Designing student worksheet for rich mathematical tasks

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Abstract. Implementing rich tasks in daily mathematics classroom requires a supporting document for teachers who want to use an approach. This study developed a student worksheet that would act as cognitive scaffolding to support the students’ immediate construction of knowledge and provides the basis for future independent learning of the students in solving rich mathematical tasks. The study was conducted within research and development design which consisted of three phases: preliminary research, designing and experimenting phase. This paper is primarily concerned with the first and second phase of development study by focusing on the design of rich task based student worksheet and implication for pedagogy. Mathematics teachers and their students from one of the junior high schools in Banda Aceh were involved in this study. The study found that the student worksheet could be used by teachers to improve their students’ ability in solving rich mathematical tasks in a daily mathematics classroom. The document also aids the students to solve rich tasks independently through tasks’ scaffold questions provided within the student worksheet. However, some revisions are still needed before it will use extensively in schools.

1. Introduction

Providing an opportunity for students to develop a high level of mathematical competences as documented in TIMSS and PISA such as problem-solving, modeling, and reflective thinking become the center of current reform in mathematics education. Teachers are demanded to be able to arrange mathematics instructions and to provide teaching materials which could support students learning to achieve such competencies. This indicates that teachers are required to be more creative and innovative in designing learning approach and learning sources to their students.

It is argued that rich task is one of the approaches that can be used to promote students higher order thinking skills [1,2,3,4] because it could provide student learning opportunity to solve real-world problems that required higher order thinking skills including problem-solving, reflective thinking and reasoning [1,5]. Rich tasks are defined by Mould [6] as “A task that can engage students in the learning process, make contents meaningful and foster connections among ideas and disciplines. According to Fergusson [7], tasks in which the whole class can engage and are easily adjusted to students’ level of ability. Teaching mathematics using rich tasks allows entrance into the activity at multiple levels, with multiple paths possible to obtain the resulting solution [8]. Regarding these potentials of a rich task, many education standards and curriculum guidelines throughout the world mandate mathematics teachers to create more complex tasks to prepare students to live in the challenging world. However, designing rich tasks is not an easy task for teachers. Suardja, Fitriati and Novita [9] found that mathematics teachers in Indonesia rarely developed their own mathematical
tasks. Most of them use learning materials such as lesson plan, textbooks and student worksheet provided by government because they lack knowledge and skill to design mathematical tasks. In addition, there is now a mounting body of literature pointing to the fact that rich tasks are still not implemented in mathematics classrooms, or if implemented then routine mathematical tasks are being adopted.

This research has identified several issues in the literature in the international context as well as in local context that need to be addressed to facilitate the implementation of rich tasks in schools. To aid in the implementation of rich task in schools, this study aimed to design rich task based students worksheet that can be used as cognitive scaffolding in solving rich mathematical task and help mathematics teachers to provide learning resources in implementing rich tasks in daily mathematics classrooms.

In designing the student worksheet, this study used rich task design principles developed by Goos, Geiger and Dole [10] and each principle are described as follow:

1. A rich task should require application of mathematical knowledge. This knowledge includes not only fluency with accessing concepts and skills, but also problem-solving strategies and the ability to make reasonable estimations.

2. A rich task should promote positive dispositions such as confidence, initiative, and a willingness to apply mathematical knowledge flexibly and adaptively. Affective issues have long been held to play a central role in mathematics learning and teaching, and the importance of developing positive attitudes toward mathematics is emphasized in national and international curriculum documents.

3. A rich task should involve using tools. These tools may be representational (symbol system, graphs maps, diagram, drawing, tables), physical (model, measuring instruments), and digital (computers, software, calculators, internet).

4. A rich task also should be embedded in a range of contexts. These contexts may be drawn from real life or curriculum areas other than mathematics.

5. A rich task should develop a critical orientation (reflective thinking) in students since people not only know and use methods, they also evaluate the reasonableness of the results obtained and are aware of appropriate and inappropriate uses of mathematical thinking.

6. A rich task also needs to adopt investigative pedagogies which are defined as "contextualized problem-solving tasks through which students can speculate, test ideas and argue with others to defend their solutions" (p.591).

To be able to implement rich tasks, this study conjecture that the tasks for students should include a supporting document that would act as a cognitive scaffold for students in the initial stages of solving rich mathematical tasks process before they could internalize the metacognitive strategies and automatically use these strategies when faced with new rich tasks. This is important since the students not familiar with rich tasks yet. Furthermore, rich tasks related learning sources that could be accessed by students still limited. Therefore, to support them learning with rich tasks, they need a student worksheet as guidance that could be used independently. This is in line with the view that any scaffold should be gradually withdrawn as the learner becomes more competence [11].

Thus, this study was directed towards the development of this important document that is known as the student worksheet. The student worksheet is developed by incorporating the idea of cognitive scaffolding as used by Dindyal et al. [11] in developing a practical worksheet for a problem-solving task which included the use of questions, modeling, assisting with making a plan, drawing diagrams and encouraging the students to work in group. One of the reasons why it is important to develop rich task based students worksheet is because the way a task is imagined and intended by the teacher may be quite different from the way it is understood and carried out by the students. The intended learning by students may not happen if they misunderstand the tasks. Also, if teachers give too many directions, the solution process may become too trivial for students and the solution process may be reduced to a sequence of steps. In contrast, if teachers give too few directions, the students may focus
on different things and the intended learning may not happen. Therefore, the implementation of rich tasks in the classroom ultimately needs to involve the teacher. This study, especially in the designing process, have paid careful attention to teacher preparation for implementing the rich task, including the use of student worksheet. As suggested by Slavit and Nelson [5], teachers were introduced to and thought about rich tasks and its characteristics as well as its principles as described before. So, they know how to help students to solve rich tasks.

2. Method
The development of student worksheet for rich tasks was conducted in three phases within research and development design [12] which have been simplified by Sukmadinata [13]. This includes: (1) preliminary study phase (literature review and survey); (2) the development phase which consist of three activities: designing student worksheet, operational field testing and main field testing; and (3) final phase is dissemination or implementation phase. This paper is primarily concerned with (1) and (2) phase of development study by focusing on the design of rich task based student worksheet and implication for pedagogy. Quantitative and qualitative data gathered from teachers and their students through questioner and interview were used in this study to develop rich tasks based student worksheet with descriptive approach.

The first stage of design research began in 2015 where the research team conducted preliminary research. In this phase, they studied the literature about rich task, analyzed the demand of solving mathematical tasks in Indonesian school curriculum and conducted a survey in four high ability junior high schools in Banda Aceh. The survey was carried out to find the information related to common teaching practices implemented by teachers in mathematics classroom, how students experience learning mathematics, what are learning sources used during instruction process.

The second stage of student worksheet development was designing process. The findings from literature and survey were used to design student worksheet. In this phase, this research paid more attention to the structure of student worksheet especially to ensure the design could work as cognitive scaffolding for students to solve rich tasks. Scrutinizing rich tasks principles was also conducted to satisfy the demand of the stated parameters. The first prototype of the student worksheet was developed in this stage. Before the designed student worksheet used in limited field test phase which is the final stage, the first prototype or prototype 1 was validated by several mathematics education experts and practitioners. This was done to check the appearance and content validity of the developed student worksheet. The prototype 1 was revised then by taking into account all suggestions from validators. This activity produced the second prototype of student worksheet (prototype 2).

The second prototype of student worksheet then used in field test through experimental design. The field test administered within two stages: (1) operational field test where the experiment conducted only in one school; and (2) main field test where experiment conducted in three schools. The operational field test was carried out in 2016 where the research team experimented on the prototype 2 of student worksheet. This study adopted a design experiment approach to produce a workable "design" (an initiative, artifact or intervention, for instance) that could be adapted by the schools. Teachers were involved in this stage where they have to use the student worksheet designed by the research team. It appeared necessary that the teachers make the proposed instructional approach a routine sufficiently familiar to them that the approach become classroom practice. To reach this aim, it seemed essential for teachers to adapt the researchers’ ideas to make them their own, in the sense of their beliefs of mathematics and of solving rich mathematical tasks are transformed. Such a process would pass through a stage where the teachers negotiate and change the lesson. Therefore, the research team conducted a short workshop and discussion with teachers about the rich task and how to implement rich task based student worksheet in their mathematics classroom.

The experiment of the second prototype was conducted in one of high ability secondary schools in Banda Aceh where one teacher and twenty students of the school were involved. The observation was also conducted by the research team during the experiment session to monitor teacher teaching practice using rich task based student worksheet and to gather information related to the weaknesses of
instruction process using the designed instrument. The student worksheet used by students during the teaching process and field notes during classroom observation were gathered by the research team to be used in revising the second prototype so that the third prototype will be produced.

3. Results and discussion

3.1. Choosing the right game

In solving the task in Figure 1, this study emphasized the student learning and reinforcing of rich tasks model by Goos, Geiger and Dole [9]. An audit of Indonesian 2013 curriculum identified distinctive rich task demands for mathematics subject taught in Grade 7. For example, the mathematics curriculum for Grade 7 semester 1 is organized into four topics: number, set, algebra form, linear equation and inequality. The rich task audit found that all these topic contain mathematical knowledge for designing project. Students must combine knowledge from a variety of previous math topic [14]. Contexts for rich task development included personal experience, the study of the social, economic and ecological system. Students were expected to develop dispositions enabling them to be active in solving real-life problems. The use of tools such as symbol, diagram, tables, graph and models was vital to learning in this subject. The goal of enabling students to solve real-life problems requires the development of critical orientation to viewing information and evaluating all possible solutions. Presenting the audit findings to teachers was intended to raise awareness of their subject’ rich task demands.

| No | Subject | Weight | Height |
|----|---------|--------|--------|
| 1  | Febi    | 55kg   | 149cm  |
| 2  | Brother | 24kg   | 126cm  |
| 3  | Father  | 70kg   | 173cm  |
| 4  | Mother  | 51kg   | 162cm  |

Figure 1. Example of rich task in student worksheet for inequality equation topic

The cognitive scaffolding used to help students solve the given rich task which meets also rich task’ principles is provided in Table 1. This study helps students by asking several questions through follow up activities to give task specific hints, which essentially is a throwback to the usual help afforded by mathematics teachers.
Table 1. The task’ scaffolding.

| Rich Task Principles | Task Features | Example based on choosing the right game task |
|----------------------|---------------|---------------------------------------------|
| Application of mathematical knowledge | Applying inequality concept in solving the task | What are the mathematical concepts you have to apply to solve the given tasks? |
| Positive disposition (attitude) | Taking the initiative and a willingness to solve real-life problems | What exactly are you doing to solve the task? Why are you doing that? |
| Using tools | Using symbol, graphs maps, diagram, drawing, tables and modeling | What representations can you use to get a sense of what this is about?, How can the problem be modeled? |
| Embedded a range of context | Using student personal context | Where is the problem happen? |
| Critical Orientation | Viewing and evaluating the answer | Have you found all the possibilities?, do you think we have found the best solution? |
| Contextualized Problem Solving | Solving the problems | What objectives are required? Have you met anything like this before?, What is your plan of action? How reasonable is your solution? |

The objective of student worksheet is for students to internalize the step in solving the rich task, and to ensure that they are in rich task learning trajectory through cognitive scaffolding. Assessment of rich task is certainly another issue that guides students in solving rich tasks. To this end, an accompanying assessment rubric was developed to focus students on what is valued in solving rich tasks process. At the same time, the rubric gives them feedback on their strengths and weaknesses.

3.2. The student worksheet

Based on the audit of mathematics curriculum for junior high school, the research team decided to design student worksheet for inequalities linear equation topic which is learned by Year 7 students in the first semester. As mention before that the student worksheet would act as cognitive scaffolding for students to solve rich task; therefore the structure of the designed student worksheet was arranged to include a number of activities that could help students to work independently in solving rich tasks.

The student worksheet consist of five parts: (1) basic competencies that should be achieved through the learning process, (2) what students will learn, (3) instruction how to use the student worksheet, (4) one rich mathematical tasks following by four activities to allow students understanding of the given mathematics topic (inequality equation), and (5) summary activity. The student worksheet also provides several questions related to rich tasks to guide students to solve it. The questions follow the learning trajectory expected from mathematics instruction using rich tasks especially the task’ scaffolding as shown in Table 1. The questions on the worksheet include context, mathematical concepts, problem-solving, and critical thinking and all of these are arranged in the last page of student worksheet with space for students to write their answer, solution and/or reason. Example of student worksheet based on rich task is shown in Figure 2.
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4. Conclusion
The student worksheet developed through this study has implications for teachers, researcher, and curriculum developers. It could be used by teachers who want to incorporate rich task based instruction in a daily mathematics classroom. The documents work as cognitive scaffolding that supports the immediate construction of knowledge by students and as well as provides the basis for future independent learning of the student. However, some revisions are still needed before it will use extensively in schools. Taken altogether, the rich task design, which includes student worksheet and rich tasks based lesson plan have shown great potential in developing students’ ability in solving the rich mathematical task.

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