Advances in Social Science, Education and Humanities Research, volume 550
Proceedings of the 1st International Conference on Mathematics and Mathematics Education (ICMMED 2020)

Learning Mathematical Modelling : How to design visual-formed Student's Worksheet Using Traditional Food Context

NP Setiawati[1,] Darmawijoyo[1,*]Y Hartono[1]

[1] *Mathematics Education Department, Sriwijaya University*
[*]*Corresponding author. Email: darmawijoyo@unsri.ac.id*

ABSTRACT
This article studied designing a Visual-formed Student's Worksheet the traditional food context under a mathematical modelling framework. This article only discusses the preliminary stages of the developed students' worksheet. The preliminary stage covers two steps; there are analysis and design steps. The analysis step focused on the analyzing of the curriculum, that is in the form of students' difficulty in real-world problem solving, as well as in the designing step that focused on the initial design of students' worksheet based on the principles of developing math modelling problems that put forward by Catherine Paolucci and Helena Wessels so that the resulting prototype of students' worksheet for teaching mathematical modelling.

Keywords: *Mathematical modelling, visual-formed, student's worksheet, traditional food context*

1. INTRODUCTION

The curriculum 2013 defines problem-solving skills as a general-purpose of math learning, which means problem-solving is one of the competencies students need. The Ministry of Education expects students to solve problems that include problem-solving skills, designing mathematical models, solving models, and interpreting acquired solutions [1]. Not only that but problem-solving also goes into one of the must-have abilities of students in the 21st century. Capabilities in the Partnership for the 21st century include communication and collaboration, creativity and innovation, and critical thinking and problem-solving.

The The importance of problem-solving skills is not as appropriate as reality. The results of TIMSS in 2015 show that the average score of Indonesian students is still far from the International average score of each cognitive domain, such as 32% on the knowledge domain, 24% on the applying domain, and 20% on the reasoning domain [2]. It means the lowest average obtained at the cognitive domain of reasoning level in TIMSS the domain is solving non-routine problems related to daily life [3]. The non-routine problem is the word problems, and through it, students will transfer formal mathematics knowledge and skills that have been learned at school into daily life [4, 5].

Students' difficulty understanding word problems is caused by the lack of concentration in comprehending the problems that cause them got misunderstanding the given problem. Lack of concentration can make students less interested in solving problems. It is in line with the study Phonapichat, Wongwanich & Sujiva that students are less interested in solving math problems cause of too long and too complex problems that make students lose their spirit to solve the problems [6]. The results from Hoogland, Koning, Bakker, Pepin, & Gravemeijer showed much better learning outcomes on image-rich stories than ordinary word-rich stories with a 2% increase in responses [7]. Furthermore, Hoogland, Koning, Bakker, Pepin, & Gravemeijer added that the story problem given by reducing words and adding more images would be an optimal combination of students learning performance [8]. However, this statement is still a hypothesis.

One of the approaches that can be used to improve students' ability to solve problems is mathematical modelling [9,10]. Studying mathematical modelling can help students understand real-world problems. The study results concerning the understanding of the word problems show that the approach of learning mathematical modelling contributes to the understanding of problems about the word problems in the visual form [11,12]. Furthermore, Hoogland, Koning, Bakker, Pepin, & Gravemeijer learning in visual questions is preferred by students over text-questions in general. Besides, in research Lusiana, visual-formed problems can help students better understand the existing problems [13]. The word problem was used in the study Novriani & Surya, similar to the form of the word problem in students' textbooks, but the researchers added questions gradually to help students solve the problems [14]. Research has been widely conducted, even developing word problems [[7], [10, 11], [14]]. However, there is rarely found research that presents a solution in the form of understanding the problem by visualizing the word problems into posters or images using a mathematical modelling approach. Therefore, this article discusses designing a visual-formed student's worksheet design using the traditional food context under a mathematical modelling framework.

2. RESEARCH METHOD

The research method used in this article was development research that aims to produce visually-formed students' worksheet designs using traditional food context under a mathematical modelling framework. The design stages are as follows :

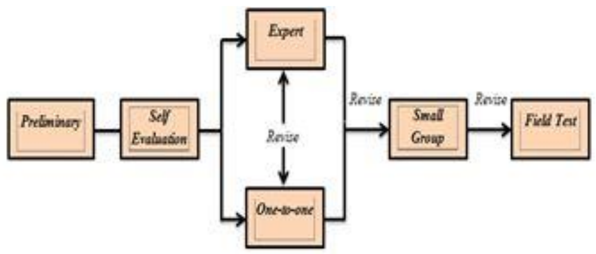

Figure 1 Design Stages [16, 17]

The on Figure 1, this article only discusses the initial stage, namely preliminary or initial design, consisting of the analysis and designing stage of the visual-formed students' worksheet using traditional context under a mathematical modelling framework. In the analysis stage, researchers analyzed students' abilities and the curriculum. In the design stage, researchers used the principles of developing mathematical modelling problems as in [18], see Table 1. Whereas, steps solving the problem, researchers used Blum's mathematical modelling framework [19], see Table 2.

Table 1. Principles and Criteria for Designing Mathematical Modelling Problems

Principles	Criteria
Principle 1 There is a connection to students' real-world problems	It has a real-world connection and aims to motivate students and describe mathematical relationships in students' life
Principle 2 Opportunity to identify and determine mathematical questions of common problems.	a. Requires students to represent context mathematically through images, graphs, tables, sentences, etc. That possibly help them to solve the problems. b. There is a sub-question of the common problem given.
Principle 3 Formulating solutions is feasible, involving the use of mathematics that students can access, making the necessary assumptions, and collecting the data needed	a. Involves the use of mathematics accessible to students. b. Appropriate assumptions to solve the problem. c. Require students to collect the necessary data.
Principle 4 A problem is a logic for students so that the solutions and interpretations are possible for them	Have one/more solutions that allow students to conclude the problems.
Principle 5 There are evaluation procedures that make it possible to check the mathematical accuracy and suitability of a solution in context.	a. There are procedures for examining the solutions. b. Solutions from the problems have relationships with real-world students.
Didactic Design Principles Problems can be structured into sequential questions that maintain the integrity of real situations (These can be given as instructions for teachers)	Problems are organized into sequential questions.

Besides using the principle of problem development. Mathematical modelling has seven learning processes [19], and it will be used in designing the problems in this article listed in Table 2 below :

Table 2. Mathematical Modelling Process and Indicators

No.	Principles	Criteria
1	*Constructing* (Understanding the Problem)	Identify a given issue.
2	*Simplifying/ Structuring* (*Simplification*/ *Building Structure*)	a. Make assumptions of a problem b. Determine the necessary variables in resolving the problem.
3	*Mathematising*	Designing mathematical models from Problems
4	*Working Mathematically*	Solving problems from established mathematical models.
5	*Interpreting*	Generalize math results obtained into a real-world context.
6	*Validating*	Re-examining the results obtained.
7	*Exposing*	Describing the final solutions.

3. DISCUSSION AND RESULTS

3.1. Analysis

The analysis stage is the first step in the process of designing students' worksheets. At this stage, the curriculum's analyzing process is carried out in the form of curriculum demands on learning, especially on math learning. The curriculum 2013 defines problem-solving skills as a general goal of math learning. In solving problems such as word problems, capabilities, and skills are needed to solve problems that are very useful in daily life. However, not all students can easily solve the word problem. It is already seen that the lack of students' concentration in reading problems makes students get misunderstanding the given problem and that reading too long questions text makes students lack students' interest. Students' ability to solve problems is also assessed at International events such as TIMSS, where the results of TIMSS 2015 show that the average score of Indonesian students is still far from the International average, scoring 32% on the domain of knowing, 24% on the applying domain, and 20% on the reasoning domain [2].

Country	Overall Mathematics	Mathematics Cognitive Domains		
		Knowing	Applying	Reasoning
Australia	51 (0.7)	56 (0.7)	50 (0.7)	46 (0.7)
Bahrain	36 (0.4)	44 (0.5)	33 (0.4)	29 (0.5)
Belgium (Flemish)	58 (0.6)	66 (0.6)	56 (0.6)	48 (0.7)
Bulgaria	53 (1.3)	60 (1.3)	51 (1.3)	44 (1.3)
Canada	49 (0.5)	55 (0.6)	47 (0.6)	45 (0.6)
Chile	37 (0.5)	42 (0.6)	35 (0.6)	33 (0.5)
Chinese Taipei	70 (0.4)	80 (0.4)	68 (0.5)	58 (0.6)
Croatia	47 (0.5)	53 (0.5)	43 (0.5)	41 (0.6)
Cyprus	53 (0.6)	58 (0.6)	52 (0.7)	45 (0.6)
Czech Republic	53 (0.6)	58 (0.6)	51 (0.7)	50 (0.7)
Denmark	56 (0.7)	62 (0.8)	54 (0.7)	51 (0.8)
England	58 (0.7)	66 (0.7)	56 (0.7)	50 (0.8)
Finland	55 (0.5)	60 (0.5)	53 (0.5)	50 (0.7)
France	43 (0.7)	50 (0.7)	41 (0.7)	38 (0.7)
Georgia	39 (0.8)	45 (0.9)	37 (0.8)	31 (0.8)
Germany	52 (0.5)	58 (0.6)	48 (0.6)	48 (0.6)
Hong Kong SAR	75 (0.7)	80 (0.6)	76 (0.7)	64 (0.9)
Hungary	55 (0.7)	62 (0.7)	52 (0.8)	48 (0.8)
Indonesia	26 (0.6)	32 (0.8)	24 (0.6)	20 (0.5)
Iran, Islamic Rep. of	32 (0.6)	39 (0.7)	31 (0.6)	25 (0.6)
Ireland	59 (0.6)	67 (0.6)	57 (0.6)	48 (0.6)
Italy	48 (0.6)	56 (0.7)	45 (0.6)	40 (0.6)

Figure 2 Indonesian Cognitive Domain Score

Figure 2 above shows that the lowest average is obtained in the cognitive domain of reasoning level, wherein TIMSS the domain is solving non-routine problems related to daily life [3].

3.2. Design

The design stage is the next stage after the analysis stage. At this stage, the initial design of students' worksheet was carried out based on the principle of developing mathematical modelling problems according to Catherine Paolucci [18]; it is related to mathematical modelling measures according to Blum [19], and the designing process will be explained as follows :

3.2.1. First Principle

In the first principle, there is a relationship to the students' real-world problems used as a first step in creating mathematical modelling problems. According to the definition of mathematical modelling itself, mathematical modelling is a process of representing real-world problems into the form of mathematics problems to obtain the solutions. It means that the problem of mathematical modelling must be related to the students' real world. It also fits the criteria of the first principle that the problem of mathematical modelling has a real-world connection and aims to motivate students as well as describe the relationship of mathematics in the student's life. In the designed students' worksheet, the first principle is used to create a mathematical modelling problem about "Food Recipe Adaptation," where the selected food recipe is one of South Sumatra's typical foods, namely Talam Gandus, with the problems and ingredients that are also known by students.

Figure 3 Mathematical Modelling Problems

3.2.2. Second Principle

After creating the initial problem based on the criteria and the first principle, the next step is to use the second principle to provide an opportunity for students to identify and determine the math questions of the common problem. This kind of criteria of: Consists of something that mathematically represents context such as pictures, charts, tables, sentences, et, to help students solve the problems. In the design process the problem of mathematical modelling is presented in the form of visual or image-rich problems so the students more easily understand the real-world problems given. Such as Figure 4 bellow

Figure 4 Mathematical Modelling Problems that presented visually or in image-rich Problems

Besides, the second principle also has criteria in the form of questions consisting of sub-questions of common problems. In students' worksheet designed, for students that can answer the core question in the form of such as "How much material is needed to make Talam Gandus as many as 12 portions?", Students have to answer the sub-questions that consisting of mathematical modelling stages such as Figure 5 bellow

a. Informasi apa saja yang penting pada permasalahan diatas ?

b. Masalah apa yang harus diselesaikan dari soal di atas ?

c. Berapa banyak bahan yang digunakan untuk membuat 12 talam gandus ?

Banyak porsi yang akan dibuat	Tepung Beras	Santan	Air	Ebi Kering
1				
2				

Figure 5 Sub Question

The question in Figure 5 is a mathematical modelling step in the construction stage. In this stage, students first have to identify the given problem, such as the important information, and the problems that will be solved.

3.2.3. Third Principle

The third principle is the process of formulating the solution in the problem is feasible, involving the use of mathematics accessible to students, making the necessary assumptions, and collecting the necessary data. The third principle criteria consist of 1) Involving the use of mathematics that can be accessed by students, 2) Make an assumption that suitable to solve the problem, and 3) Activities that require students to collect the necessary data. The third principle contained on the activities that carried out by students on the sub-question students' worksheet, such as in Figure 6 bellow

a. Informasi apa saja yang penting pada permasalahan diatas ?

b. Masalah apa yang harus diselesaikan dari soal di atas ?

Figure 6 Sub-question in the student activity section consider the problems and data colletion

Based on the question in Figure 6, the appropriate modelling step in *simplifying/ structuring*, in which students will collect the necessary data and make assumptions of what is needed to solve the problem.

3.2.4. Fourth Principle

Futhermore, the fourth principle is a logical-mathematical solution and a visible interpretation with one/more solutions and allows students to draw conclusions from the problem. To make the fourth principle fulfilled, the problem of mathematical modelling is designing in the form of *open-ended.* In the fourth principle modelling there are steps such as *Mathematizing and Working Mathematically*, which consists of questions in Figure 7

c. Berapa banyak bahan yang digunakan untuk membuat 12 talam gandus ?

Banyak porsi yang akan dibuat	Tepung Beras	Santan	Air	Ebi Kering
1				
2				

d. Apa yang membuat perhitungan pada setiap bahan makanan yang akan digunakan berbeda ?

e. Buatlah perhitungan yang telah dilakukan ke dalam untuk ke dalam bentuk matematika (rumus matematika)

$$Bahan\ Baru = \frac{Bahan\ Awal}{30} \times Banyak\ porsi\ yang\ akan\ dibuat$$

Figure 7 Sub-question in the Fourth Principle Containing *Mathematising and* Working *Mathematically Steps*

To be able to answer the question in Figure 7, students have to solve the problem mathematically. After that, the student creates/designs mathematical modelling of the calculation steps done before.

3.2.5. Fifth Principle

Futhermore, in the fifth principle, an evaluation procedure makes it possible to check the mathematical accuracy and suitability of the solution contextually. Fulfilled or not, a mathematical modelling problem toward the fifth principle can be adjusted to the criteria, such as 1) There is a procedure of examining the solution obtained, and 2) The solution of the problem has a relationship with the real world students.

In the mathematical modelling step, the fifth principle corresponds to the steps of *Interpreting and Validating*. Which is in interpreting step students generalize the mathematics results that obtained into a real-world context, it means that when calculating process students get a measure of water use as much as 133.3 ml then the size of the water is not real/appropriate, so the result needs to be adjusted / generalized to be 140 ml to make it more appropriates with the real-world context. Then for the *Validating step*, there is a question given such as in Figure 8

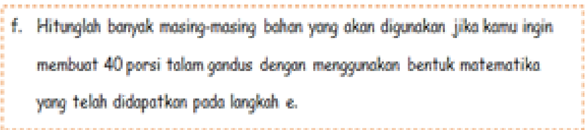
f. Hitunglah banyak masing-masing bahan yang akan digunakan jika kamu ingin membuat 40 porsi talam gandus dengan menggunakan bentuk matematika yang telah didapatkan pada langkah e.

Figure 8 Validation Step Questions

At the working stage of Question Picture 8, students no longer need to search using tables. Students can directly use the mathematical model found in the previous step.

3.2.6. Didactic Principle

The principle of didacticism is the last principle based on the principle in designing the problem of mathematical modelling in the form of problems that can be structured into sequential questions by maintaining the integrity of the real situation (it could be given as guiandce for teachers). In this design, the principle of didacticism is applied in compiling questions in sequence and structured so the students can solve each problem on each question properly, and they can find solutions from the initial questions given to the problem, and those questions are adjusted by following the steps of mathematical modelling.

4. CONCLUSIONS

Based on the preliminary design results at the preliminary stage produced students' worksheet in the form of a visual wod problem it is based on mathematical modelling that already meets the criteria or standards of designing the problem of mathematical modelling, using the principles and criteria of the mathematical modelling problem.

REFERENCES

[1] Kemendikbud, Buku Guru Matematika, Jakarta : Kemendikbud, 2017

[2] IEA, TIMSS 2015 International Results in Mathematics, US : TIMSS & PIRLS International Study Center, 2015

[3] E. Susanti, Pengembangan Soal Matematika Tipe TIMSS Menggunakan Konteks Rumah Adat untuk Siswa Sekolah Menengah Pertama, J. Pend. Mat Unsri, vol. 10, 2016, pp. 1-22. DOI : 10.22342

[4] B. Greer, Modelling reality in mathematics classrooms: The case of word problems, Learn and Instr, vol. 7, 1997, pp. 293-307. DOI : 10.1016/S0959-4752(97)00006-6

[5] L. Verschaffel, E.D. Corte, H. Vierstraete, Upper Elementary School Pupils' Difficultes in Modeling and Solving Nonstandard Additive Word Problem Involvng Ordinal Number, J Res Math Educ, vol. 3, 1999, pp.265-285. DOI : 10.2307/749836

[6] P. Phonapichat, S. Wongwanich, S. Sujiva, An Analysis of Elementary School Students' Difficulties in Mathematical Problem Solving. Procedia—Social and Behavioral Sciences, Procedia Soc Behav Sci, vol. 116, 2014, pp. 3169-3174. DOI : http://dx.doi.org/10.1016/j.sbspro.2014.01.728

[7] K. Hoogland, B. Pepin, A. Bakker, J. de Koning, K. Gravemeijer, Representing Contextual Mathematical Problem in Decriptive or Depictive Form : Desgn of an Instrument and Validation of Its Uses, Stud. Educ. Evaluation, vol. 50, 2016, pp. 22-32 DOI : 10.1016/j.stueduc.2016.06.005

[8] K. Hoogland, J. de Koning, A. Bakker, B. E. U. Pepin, K. Gravemeijer. Changing Representation in Contextual Mathematical Problem from Descriptive to Depictie : The Effect on Students' Performance, Stud. Educ. Evaluation, vol. 58, 2018, pp. 122-131. DOI : 10.1016/j.stueduc.2018.06.004

[9] K. Gravemeijer, M. Stephan, Emergent models as an instructional design heuristic. In K. Gravemeijer, R. Lehrer, B. Oers, & L. Verschaffel (Eds.), Symbolizing, modeling and tool use in mathematics education, Netherlands: Springer, 2002

[10] R. Lesh, H. Doerr, Foundations of a models and modeling perspective on mathematics teaching, learning, and problem solving, New Jersey : Lawrence Erlbaum, 2003

[11] I. P. S. Yoga, Pengaruh Pembelajaran Matematika Modelling terhadap Kemampuan Memahami Soal Cerita Siswa Sekolah Menengah Pertama Negeri 1 Palembang, Inderalaya: Universitas Sriwijaya, 2018

[12] M. D. Saputra, Pengaruh Pembelajaran Matematika Modelling terhadap Kemampuan Memahami Soal Cerita Siswa Kelas XI SMA YPI Tunas Bangsa

Palembang, Inderalaya: Universitas Sriwijaya, 2018

[13] Lusiana, Pemecahan Masalah Melalui Pemodelan Matematika dalam Aplikasi Kalkulus Integral, Prosiding NaCoME 2019, vol. 1, 2019, pp. 1-9

[14] M.R. Novriani, E. Surya, Analysis of Student Difficulties in Mathematical Problem Solving Ability at MTs SWASTA IRA Medan, Int. J. Sci, vol. 33, 2017, pp. 63-76. DOI : 10.18483/ijSci.2407

[15] S. Gooding, Children's Difficulties with Mathematical Word Problems, Proceedings of the British Society for Research into Learning Mathematics, vol. 29, 2009, pp. 31-36

[16] M. Tessmer, Planning and conducting Formative Evaluations, London: Kogan Page, 1993

[17] Zulkardi, Formative evaluation: what, why, when, and how, 2006, [Online] : https://www.oocities.org/zulkardi/books.html

[18] C. Paolucci, H. Wessels, An Examination of Preservice Teachers' Capacity to Create Mathematical Modeling Problem for Children, Journal of Teacher Education, vol. 68, 2017, pp. 330-334. DOI : 10.1177/0022487117697636

[19] W. Blum, M. Niss, The Learning and Teaching of Mathematical Modelling, New York : British Library, 2020