Development of students activities sheet (SAS) of linear programming based on Krulik dan Rudnick problem solving to improve problem solving abilities

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Abstract. Problem-solving competence is one of the abilities as a primary objective of the national curriculum because this ability is required to face future challenges. On the other hand, the ability of students to solve linear programming problems is still low. Where to improve this competency needs a systematic effort. Therefore, this study aims to: 1) improve student problem solving, 2) measure the level of validity, effectiveness, and practicality of the SAS developed. The type of this research is Research and Development (R&D) by Thiagarajan, Semmel and Semmel Model. The instrument developed was a student activity sheet (SAS) based on the Krulik dan Rudnick problem-solving. Furthermore, to obtain data in this study using four types of instruments: 1) observation sheets, 2) questionnaires, 3) validation sheets and 4) essay test based on Krulik and Rudnick problem-solving. This research conducted in the mathematics education study program in class C and bilingual. The results of data analysis showed an increase in students' problem-solving skills. Besides, the activity sheet has met the criteria of validity, practicality, and effectiveness.

1. Introduction.
Based on the national curriculum, improving problem-solving skills is one of the main objectives of the learning process [1, 2]. Also, this ability is as the main basic competency to improve students' thinking processes [3]. However, the problem-solving ability of students of mathematics education in bilingual class and class c in semester v is still relatively low. They have not been able to solve mathematical problems systematically. Therefore, an effort is needed to improve it. Humans are always dealing with problems, and this is due to human desires and hopes that are not in line with reality. To overcome this, we need a creative way to get the right decision [4, 5, 6]. Furthermore, the mathematical problem-solving ability is a systematic technique or procedure that is applied to solve problems rationally [7]. This capability is required by every human being especially millennial generation in order to survive facing challenges in the industrial revolution era 4.0.
On the other hand, based on preliminary research that students have not been able to solve mathematical problems procedurally. It caused by 1) the learning process is still in lecturer-centred learning. Consequently, they have little opportunity to construct their knowledge through problem-solving, 2) there are no learning tools available such as SAS, books or media, which are developed systematically in order to improve this ability. Therefore, to improve students' problem-solving skills, it is necessary to improve the learning process and develop a systematic and measurable student activity sheet.
2. Methodology
There are several opinions of experts regarding problem-solving. The first definition states that problem-solving consists of 5 stages: 1) reading the problem, 2) analyzing the problem, 3) developing the problem, 4) implementation process and 5) verification [8]. Furthermore, Bransford and Stein divide the problem-solving stage into five: identifying the problem by finding information and compiling questions regarding the problem, defining the problem by compiling the information and questions, exploring a strategy or pattern, overcoming the problem by applying the strategy and pattern, and evaluating the results [9]. In addition, Polya believes that the problem-solving process consists of four stages: 1) understanding the problem well, 2) carrying out the plan or steps needed to solve the problem, 3) executing the problem based on the plan, 4) looking back the finding [7]. Meanwhile, Rudnick and Krulik argues that there are five ways to solve a problem: 1) read and think about a problem, 2) explore the problem and plan the solution, 3) determine the strategy to be used, 4) find and solve the problem, 5 ) reflect and develop the results [10].

This study aimed to determine the level of validity, effectiveness, and practicality of the SAS. Besides, this study also described the improvement of students’ problem-solving skills after using SAS in the learning process. The problem-solving ability was measured based on indicators of problem-solving by Krulik and Rudnick [10]. This research was a research and development (R&D), which consists of four stages: 1) the definition process, 2) the design process, 3) the development process, and 4) the dissemination process [11].

The design of this study is one group pre-test and post-test design. The index gain value used to find out the improvement of students’ problem-solving skills [12] where the gain index categorization (g) consists of three: low if g≤0.3, moderate for 0.3 <g ≤0.7, and high if it reaches g˃0.7. This research conducted a mathematics education study program, state university of Medan. The students consisted of 21 students from a bilingual class and class c consisting of 43 students. Furthermore, the instruments used to obtain research data are 1) observation sheets on student activities, 2) lecturer response questionnaires, 3) student response questionnaires, and 4) SAS validation sheets.

The main purpose of the observation sheet is to obtain accurate data regarding the feasibility of learning by students. Where the level of activity will be seen based on aspects that often arise during learning takes place [13]. Then, the indicators on the SAS validation sheet are level of content synchronization, the suitability of the format, the arrangement of the sentences, and the accuracy of the illustrations to the objectives where the level of validation can be known based on the average value of the instrument [14].

The teacher response sheet is useful to reveal the extent of the teacher's positive response using the SAS. The positive responses grouped into four parts: 1) excellent for scores in the range of 3.25 to 4, 2) the excellent category in the range of 2.50 to 3.24, 3) the fair category if it lies in the range 1.75 to 2.49, and 4) the poor category if there is a range 1 to 1.74 [15]. Meanwhile, the level of student response to SAS is known based on data on the student response sheet. Where the sheet reflects whether students feel happy, interest, new, and clear of the SAS, where the proportion is determined based on the formula described by Trianto [12]

3. Result and Discussion.
The results and discussion of this study are described based on the stages of development by Thiagarajan as follows.

3.1. Problem Defining Phase
The purpose of the defining stage is to establish and define learning requirements. At this stage, the objectives and limits of the linear program material determined. At this stage, the following phases carried out: initial-end analysis, student analysis, concept analysis, task analysis, and formulation of learning objectives.

Based on the initial analysis, it knew that the problem-solving ability of students in linear program subjects is still relatively low. It means the problem-solving process is not systematic. After further analysis of the problems that occur, the root of the problem is the instrument used when the learning
The process cannot stimulate an increase in this ability. Therefore, it is necessary to build an instrument that can improve students' problem-solving abilities, such as SAS or book. Cognitively and intelligently, it is inevitable that students included in the middle to the top category because they are the result of a rigorous selection to be a student in the mathematics education study program.

In the analysis of concepts and material found that the characteristics of appropriate materials were: 1) modelling linear program problems, 2) graphical methods, and 3) simplex methods. While the task analysis determined that the task was designed based on indicators contained in essential competencies. Furthermore, the learning objectives were problem-solving competencies based on the Krulik and Rudnick indicators.

3.2. SAS Designing
This stage aims to determine SAS prototypes that will be used in the learning process to improve students' problem-solving skills. In this phase, the preparation of research instruments is carried out, namely: test instruments, media selection, format selection, and initial design.

3.3. SAS Development Phase
At this stage is developing SAS. Then, measure the quality of the SAS through tests of validity, effectiveness, and practicality.

3.4. SAS Validity Process.
There are five indicators considered in the SAS validity process: 1) aspects of language, 2) format, 3) content, 4) illustrations, and 5) learning objectives. Where SAS validated by three lecturers, who are experts in their fields. The validation results are shown in Table 1 below.

| Table 1. SAS score and criteria validation process |
|-----------------------------------------------|
| **Indicators** | **Expert Validator** | **Average of Score** | **Category** |
| Format of SAS | 4.5 | 4.3 | 4.5 | 4.4 | good |
| Language of SAS | 4.3 | 4.2 | 4.3 | 4.3 | good |
| Content of SAS | 4.3 | 4.2 | 4.2 | 4.2 | good |
| Illustration of SAS | 4.2 | 4.0 | 4.1 | 4.1 | good |
| Learning Objective of LP | 4.4 | 4.5 | 4.4 | 4.4 | good |

Table 1 describes that all indicators of validation of student activity sheets are in a proper category. Therefore, it can conclude that the activity sheet is suitable for use. However, there is a note that "activity sheets can use if there is a slight improvement to the illustration indicators".

Then, Table 2 shows the results of the validation of 5 essay tests by three expert validators where the questions are designed based on Rudnick and Krulik indicators to measure students' problem-solving competencies.

| Table 2. The results of the validation of essay tests |
|-----------------------------------------------|
| **No** | **Validator A** | **Validator B** | **Validator C** |
| **Content of SAS** | **Language of SAS** | **Final Recommendation** | **Content of SAS** | **Language of SAS** | **Final Recommendation** | **Content of SAS** | **Language of SAS** | **Final Recommendation** |
| 1 | valid | DM | TP | valid | DM | TP | valid | DM | TP |
| 2 | valid | DM | TP | valid | DM | TP | valid | DM | TP |
Valid DM (understood), TP (there is no revision), SP (there is a little bit revision).

In conclusion, the five test essays can be used to measure students’ problem-solving abilities based on Rudnick and Krulik indicators. However, there is a suggestion to make a slight correction to question number 3.

### 3.4.1 Determination of the effectiveness of SAS

There are two measurements used to determine the level of effectiveness of SAS, namely: increasing students' problem-solving abilities and the level of activity of student activities. Where the effectiveness requirements determined by researchers consist of two: 1) if the gain index is in the high category, 2) each indicator of student activity is at least in the current category.

#### Table 3. A score of problem-solving ability and index gain

| Competence | First Trial Average Score Pre-test | Index Gain | Category | Second Trial Average Score Pre-test | Index Gain | Category |
|------------|----------------------------------|------------|----------|-------------------------------------|------------|----------|
| Problem Solving Ability | 52 | 82 | 0.625 | Medium | 53 | 90 | 0.78 | high |

Table 3 describes that students’ problem-solving abilities in the first trial were in the medium category. However, during the second trial, the gain index rose to 0.78 in the high category. It shows that there is an increase in problem-solving skills after using the student activity sheet. Furthermore, data on the level of student activity is shown in Table 4.

#### Table 4. The level of student activity during the learning process

| No | Observed aspects | First Trial % Category | Second Trial % Category | Ideal time | Effectiveness Interval |
|----|------------------|-----------------------|------------------------|-----------|------------------------|
| 1  | Reading the problem | 17 active | 18 active | 14% | 9%-19% |
| 2  | Explore and plan the information | 16 active | 18 active | 11% | 6%-19% |
| 3  | Select a good strategy | 32 not active | 41 active | 38% | 33%-43% |
| 5  | Find the solution | 15 not active | 24 active | 24% | 19%-29% |
| 6  | Reflect and extend | 6 not active | 11 active | 13% | 8%-18% |
| 7  | Activities out of plan | 11 not active | 3 active | 0% | 0%-5% |

The data in Table 4 explains that in the first trial, the activeness category did not meet the ideal requirements. Because there are still inactive categories on aspects: 1) select a good strategy, 2) find the solution, 3) reflect and extend, and 4) activities out of the plan. However, on the contrary, all categories were active during the second trial. Depends on tables 3 and 4, it concluded that two effectiveness criteria met. Therefore, it can state that the SAS is effectively used to improve students' problem-solving abilities.
3.4.2 Measuring Practicality of SAS
The practicality of the student activity sheet is measured based on the response from both the lecturer and student.

| No | Aspect                        | First Trial | Second Trial |
|----|-------------------------------|-------------|--------------|
|    |                               | Average     | Category     |
| 1  | Content of SAS                | 2,3         | fair         |
|    | Illustration of SAS           | 1,6         | poor         |
| 2  | Benefit of SAS                | 2,9         | good         |
| 3  | Implementation                | 2,8         | good         |

Table 5 illustrates that the student activity sheet is not practical in the first trial, because there is still a proper category in the aspect of the content of SAS and poor in the illustration category of SAS. However, after finding weaknesses and correcting them, finally in the second trial, all categories were already in the top category. The second practical criterion is the student's positive response to the activity sheet. Where the response illustrated in Table 6 below.

| No | Aspect                        | First Trial | Second Trial |
|----|-------------------------------|-------------|--------------|
|    |                               | Number of Student | %         | Number of Student | %         |
| 1  | Learning objectives           | 17          | 80,952381    | 37 | 86,04651 |
| 2  | Language of SAS               | 16          | 76,190476    | 36 | 83,72093 |
| 3  | Content of SAS                | 16          | 76,190476    | 35 | 81,39535 |
| 4  | Illustration of SAS           | 15          | 71,428571    | 35 | 81,39535 |

Table 6 illustrates that the student activity sheet is not practical in the first trial, because there is still a proper category in the aspect of the content of SAS and poor in the illustration category of SAS. However, after finding weaknesses and correcting them, finally in the second trial, all categories were already in the top category. The second practical criterion is the student's positive response to the activity sheet. Where the response illustrated in Table 6 below.

Table 5 shows that the practical requirements have not been reached after the first trial because aspects of language, content, and illustration are still below 80%. However, after correcting every aspect, all aspects have reached more than 80%. Based on the data in Table 5 and 6, it saw that the student activity sheet had fulfilled the two categories of practising (aspects of lecturer and student responses). Consequently, this activity sheet is practical and recommended for use.

3.5 Product Dissemination Phase
In this research, the dissemination stage is limited to the process of introducing student activity sheets to peers, especially for lecturers who teach courses in linear programming. For good cooperation, the team of lecturers will consider using it in the odd semester of the academic year 2020/2021.

4. Conclusion
After measuring the characteristics of the success of this study (validity, effectiveness, and practically), it concluded that the student activity sheet has fulfilled the three requirements. Furthermore, the use of student worksheet can significantly improve students’ mathematical problem-solving abilities. Therefore, the researcher recommends to the lecturers or the linear programming subject to use this student activity sheet in learning process to increase mathematical problem solving competence.
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