRI APPROACH WITH A MOSQUE CONSTRUCTION CONTEXT

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Abstract

The background of this research is based on the importance of students' conceptual understanding of geometry in the context of mosque construction. The geometry of the space has an important role in creating a beautiful and meaningful mosque design. The aim of this research is to understand the extent to which the PMRI approach can be applied to spatial geometry in the context of mosque construction. This research uses a design research method with a PMRI (Indonesian Realistic Mathematics Education) approach for class VIII students at Ulul Albab Takokak Cianjur Integrated Qur'an Middle School with a focus on Geometry and Space Building material. Data collection was carried out by means of observation, interviews and documentation. The results of this research are that students can find out how the concept of building space can be applied to everyday life, especially in building mosques.

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INTRODUCTION

Geometry has an important role in the construction of mosques as an element that reflects the beauty and grandeur of architectural design (Arlene & Fauzy, 2017; Ghozali & Zuhri, 2020; Rony, 2014). Understanding and applying good geometry in the context of mosque construction not only improves visual aesthetics, but also enriches religious meaning and produces a spiritual environment that combines beauty and function. (Redjeki, 2022). Therefore, research regarding the role of geometry in mosque construction is very relevant and important to carry out.

In several previous studies, evidence has been found that geometric concepts can influence harmonious and symbolic mosque designs (Dabbour, 2012; Dewi, 2003;

Wardani & Nugroho, 2019). For example, proportion, symmetry, and geometric patterns can create interesting visual effects in the design of domes, mihrabs, and other mosque ornaments. (Wardani & Nugroho, 2019). This research also shows that a deep understanding of geometry can provide a better understanding of the use of space, lighting and acoustics in a mosque, thereby creating a comfortable and solemn environment for the congregation.

However, although the importance of geometry in mosque construction has been recognized, there is still a gap between theory and practice (Novaldin, 2022). Several studies show that students often have difficulty understanding geometric concepts and relating them to everyday life, especially concrete mosque construction (Fauzi & Arisetyawan, 2020). This indicates the need to develop a learning approach that is relevant in the context of mosque construction.

To fill this gap, this research uses an approach PMRI (Pendidikan Matematika Realistik Indonesia) in learning geometry at Ulul Albab Takokak Cianjur Integrated Qur'an Middle School. This approach can be used to study conceptual mathematics and relate it to real contexts (Arrafi & Masniladevi, 2013); (Pebriana, 2017), including the construction of a mosque. In this research, we aim to apply the PMRI approach in learning spatial geometry material in the context of mosque construction. mosque.

With the gap between theory and practice that needs to be overcome, it is hoped that this research can contribute to filling the knowledge gap and offer recommendations for approaches to learning geometry in the context of mosque construction. Through this research, we hope to reveal the advantages and uniqueness of PMRI's approach to the role of geometry in mosque construction. Thus, the main aim of this research is to apply the PMRI approach to students and develop their appreciation of the beauty of geometry in a religious context.

METHOD

This research uses a design research method with an approach PMRI (Pendidikan Matematika Realistik Indonesia) for class VIII students. Gravemeijer and Cobb (Ramury et al., 2015) states that there are three stages in implementation design research among them namely preparing for the experiment/preliminary design , the design experiment and retrospective analysis. These three stages are carried out sequentially and several activities are carried out at each stage (Saputri et al., 2016), namely as follows:

Level I: Preliminary Design. Geometry (space shapes), the PMRI approach and design research as a basis for formulating students' initial alleged strategies in learning geometry. The next step is designing hypothetical learning trajectory (HLT). According to Simon (Sohilait, 2017) HLT is a series of equivalent fraction learning activities using the PMRI approach which contains learning objectives, learning activities and student thought predictions. This is used as a guide to anticipate students' thoughts and strategies that will emerge and develop during learning activities. Planning begins with identifying research needs and context, as well as formulating specific research objectives.

This research was carried out at Ulul Albab Takokak Cianjur Integrated Qur'an Middle School with research subjects totaling 25 class VIII students. The material that is the focus of the research is spatial geometry in the context of mosque construction. This is dynamic

in nature so that when students respond to learning, it can be adjusted and revised at any time teaching experiment.

Level II: The Design Experiment. The second stage, the design experiment (experimental design) which consists of preliminary teaching experiment (pilot experiment) and teaching experiment. Pilot experiment was conducted to try out the HLT that had been designed on students in small groups to collect data in adjusting and revising the initial HLT used in the teaching experiment later (Septiana et al., 2017).

At the development stage, an integrated spatial geometry learning design was carried out with the PMRI approach. Learning is designed to activate students in the process of constructing geometric knowledge through various activities that are relevant to the context of mosque construction. Learning material includes geometric concepts of spatial structures, properties of spatial structures, measurements, and their application in mosque design.

In the teaching experiment, the HLT which has been tested at the pilot experiment stage and has been revised is then tested again in the class which is the research subject (Novita & Putra, 2017). Next, the learning that has been designed is implemented. Learning is carried out using various strategies, such as group discussions, field observations, and project-based activities. During the learning process, data is obtained through observations, field notes, and student work.

Level III: Retrospective Analysis. Third phase, retrospective analysis. Data obtained from stage teaching experiment analyzed. The results of this analysis are used to plan activities and develop activity designs for the next lesson. The purpose of retrospective analysis in general is to develop Local Instructional Theory (LIT) (Meirida et al., 2020). At this stage, HLT is compared with actual student learning, the results are used to answer the problem formulation. Data collection techniques used during research include video recordings, observations, interviews, documentation and field notes which are collected and analyzed to improve the HLT that has been designed. The data obtained was analyzed sequentially retrospective with HLT as the model. After obtaining the data, it was then analyzed using a qualitative approach. Analysis is carried out by identifying patterns, themes and the emergence of geometric concepts that appear in students' work and their responses to learning.

Data analysis was discussed with supervisors and model teachers for reliability and validity in this research in the form of observations, interviews and documentation carried out qualitatively. The evaluation was carried out to evaluate the effectiveness of learning geometry using the PMRI approach. Evaluation is carried out through classroom observations, interviews with students, and the use of relevant assessment instruments. The evaluation results are used to identify the success of the PMRI approach in learning spatial geometry in the context of mosque construction.

RESULTS AND DISCUSSION

This learning is designed to produce a learning trajectory that helps students finding geometric algorithms in the context of mosque construction through designed activities. This article focuses on teaching experiment which was tested on 25 students. Through activities carried out to help students overcome difficulties in understanding the material

and solving problems. This is because according to Soedjadi (Hartati et al., 2018) that the causes of students' difficulties learning mathematics can originate from within the student or from outside the student, for example the way learning material is presented or the learning atmosphere. Based on the learning trajectory design that has been designed and carried out by researchers, the learning trajectory in learning equivalent fractions includes determining the area of the mosque to be built and the surface area of the mosque itself. In this case, the PMRI approach, which is a series of activity sequences and several geometry lessons, is the main reference in each learning activity.

The research process was carried out with 2 activities, where activity 1 focused on calculating the area for building the mosque and activity 2 focused on the surface area of the mosque. In each activity, a case is given which will be analyzed and completed by each student in a group. In each activity there are also several activities carried out by students, including reading descriptions, using context, using models for progressive mathematics, utilizing student construction results, linkages and interactivity and drawing conclusions.

Learning is carried out using the context of mosque construction and calculating the area of the building space to start material about geometry then continuing with surface area calculations in the context of mosque renovation. The activities carried out show that students explore initial knowledge through analysis of geometry material. The initial stage aims to remind students and relate them to the material they have studied previously. For example, in area calculations using the concept of multiplication, students are invited to remember multiplication again and apply the concept to the next material that will be studied at this time.

The activities carried out are in accordance with the research method, namely Research Design which is used to develop learning activities that can facilitate students' understanding of mathematical concepts and the PMRI (Indonesian Realistic Mathematics Education) approach is used to link mathematics learning with real contexts related to everyday life. During the learning process, students were very enthusiastic in working on each question on the activity sheet with the context of the role of geometry in building mosques. According to de Lange in Wijaya, activity design must refer to the five characteristics of PMRI, namely that learning must begin with the use of context which aims to motivate and interest students in learning. (Surya et al., 2017). Through activities that have been designed, students' knowledge can increase in solving problems about geometry. Most students have been able to solve problems regarding geometry. Not only that, at the end of the activity several students were also able to conclude the activities carried out and express their reasoning well.

Table 1. Hypothetical Learning Trajectory (HLT) learning trajectory

Goal	Teacher's Activity	Student's Activity and Response	Possible Math Behind the Activity
Can apply the material to everyday life (geometry material in mosque construction)	Activity 1 The teacher presents a case related to flat shapes as an introduction to geometric concepts in mosque	In solving this problem, students are invited to create a mathematical model which is then completed. Possible student activities	Geometry

construction.

Kakek memiliki sebidang tanah berbentuk persegi panjang dengan panjang 35 m dan lebar 20 m. Kakek ingin mewakafkan tanahnya untuk membuat masjid dengan harapan masjid tersebut memiliki teras luar di dua pintu masuk dengan ukuran teras samping 3 m dan teras depan 5 m. Bantu kakek untuk menghitung luas masjid yang akan dibangun dengan tanah yang tersisa setelah sebagian dibuat untuk teras masjid!

The teacher invites students to discuss how to solve these problems using mathematical models. The teacher also explains how the formula will be used and finds the area first.

Activity 2

After students understand the geometric concept of flat shapes, students are invited to complete the second case, namely calculating the surface area of a mosque.

Seorang donatur ingin merenovasi masjid di suatu pedesaa. masjid tersebut berbentuk balok dengan panjang 19 m, lebar 14 m dan tinggi 3,5 m. sebelum merenovasi donatur tersebut ingin mengetahui luas permukaan dari masjid tersebut. Ayo bantu donatur tersebut menyelesaikan masalah tersebut!

The teacher invites students to discuss how to solve these problems using mathematical models. The teacher also explains the formula that will be used

include analyzing mathematical symbols that will be used and then modeling them.

p_1 = length of the entire land

l_1 = width of the entire land

p_2 = size of side terrace

l_2 = size of the front porch

L = area of the mosque to be built

So we get the formula

$$L = (p_1 - p_2) \times (l_1 - l_2)$$

Then substitute into

$$\begin{aligned} L &= (35 - 3) \times (20 - 5) \\ &= 32 \times 15 \\ &= 480 \text{ m}^2 \end{aligned}$$

So it is found that the area of the mosque to be built is 480 m^2

In solving this problem, students are invited to create a mathematical model which is then completed. Possible student activities include analyzing mathematical symbols that will be used and then modeling them.

p = length

l = width

t = height

LP = surface area

So we get the formula:

$$LP = 2 (pl + pt + lt)$$

Then substitute into

$$\begin{aligned} LP &= 2 (19 \cdot 14 + 19 \cdot 3,5 \\ &\quad + 14 \cdot 3,5) \\ &= 2 (266 + 66,5 + 49) \\ &= 2 (381,5) \\ &= 763 \text{ m} \end{aligned}$$

and finds out how to So, the surface area of calculate the surface area of the mosque is 763 m the mosque.

In activity 1, students are invited to first remember the previous material, namely the area of flat figures, so that they can imagine the main context, namely spatial figures. Activity 1 was developed in research involving a grandfather who owned a rectangular plot of land 35 m long and 20 m wide. Grandfather wanted to calculate the area of the mosque that would be built using the remaining land after part of the land was used for the mosque terrace. There are specifications for external terraces at the two entrances with a side terrace measuring 3 m and a front terrace measuring 5 m. Activity 1 aims to determine the area of the building space in the context of the area of the mosque to be built by taking into account what is already used by the mosque terrace. The use of real context in this activity provides relevance and meaning for students. The context used is the grandfather's desire to donate his land for the construction of a mosque. This provides a real background and motivates students to study mathematics in a meaningful context.

After being given a case in activity 1, students are asked to read the problem carefully and understand the information given. Students are facilitated with discussions in several small groups to share their initial understanding and ideas about how to overcome this problem. Some students responded with curiosity and curiosity about the problem. Some of these students felt a little overwhelmed or confused because this problem had several complex aspects. But there are also some students who feel challenged to solve problems and try to find solutions.

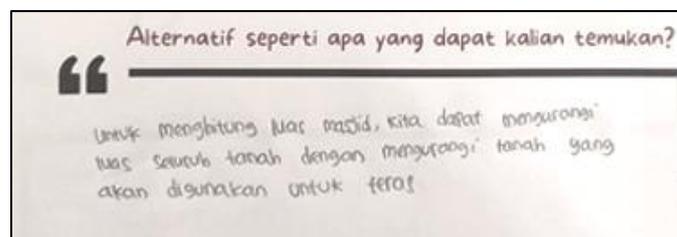


Figure 1. Alternative solutions from students

In activity 1, students use a progressive mathematical model, where students are invited to identify relevant mathematical concepts and use them progressively in solving the problem. Students are asked to understand and apply the concept of rectangular area, subtract the area of the side terrace and front terrace of the mosque from the land area on which the mosque will be built and finally calculate the area of the mosque to be built. There are difficulties faced by students, namely difficulty understanding the concept of the area of a rectangle and calculating its area. They also have difficulty visualizing how the area of the terrace at the two entrances can affect the area of the mosque to be built and also have difficulty applying the concept of calculating the remaining area of land after part of it has been made for the mosque terrace.

Seeing the difficulties students face, students are given visual examples and pictures that help students visualize the mosque and its terraces. Students are given the opportunity to discuss in small groups, share ideas, and help each other understand and solve problems. Students are also given instructions and questions that direct students to use the formula for the area of a rectangle and calculate the remaining area of land after the terrace is

built. That way students feel relieved and satisfied after finding the right solution. They can feel more confident in understanding and applying the concept of area of a rectangle. Students also feel happy because they can connect mathematics learning with real situations.

Handwritten mathematical model on a piece of paper:

$$\begin{aligned} \text{Misal: panjang seluruh tanah} &= x = 35 \text{ m} \\ \text{lebar seluruh tanah} &= y = 20 \text{ m} \\ \text{teras samping} &= x_1 = 3 \text{ m} \\ \text{teras depan} &= y_2 = 5 \text{ m} \\ \text{Luas masjid} &= ? \\ \text{Diketahui: } Z &= (x - x_1) \cdot (y - y_2) \end{aligned}$$

Figure 2. Mathematical model created by students

In utilizing construction results, students are given the opportunity to carry out construction or manufacture to carry out construction or create diagrams that represent land, terraces and mosques. This construction helps students visualize problems and makes their understanding and calculations easier. The results of student construction can also be used as a visual aid in explaining solutions to group friends, classmates and teachers.

Handwritten calculation of the remaining area for the mosque:

$$\begin{aligned} \text{Model matematis:} \\ Z &= (x - x_1) \cdot (y - y_2) \\ &= (35 - 3) \cdot (20 - 5) \\ &= 32 \cdot 15 \\ &= \begin{array}{r} 32 \\ \times 15 \\ \hline 160 \\ 320 \\ \hline 480 \end{array} \end{aligned}$$

Jadi luas masjid yang akan dibangun dengan tanah yang tersisa setelah sebagian tanah dibuat untuk teras masjid yaitu 480 m²

Figure 3. Utilization of student construction results

The connection between mathematical concepts and real-life contexts in activity 1 is emphasized. Students see how the concept of rectangular area can be applied in the construction of a mosque. In addition, students interact with grandfather, asking questions and gathering information needed to solve problems. This interactivity helps students understand the relevance of mathematics in life. Students can share their thoughts and solutions with the class as a whole. They feel proud of their efforts and hard work in solving this problem. Several students felt inspired and interested in exploring further mathematical concepts in everyday life.

Handwritten text on a piece of paper:

Konsep apa yang dapat Kalian temukan dalam permasalahan tersebut?

— — — — —

1. Konsep Pengurangan
2. Konsep Perkalian
3. Konsep Aljabar
4. Bangun datar

Figure 4. Concepts that students discover

Next, activity 2 was carried out, where the activity developed was introducing the problem to students by providing a description of the mosque that would be renovated. The mosque has the shape of one building, namely a beam with a length of 19 m, 14 m wide and 3.5 m high. Donors need to calculate the surface area of the mosque to find out the amount of material needed for the renovation process. Activity 2 aims to calculate the surface area of a building that is related to the context of mosque renovation. There are questions asked to students about what donors need to know before renovating a mosque, this can encourage students to discuss in small groups and record important information.

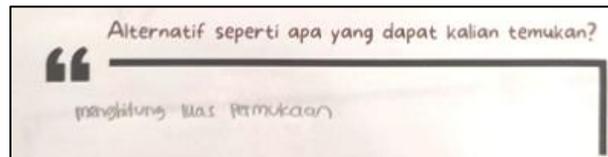


Figure 5 Alternative solutions found by students

After giving the second problem, the students responded enthusiastically and wanted to find out how to calculate the surface area of a mosque. Some students felt challenged because they were not familiar with the concept of surface area and spatial shapes. However, in the process students experienced difficulty in identifying the shape of the mosque as a block and also had difficulty remembering the formula or how to calculate the surface area of the block. Therefore, students are given concrete examples of blocks in class and compare them with the shape of a mosque. Students are helped to remember the formula for the surface area of a block ($2 \times \text{length} \times \text{width} + 2 \times \text{length} \times \text{height} + 2 \times \text{width} \times \text{height}$), after which students work in groups to help each other and exchange ideas.

After understanding the formula and seeing concrete examples, students feel more confident in calculating the surface area of a mosque. They can start applying this formula to the context of the mosque that will be renovated. Students also compare their calculation results with their group friends to ensure accuracy. The use of real context in this activity provides relevance and meaning for students. The context used is a donor's desire to renovate a mosque. This provides a real background and motivates students to study mathematics in a meaningful context.

As in activity 1, in activity 2 there is also progressive mathematical modeling. Students see how the concept of block surface area can be applied in calculating the surface area of a mosque. Additionally, students can interact with donors to gather needed information, ask questions and explain their solutions. This interactivity helps students understand the relevance of mathematics in life.

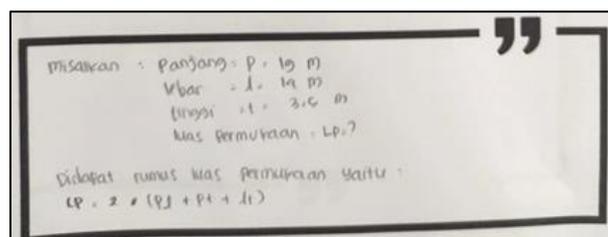
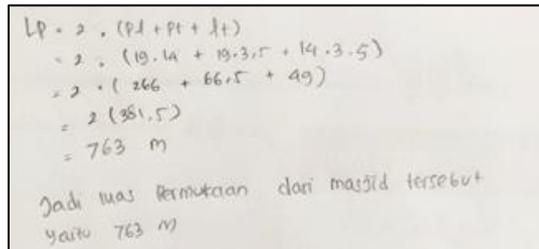


Figure 6. Mathematical modeling created by students

Regarding the use of construction results, students can carry out construction or make diagrams that represent mosques. This construction helps students visualize the problem and makes it easier to understand their calculation problems. The results of student construction can also be used as a visual aid in explaining solutions to group friends, classmates and teachers.



Handwritten calculation showing the perimeter of a mosque:

$$\begin{aligned}
 Lp &= 2 \cdot (Pl + Pt + Lt) \\
 &= 2 \cdot (19 \cdot 14 + 19 \cdot 3,5 + 14 \cdot 3,5) \\
 &= 2 \cdot (266 + 66,5 + 49) \\
 &= 2 \cdot (381,5) \\
 &= 763 \text{ m}
 \end{aligned}$$

Jadi luas permukaan dari masjid tersebut yaitu 763 m

Figure 7. Results of student construction

The linkages in this activity also emphasize the connection between mathematical concepts and real contexts. Students can see how the concept of block surface area is applied in calculating the surface area of a mosque. Additionally, students can interact with donors to gather needed information, ask questions and explain their solutions. This interactivity helps students understand the relevance of mathematics in life. After completing the calculations, students feel happy and proud of their ability to apply mathematical concepts in real life. They can share their calculation results and understanding of the surface area of a mosque with classmates. In the final activity, students are given the opportunity to present their solutions and share thoughts about the approach used. Class discussions can be facilitated to compare solutions.

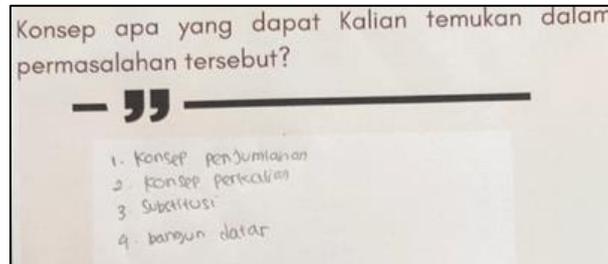


Figure 8. mathematical concepts discovered by students

Students' conceptual understanding of shaped geometry. The results of this research show that there is learning regarding students' conceptual understanding of spatial geometry after following learning using the PMRI approach in the context of mosque construction. At the pretest stage, most students showed limited understanding of spatial geometric concepts and difficulty in relating them to mosque construction. However, after following learning using the PMRI approach they were able to identify and explain the properties of spatial structures, apply geometric concepts in mosque design, and relate them to the use of space, lighting and acoustics.

Application of the PMRI approach in geometry learning. The PMRI approach helps students to be actively involved in the construction of geometric knowledge through activities that are relevant and meaningful to them (Ningsih, 2014). In this lesson, students are encouraged to observe and describe spatial structures in the mosque environment, conduct group discussions to compare the properties of spatial structures,

and design mosque designs using geometric concepts. Thus, the PMRI approach provides meaningful and contextual learning experiences for students, thereby strengthening their conceptual understanding.

The relationship between geometry and mosque construction. Learning geometry in the context of mosque construction helps students to relate geometric concepts to the real world and understand the role of geometry in mosque design and construction. Students can see how spatial geometry is applied in the form of domes, mihrabs and other mosque ornaments. They also realize that a good understanding of geometry can influence the design and function of a mosque, creating a comfortable and spiritual environment for the congregation. Therefore, learning geometry in the context of mosque construction opens students' insight into the importance of understanding geometry in the field of architecture and stimulates their interest in studying mathematics.

Comparison with another research. Previous studies show that learning geometry in real contexts (Sarjiman, 2006), including the construction of mosques, is an interesting thing in studying geometry. However, this research provides a new contribution by focusing on the use of the PMRI approach in learning spatial geometry in the context of mosque construction. This shows that the PMRI approach can be well adapted to the context of mosque construction.

CONCLUSION

Based on the results and discussion above, it can be concluded that this research describes the development of mathematics learning activities using the design method *research* with the PMRI approach as already explained. This activity involves the use of real contexts, progressive mathematization models, utilization of student construction results, as well as linkages and interactivity. It is hoped that this research can contribute to the development of more contextual mathematics learning. Application and approach of PMRI in learning spatial geometry in the context of mosque construction at Ulul Albab Takokak Cianjur Integrated Qur'an Middle School. Learning geometry in the context of mosque construction also helps students relate geometry to the real world and understand the role of geometry in mosque design and construction. The results of this research provide a new contribution in the development of the PMRI approach and show the importance of introducing real context in geometry learning. Therefore, it is recommended that the PMRI approach continue to be applied in geometry learning in schools by utilizing contexts that are relevant and interesting for students. Conclusions should answer the objectives of the research. Tells how your work advances the field from the present state of knowledge. Without clear conclusions, reviewers and readers will find it difficult to judge the work, and whether or not it merits publication in the journal. Do not repeat the Abstract, or just list experimental results. Provide a clear scientific justification for your work, and indicate possible applications and extensions. You should also suggest future experiments and/or point out those that are underway.

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