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by

Jurnal Elemen, 8(1), 1-9, January 2022
https://doi.org/10.29408/jel.v8i1.XXXX

e- ISSN: 2442 - 4226

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Exploring Teacher's Design of Rich Mathematics Tasks

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Abstract

The current phenomenon at school is that teachers rarely modify their assignments. The teacher's activities to change the tasks and always build student arguments and support every solution and defend student arguments without long debate are important and exciting things to study. This study aims to explore teachers' ideas about tasks design and practice in teaching mathematics. The author surveyed a group of teachers who teach high school mathematics in East Java. First, the authors made initial observations for six months in eight high schools in East Java Province. Second, the author states that a teacher is attractive and consistent in designing rich mathematics tasks. Third, the authors began to examine the teacher's ideas through unstructured observations and interviews. The results and the survey were conducted by triangulation with direct observation at SMA in East Java. The results show how the teachers' ideas about tasks design improve students' creative thinking processes by reforming tasks from textbooks into rich mathematics tasks. Teachers' ideas about task design and their teaching mathematics practice are discussing more detail in this article.

Keywords: tasks design, rich mathematics tasks

Received: Date Month Year | Revised: Date Month Year
Accepted: Date Month Year | Published: Date Month Year

Introduction

Teachers can choose math tasks already in the book or tailor to students' needs and interests, or create new assignments. Teachers are also expecting to select appropriate lessons for assessment, evaluate the effectiveness of their classroom tasks, and determine a sequence of functions to support their student's learning. It lines with (Levenson et al., 2018) that the teacher's mathematics assignments should be in order according to the students' abilities.

The International Council on Mathematics Instruction (ICMI) (2013) compiles and summarizes research relevant to task design and the difficulties encountered when designing and carrying out assignments. ICMI (2013) considers the role of teaching to include "selection, modification, design, sorting, observation, and task evaluation." By practicing selecting and using appropriate tasks, teachers believe that textbooks will need to reform assignments (Bakken & Andersson-Bakken, 2021). Despite attempts to divert teachers from using books as the sole provider of the mathematics curriculum, readers continue to be a mainstay in traditional classrooms. (Li & Schoenfeld, 2019) encourages teachers to select and perfect the tasks suggested in the textbook but must be able to refrain from using the whole mathematics task in them.

Textbooks can follow as long as they follow the curriculum, but teachers often use assignments presented in books but do not present material that is not covered in textbooks. (van den Ham & Heinze, 2018). A study conducted by (Bademo & Tefera, 2016) provides evidence linking task selection with teacher decisions. These decisions are made based on how the teacher views the task based on their own beliefs and how students react to the lessons. Teacher beliefs and student diversity are some of the factors that play a role in teachers' decisions to make task choices and adaptations. Therefore it is not easy to generalize about how teachers make these decisions.

Teachers stated that they often gave the same tasks to their students. It will affect the task or other contributions to the task selection factors (Peteros et al., 2020). A study aimed at describing how teachers evaluate the importance of real-world-related tasks shows that most teachers focus on the significance of the mathematics skills underlying the task and how they are familiar to students (Darling-Hammond et al., 2020; Kim et al., 2019). (Johnson et al., 2017) urge teachers to provide challenging tasks for students. They argue that "effective tasks are those that provide opportunities for students to investigate the structure of mathematics, to generalize, and to set an example."

To change how teachers perceive and create ideas about tasks, they must give sufficient opportunities to learn about the complexity of tasks and practice selecting and implementing appropriate lessons (Darling-Hammond et al., 2020; Kim et al., 2019; Sullivan et al., 2013). Thus, teachers are encouraged to practice selecting tasks based on the thinking process (Albay & Eisma, 2021). The selection of assignments is an essential role for teachers. Still, many teachers have little instruction on selecting an appropriate task for their class if tasks bridge student learning with mathematical understanding.

In this study, the teacher selects mathematics tasks based on the criteria for rich mathematics tasks. Rich mathematics tasks are one approach that can use to promote students' higher-order thinking skills (Lithner, 2017). They can provide students with learning opportunities to solve real-world problems requiring higher-order thinking skills, including solving problems, reflective thinking, and reason.

Several studies on rich mathematics tasks have been conducted, such as (Fitriati et al., 2020; Mastuti et al., 2016) which shows that the role of rich tasks in developing student learning. A body of literature (Barrot et al., 2021; Bringula et al., 2021; Stehle & Peters-Burton, 2019) has reported rich task potential such as student challenges to solving problems that have links to the world outside the classroom. Encouraging them to think reflectively and offering various opportunities to meet the different needs of students. In connection with the rich mathematics tasks potential, it is suggesting that the rich task can use to answer several problems in mathematics education in Indonesia. Especially in improving students' high order thinking skills in mathematics, which are still weak, as previously reported by (Hamdi et al., 2018; Hilmi & Dewi, 2021). Also, learning about the application of rich tasks in mathematics classes in Indonesia is still limited; even the rich task approach has not been widely using in Indonesia. Consequently, this research appears to bridge the gap as additional knowledge in this approach.

The preliminary study results show teachers who provide rich mathematics tasks (Mastuti et al., 2016). Thus it is necessary to explore the teacher's rich mathematics tasks design. In this research, several things will be done. The researcher must observe the teacher's ideas in providing the task design, observe the teacher's learning process, and clarify the assignment's concept to the teacher.

Methods

This research is a qualitative descriptive study, which is a case study. Qualitative research aims to explore teachers' ideas about tasks design and practice in mathematics teaching. This research is a case study, where the research subject is considering very rare because it takes a teacher who is consistent in providing rich mathematics tasks.

Participants

Participants in this study initially consisted of 12 selected teachers who were members of the MGMP in 4 cities in East Java, namely Jombang, Mojokerto, Malang, and Surabaya. The conditions for determining research participants are: 1) the teacher can teach at least five years or a teacher who has taken a master's degree; 2) a mathematics teacher who has characteristics in designing assignments during teaching, is observed and proven by their portfolios; 3) a mathematics teacher who is willing to be research participants; 4) Teachers are divided into four groups, for initial observation in each school. It turned out that only three teachers designed and implemented rich math tasks in learning mathematics during the statement. In the field observation stage in 6 months, only a teacher consistently develops and executes rich mathematics tasks in mathematics learning. Next is the clarification stage to explore designing and implementing rich mathematics tasks in mathematics learning.

Instrument

To find out how the teacher's ideas in rich mathematics tasks, the researcher asked the teacher to do rich mathematics tasks based on learning. Therefore, this research instrument is the researcher's primary instrument and the interview sheet to explore the teacher's ideas about the task design. The researcher's interview sheet instrument has gone through the validation stage by a team of experts.

Method of collecting data

This study explores teachers 'ideas about rich mathematics tasks that cause students' reasoning to develop over time. Attend to the problems presented in mathematics tasks. This study focuses on tasks' characteristics (Mastuti et al., 2016; Mata-Pereira & da Ponte, 2017). These characteristics include: 1) multiple questions of varying levels of challenge, emphasizing exploratory problems and items; 2) generalization questions arise; 3) questions asking to justify answers and the resolution process; 4) questions that allow various completion processes.
Data collection consisted of primary research data from classroom observations, teacher interview transcripts, and researcher notes, while documents such as teacher notes were secondary data. In conducting the research, researchers used several recording tools to record learning that involved tasks in class. After each lesson, the researcher immediately clarifies the subject. This research pattern was carried out several times by researchers until the results were saturating. Before analyzing the data, the researcher triangulated the data.

Data analysis

Data analysis is centering on each teacher's actions during class and the results of in-depth interviews with the teacher. Data analysis was direct to determine the focus of research on teacher ideas about the tasks' design. When the researcher began to collect data, the study carried out on the questions asked based on the subject's responses. The data collected and was still in recorded form was then transformed into interview transcripts. The transcripts were then analyzed to obtain the research results.

Results

Researchers have made observations ten times. However, in this study, only one rich mathematics task was present because its lesson was consistent. One example of a math assignment given by a teacher in class is about algebra, as follows.

Consider the following system of equations: $\begin{cases} (a-1)x^2 + \left(\frac{b}{2} - 3\right)x - 1 = y \\ 2x^2 - 2x + (3 - 2c) = y \end{cases}$, Does the following system of equations have multiple solutions or not? Explain your opinion!

The teacher task's design follows the characteristics (1), where students are involved in various questions of various levels of challenge, emphasizing problems, and exploratory questions. The task directs students to generalize procedures according to characteristics (2). Students are asking to choose a solution, then asked to express their opinion, which results from generalizing some of the solutions they have chosen. Tasks also ask for justifications, and implicit reasons are asked indirectly on students' views (3) because students are not expected only to indicate whether the task has many solutions or not at all. The teacher task also has various completion processes (4); students ask to think of multiple answers. Each student may have a different solution for logical reasons. Design principles for teacher action regarding student work and whole-class discussion are considering in the lesson plans used throughout the lesson.

The teacher tries to dig up the students' conceptual knowledge about the Quadrat and Quadratic Equation System during the task. Seen from the universe, whether the Quadrat and Quadratic Equation System requirements have the right solution or not from the coefficients or use discriminant requirements to see whether the curves intersect, coincide, or not. Teachers' instructional skills and strategies, how they try to identify students' prejudices and learning difficulties, and what teachers do to correct misconceptions, if any.

After observing the learning using the Mathematical task of Quadratic and Quadratic Equation Systems for 40 minutes, the researcher conducted interviews with the teacher about the mathematics task design ideas. The following is part of the interview transcript.

Interview excerpt #1

Researcher: Where did you get the initial idea to create problems in your task today?

Teacher: The idea of his task was from the two-variable system of linear equation task last week. It is a routine problem in the student book; I revised it a little.

Researcher: Oh, yes, what was revised, sir?

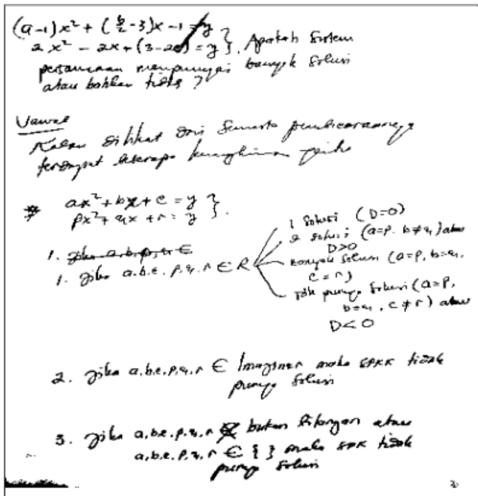
Teacher: if the problem in the book says, "Look at the following system of equations: $\begin{cases}(a-1)x^2+\left(\frac{b}{2}-3\right)x-1=y\\ 2x^2-2x+(3-2c)=y\end{cases}$, if the system has many solutions, what is the value of $a^2+b^2-c^2$? the answer is easy, if $a,b,p,q \in R$ and the constant $c,r \in R$. Has multiple solutions if $a=p, b=q$ dan $c=r$, then $a^2+b^2-c^2=3^2+2^2-2^2=9$. The understanding is a little unattractive compared to my question earlier.

Researcher: continue, what are the main concepts that you want to show your students this time?

Teacher: The general form of a quadratic and quadratic linear equation system and the conditions for a quadratic and quadratic linear equation system have possible solutions based on their discriminants and coefficients.

Based on the interview excerpt above, the math assignment's idea came from the previous two-variable Linear Equation System task, which was revising from a textbook's routine task. The teacher wants to show that the mathematics task can explore students' understanding and creativity compared to books. The teacher also explains the study's key concepts, namely the general form and requirements of the Kudrat and Quadratic Equation System, having possible solutions based on the discriminants and their coefficients. The teacher also explains his notes about possible answers that students might answer when giving the task (Figure 1).

The teacher's possible answers are made by the teacher based on the students' level of thinking in the class. In Figure 1, the teacher explains to the researcher that their students can answer three possibilities. One student may think if $a,b,p,q \in R$, then the quadratic and quadratic linear equations can have one solution, two solutions, not many solutions, or no solution. Two students may think if $a,b,p,q \in imaginer$, then the quadratic and quadratic linear equations system must have no solution. Three students may believe that if a,b,c,p,q,r are not numbers $a,b,p,q \in \{\}$, then the system of quadratic and quadratic linear equations also has no solution.



$$\left.\begin{aligned}(a-1)x^2\left(\frac{b}{2}-3\right)x-1=y\\ 2x^2-2x+(3-2c)=y\end{aligned}\right\}$$

Does the system of equations have many solutions or not?

Solutions:

If you look at the universe of the conversation

There are several possibilities, namely

$$\left.\begin{aligned}ax^2+bx+c=y\\ px^2+qx+r=y\end{aligned}\right\}$$

1. If $a, b, c, p, q, r \epsilon R$

$$\begin{cases} 1 \text{ Solution } (D=0) \\ 2 \text{ Solutions } (a=p, b\neq q) \text{ or } D>0 \\ \text{Many solutions } (a=p, b=q, c=r) \\ \text{No solutions } (a=p, b=q, c\neq r) \text{ or } D<0 \end{cases}$$

2. $If\ a, b, c, p, q, r\ \epsilon$ Imaginary then the system of quadratic equations has no solution
3. If a, b, c, p, q, r not a numbers or $a, b, c, p, q, r\ \epsilon \{\ \}$ then the system of quadratic equations has no solution

Figure 1, an example of teacher notes in generating task ideas 2

When designing these mathematics tasks, the mathematics teacher has several considerations. The most important consideration is the student's prior knowledge and understanding of what the student might have, shown in the following quote from the teacher's statement. The students' initial knowledge is the basic concepts that students have based on the existing schemata.

Interview excerpt #2

"… My consideration is the student's understanding system of quadratic and quadratic equations and the possible solutions or solutions that the quadratic and quadratic equation systems have using either discriminants or coefficients. Student's initial knowledge also becomes my consideration. They memorize or understand the concept well."

The following interview excerpt explains the importance of teacher-designed mathematics tasks for students.

Interview excerpt #3

Researcher: looking at your task, what is the importance of such a task for your students?
Teacher: It is essential for the relationship between the procedures and concepts they have. The reason that this task does not require students to make concrete examples. It is

an assignment that requires higher-order thinking, but students of average ability can be provoking to answer logically.

Researcher: if it concerns the relationship between procedures and concepts, what are the challenges in this task for students?

Teacher: Task question this time is, "Does the system of quadratic and quadratic equations have many solutions or not at all?". I hope that students think of many possibilities, not getting stuck in the equation that looks complicated but memorizing formulas or properties rather than understanding them.

Based on the interview above, the teacher wants to show that the quadratic and quadratic equation sub-system material task seeks to establish the relationship between the procedure and the students' concepts. The teacher hopes that their students' thoughts can develop through this task. The teacher wants to improve students' reasoning, not just memorizing formulas or traits. The teacher's lessons also explain that students who initially have lower abilities are motivated to answer questions logically.

Interview excerpt #4

Researcher: When generating this task idea, did it occur to differentiate the questions for students with low and high criteria for this case?

Teacher: It occurred to me that for smart students, I want them to sketch their parabolas with the possible answers, while for ordinary students, it is enough with their initial understanding. Maybe this will continue when we discuss it again.

Researcher: How do you know the students' initial knowledge? It could be that every student is different, right, sir?

Teacher: From the way they responded to my initial question before the task, they answered the task weeks ago.

Researcher: You said earlier that you thought about asking a different question according to cognition level. Did you have any other goals when generating the task idea this time?

Teacher: Yes, a student who stands out in the class in terms of high cognitive ability can become peer tutors for their friends and understand the quadratic and quadratic equation tasks this time.

Researcher: Since when did you have the idea to design a task like this?

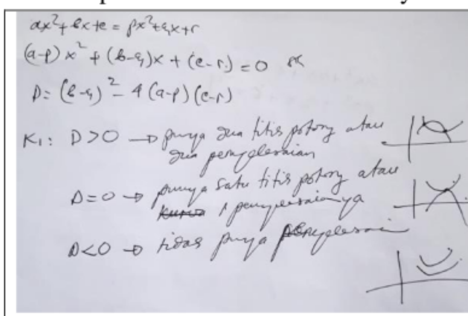
Teacher: Since they first taught in high school, since they know that the character of teenagers does not want to be cornered or demeaned, they always want to be respected and heard so that their creativity can emerge.

Based on interview excerpt # 4, the teacher shows his understanding of the students' initial knowledge. The teacher understands students' conceptual knowledge so that he has the aim to explore the potential of students who have high mathematical abilities with more demands than other students with mediocre mathematical skills. The teacher's discussion forum was forming to aim that students who have a high level of understanding can become peer tutors for their friends. The teacher also explained that his tasks design idea began when he knew the characteristics of his students. This explanation shows that the teacher makes the task design in a very understanding condition of the students.

The teacher trains students to see the completion of mathematics tasks from various perspectives. In this case, prior knowledge is needing, but the relationship between ideas and schemes in students' minds also needs to be trained. The teacher explains to the researchers that problems such as quadratic and quadratic equations often appear in the Olympics because issues like these often link several existing concepts. Therefore the teacher tries to get students to think flexibly and critically.

"I want them to look at it from the discriminant. Where the general form of a quadratic and quadratic system of equations is substituting for $(a-p)x^2+(b-q)x+(c-r)=0$. So $D=(b-q)^2-4(a-p)(c-r)$, with probability $D>0$ if the system of quadratic and quadratic equations has two solutions or the curve intersects at two points. For $D=0$ if the quadratic and quadratic equations haves one solution or the curves intersect at one point or $D<0$ if the system of quadratic and quadratic equations has no solutions or the curves drawn, will not intersect (Figure 2). Also, because this assignment often appears at the Olympics and I lead a lot of my students there, I want them to practice more of this kind of problem ".

The teacher explained that he wanted his students to solve quadratic and quadratic equations when viewed from the discrimination. As the teacher explains in Figure 2, the teacher explains if there is a possibility that the students think about a possible solution when viewed from the position of the curve that they will draw later.



$$ax^2+bx+c=px^2+qx+r$$
$$(a-p)x^2+(b-q)x+(c-r)=0$$
$$D=(b-q)^2-4(a-p)(c-r)$$

K1: $D>0$ → have two points of intersection or solution

$D=0$ → have one point of intersection or solution

$D<0$ → have no solution

Figure 2 an example of another alternative to task 2.

Indirectly, the teacher shows the material knowledge needed to produce mathematics tasks in Figure 2. This content knowledge is in line with the teacher's explanation. "The general form of a system of quadratic and quadratic equations $\begin{cases} y=ax^2+bx+c \\ y=px^2+qx+r \end{cases}$, where the coefficients $a,b,p,q \in R$ and the constant $c,r \in R$. It has many solutions $a=p, b=q$, and $c=r$, when we look at the coefficients of each equation. Moreover, there is no wrong answer because someone answered that the equations have no solution or only has one or two different solutions with logical reasons and correct conditions. It can also use the discriminant requirements that have been previously explaining". The teacher also explained to the researcher that he wanted to allow students to develop many solutions and strategies, invite unusual responses, and bring up mathematical ideas.

Discussion

In this study, researchers found that teachers needed a lot of information support to revise tasks in textbooks in designing math tasks. The teacher also uses his knowledge and understanding of the material and curriculum to modify students' mathematics books' existing mathematics tasks. The teacher also uses the material content's ability to explain each note and alternative answers he makes. It means that the teacher always writes alternative solutions that students may answer before giving to students. Content knowledge is knowledge about teachers' material, one of which is to design tasks (Mustafa & Derya, 2016). Teachers also have unique characteristics in recognizing the abilities of their students so that they affect their studies. It is part of the knowledge of pedagogical content, one of which is knowledge about students (Murtafiah & Lukitasari, 2019).

The teacher's understanding of the concept makes the teacher consider the previous experience that students have. The teacher wants to explain the students' initial knowledge to be hone using investigative questions such as tasks. The teacher also explained that he was not the type of teacher who gave spontaneous mathematics tasks because it was pre-planned. However, the teacher felt that he often used random questions in the middle of his task to practice his students' understanding, reasoning, and critical thinking skills. It is in line with (Keiler, 2018; Kim et al., 2019), which states that a good teacher is a teacher who gives tasks that can lead students to think. The teacher has more knowledge about the students' understanding, this can be seen when there is a new task that he feels challenging, but he does not give it to students because the time required will be longer. This task has a high level of difficulty and is replacing a mathematics task that he has considered great care. Teachers know recognizing student difficulties. Student difficulties are part of the teacher's understanding of their students (Blazar & Kraft, 2017; Keiler, 2018; Tiani et al., 2019).

In designing mathematics task ideas, the teacher always knows the assignment's fundamental concepts and explains them in detail. In creating the task, the teacher explains if the task results from a modification or reform of the student's mathematics book situation. It is one of the stages of decision-making, namely building assignment ideas by teachers (Murtafiah et al., 2019). A study conducted by (Hadar & Tirosh, 2019) provides evidence linking task selection with teacher decisions. These decisions are made based on how the teacher views the task based on their own beliefs and how students react to the study. A good teacher is a teacher who knows the characteristics of their students well. The teacher's confidence in the task and the students' knowledge identifies if the teacher knows about the curriculum and applies it to every math task.

Teacher belief is an essential aspect of students' learning (Norton, 2017; Pratiwi et al., 2022). Based on the teacher's explanation in each interview and observations on the assignment, the teacher knows what the students need. The teacher understands his students' initial knowledge or previous knowledge to become the teacher's consideration in developing his task. (Goethe & Colina, 2018; Gravemeijer et al., 2017; Messiou et al., 2022) highlighted the importance of considering the diverse needs of students. For example, a mathematical task that the teacher makes must meet the student's individual needs. In particular, teachers choose their assignments and trust students if they will be able to solve them. They recognize that rich mathematics tasks can change from year to year based on changing student interests but must always involve teacher experience. Teachers who have a strong knowledge base in this domain know math concepts that are difficult to understand, concepts that students usually have, including misconceptions, and know the sources of student error (Lee et al., 2018; Siregar & Daut Siagian, 2019). Also, they realize how to get rid of difficulties, mistakes, and misconceptions.

Conclusion

Teacher designed task design is rich mathematics tasks. The task design that the teacher does is creating to stimulate creative thinking. Procedural mathematics tasks are transforming into questions that invite student responses from various thinking levels. Teachers want to challenge students to think creatively. Teachers want students to come up with their problems. Teachers have unique characteristics in recognizing the abilities of their students. The most important consideration is their prior knowledge and an understanding of what their students might have. The teacher wants to improve students' reasoning rather than just memorizing formulas or traits. The teacher pays attention to students to develop many solutions and strategies and invite unusual responses and express their mathematical ideas. The teacher implements math tasks by combining several concepts in solving the problem, with the aim of students being training to think flexibly and critically in solving them.

Acknowledgment

We thank Mr. Abdillah and Mr. Abdur Rahman As'ari to share inspiring insights on these issues, Mr. Prayitno, in SMAN 3 Jombang who assist in conducting research, and friends of the Mathematics Education doctoral program who took the time for discussion.

Conflicts of Interest

The authors declare that no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely by the authors.

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