UJME 9 (2) 2020: 121-128
UNNES JOURNAL OF MATHEMATICS EDUCATION
https://journal.unnes.ac.id/sju/index.php/ujme/
ISSN: 2252-6927 (print); 2460-5840 (online)

Developing Problem Based Learning supplemental materials to increase 7th graders higher-order thinking skills

Sausallina Widad Miftiani[a,*], Rochmad[a], Muhammad Kharis[a]

Department of Mathematics, Universitas Negeri Semarang, Sekarang, Gunungpati, Semarang, 50229 Indonesia

* *E-mail address: sausallina@students.unnes.ac.id*

ARTICLE INFO

Article history:
Received 23 September 2019
Received in revised form 15 November 2019
Accepted 20 April 2020

Keywords:
HOTS;
Problem Based Learning;
supplemental materials

Abstract

The study developed Problem Based Learning supplemental materials and aimed to (1) determine the characteristics of the supplemental materials, (2) determine the validity and readability of the supplemental materials, and (3) analyze the increase of Higher Order Thinking Skills after using the supplemental materials in the classroom. The method used in this research is research and development with 3D models (define, design, and develop). The increase of Higher Order Thinking Skills was analyzed by comparing the learning outcomes of the class that used the supplemental materials and class that used the default materials provided by schools. The population in this study were six classes of 7^{th} grade of a Junior High School in Ungaran. The samples were selected by a random sampling technique to find a class for the experimental class and another class as a control class. Data were analyzed using a t-test and gain test. The study concluded that using Problem Based Learning supplemental material increased the Higher Order Thinking Skills of students.

© 2020 Published by Department of Mathematics, Universitas Negeri Semarang

1. Introduction

The results of the 2015 Program for International Student Assessment (PISA) survey of Indonesian students by the Organization for Economic Co-operation and Development (OECD) in Mathematics showed that Indonesia was ranked 65 out of 72 countries, meaning that Indonesia was still below the average International and most Indonesian students have not yet reached a satisfactory level of high-level thinking especially in solving mathematics problems. The National Council of Teachers of Mathematics (NCTM) in 2000 asserted that problem-solving is the essence of the mathematical process. Some researchers in education place problem solving as one of the important objects of their research for various reasons, including because problem-solving is one aspect of ability that is included in the category of higher-order thinking aspects or higher-order thinking (Murtiwi, 2015).

Facts on the field that teachers still do not use problem-solving as a target in learning mathematics, students often do not understand the true meaning of a problem, students only learn the mechanistic procedures needed to solve the problem. Therefore this study aims to: (1) knowing the characteristics of problem-based teaching material supplements, (2) analyzing the level of validity of problem-based mathematics teaching materials in growing Higher Order Thinking Skills (HOTS), (3) analyzing the improvement of HOTS in students after using problem-based mathematics teaching materials.

There are many learning models that are used by teachers and researchers to improve problem-solving competencies, one of which is the problem-based learning approach or Problem-Based learning (PBL). According to Ibrahim & Nur (2002), PBL is learning that presents problems, which are then used to stimulate high-level thinking that is problem-oriented, and includes learning how to learn. To implement PBL, teachers need to choose learning material that has a problem that can be solved (Rajagukguk & Simanjuntak, 2013).

To cite this article:
Miftiani, S. W., Rochmad, & Kharis, M. (2020). Developing Problem Based Learning supplemental materials to increase 7th graders higher-order thinking skills. *Unnes Journal of Mathematics Education*, *9*(2), 121-128. doi: 10.15294/ujme.v9i2.40543

According to the Learning and Teaching Support Network (2001), problem-based textbooks are a form of textbooks that prioritize problems as a context and driving force for students to learn. With problem-based textbooks, students will have high learning motivation, form a deep understanding of each lesson, and increase skills in cognitive aspects, problem-solving, group collaboration, communication, and critical thinking. Meanwhile, according to Ying in Rahmadani, Harahap, & Hasruddin (2016), problem-based textbooks adopt the main ideas in problem-based learning or commonly known as PBL.

The problem-based learning model has five phases in its implementation. The five phases are 1) giving orientation to problems to students, 2) organizing students to learn, 3) guiding individual and group investigations, 4) developing and presenting work, and 5) analyzing and evaluating problem-solving processes.

HOTS involves analyzing, evaluating, and creating. In other words, the ability of HOTS involves three parts of the revised Bloom's taxonomy (Anderson & Kratwohl, 2001). The revision of Bloom’s taxonomy can be seen in Table 1.

Table 1. Bloom’s Taxonomy Revision

Bloom’s Taxonomy (1956)	Anderson and Krathwohl (2001)
Knowledge	Knowing
Comprehension	Understanding
Application	Applying
Analyze	Analyzing
Synthesis	Evaluating
Evaluate	Creating

(Anderson & Krathwohl, 2001)

Bloom describes the level of cognitive processes from the simplest to the complex level, known as the level of cognitive skills. Level categorization is arranged into six levels, namely knowledge, comprehension, application, analysis, synthesis, and evaluation. The level was then revised by Bloom's students (Lorin Anderson et al.) to remembering, understanding, applying, analyzing, evaluating, and creating, also known as C1 through C6. While HOTS is the top three levels, namely C4, C5, and C6.

Learning steps that can trigger students to think at a higher level are given by Given in Pratini & Widyaningsih (2018), including 1) writing learning objectives to be achieved today (emotional learning), 2) doing Brain Gym in between learning (physical learning), 3) directing the use of concepts in daily life (emotional learning), 4) discussing problems in modules (cognitive learning, social learning, physical learning) and 5) introspection of learning (Reflective Learning). According to Van De Walle in Hidayati (2017), research in mathematics education has found that understanding and skills are best developed when students are allowed to grapple with new ideas, make and maintain problem-solving and participate in the community of mathematics students. Therefore, in the process of learning mathematics, students must be encouraged to be active, and the teacher must have the potential to lure students so that their curiosity becomes high and develop their own understanding.

2. Method

2.1. Define

The initial stage is the definition; the goal is to set goals and define the requirements needed in learning. After the conditions are determined and defined, then proceed to the next stage, namely the design and development of teaching materials.

2.2. Design

The design phase is carried out curriculum analysis to learn the curriculum used in learning as well as to develop and compile indicators tailored to the teacher's program in teaching as well as strategies to improve higher-order thinking skills.

2.3. Development

The development of this study consisted of planning and compiling problem-based teaching material scenarios to improve higher-order thinking skills.

2.4. Trial Phase

This trial phase consists of a test of the validity of teaching materials and a readability test. The validity test was conducted by three mathematics teachers. The validity test aims to determine the level of validity, so that information obtained by teaching materials is valid or not used as teaching materials in the learning process. The next trial is a readability test conducted by ten students in the form of a hiatus test, which aims to find teaching material easily to be understood or not.

After the teaching material has been revised based on previous trials taking into account the inputs, available teaching materials are ready to be used as teaching materials in the learning process. The next trial is in the learning process in class. The trial design used was Pretest-Posttest Design. Design patterns, as in Figure 1.

Eksperiment Class	:	$\mathbf{O_1}$ **X** $\mathbf{O_2}$
Control Class	:	$\mathbf{O_1}$ **Y** $\mathbf{O_2}$

Figure 1. Pretest-Posttest Design (Sugiyono, 2010)

In the pretest-posttest design X design is a treatment given to the experimental class in the form of the use of problem-based teaching material in the PBL model, O1 is the pre-test value before being given treatment, while O2 is the post-value test after treatment. At the same time, Y is the treatment given to the control class in the form of the Discovery Learning (DL) model and uses teaching materials that are commonly used in schools. The Control class took randomly from five classes in school without considering average score as a compartment in measuring the increase of average score or increasing of HOTS.

Data analysis in this study conducted a test of the validity of teaching materials, test readability of teaching materials, analyzing of HOTS of students, and an analysis of the improvement of analysis of higher-order thinking skills of students. The validation results from the experts are used to find out the feasibility of problem-based Mathematics teaching materials with Comparison. The level of validity can be calculated by finding a percentage. Criteria for the level of validity of teaching materials, according to Akbar (2013), can be seen in Table 2.

Table 2. Validity Criteria

Score Interval (%)	**Criteria**
$85{,}00\ \% < P \leq 100{,}00\ \%$	valid
$70{,}00\ \% < P \leq 85{,}00\ \%$	valid enough
$50{,}00\ \% < P \leq 70{,}00\ \%$	less of valid
$01{,}00\ \% < P \leq 50{,}00\ \%$	do not valid

The final results of the readability of teaching materials in the form of scores, then compared with the Bormuth criteria as quoted by Widodo (1995), are as follows in Table 3.

Table 3. Readability Criteria

Score Interval	**Criteria**
Score > 60%	teaching materials are easy to be understood
41% $\leq$ score of $\leq$ 60%	teaching materials have met the readability requirements
score $\leq$ 40%	teaching materials are difficult to be understood.

Krathwol in Lewy et al. (2009) stated that indicators for measuring higher-order thinking skills consist of analyzing, evaluating, and creating. Analyzing, which are (1) analyzing incoming information and divide or structure information into smaller sections to identify patterns or relationships, (2) able to recognize and distinguish the causes and consequences of complex scenarios, and (3) identifying/ formulating statements. Evaluating which are (1) providing an assessment of solutions, ideas, and methodologies using suitable criteria or existing suitable standards to ascertain the value of their effectiveness or benefits, making a hypothesis, criticizing or testing, and (2) accepting or rejecting a statement based on predetermined criteria. Creating which are (1) generalizing an idea or perspective on something, and (2) designing a way to solve the problem.

The three indicators are the determination of the thinking aspects of the problem-solving items. Then the determination of the level criteria aspects of high-level thinking students refer to research that has been done by Lewy et al. (2009) can be seen in Table 4.

Table 4. Higher Order Thinking Skills Level

Students score (%)	Higher Order Thinking Skills Students Level
76-100	Excellent
51-75	Good
26-50	Enough
1-25	Poor

The statistic hypothesis proposed in this study is 1) Student learning outcomes in classes using PBL models assisted by problem-based teaching material supplements meet the minimum mastery criteria in Indonesian called Kriteria Ketuntasan Minimal (KKM) is 80, 2) The proportion of students in the class using the PBL supplemented with problem-based teaching material supplements that meet the minimum KKM as much as 75%, and 3) Increasing student learning outcomes in classrooms using PBL models assisted with problem-based teaching material supplements is greater than the increase in learning outcomes in classes that use discovery learning and books used by schools.

Based on the hypothesis, the test used is the left side t-test, z test, and the right side t-test. The data used for this test is increasing in the value (difference) pre-test and post-test. Analysis of the increase in HOTS also uses a gain test. The gain test is used to find out the increase in the high-level thinking skills of students before being given treatment and after getting treatment. According to Hake, as quoted by Savinainen (2004: 60), the normalized average gain formula is as follows: $\langle g \rangle = \frac{\langle S_{post} \rangle - \langle S_{pre} \rangle}{100\% - \langle S_{pre} \rangle}$.

3. Results & Discussions

The development of teaching materials was passed through the stages of the planning stage (curriculum analysis) then the next stage of development (teaching material scenarios and the preparation of teaching materials) then the testing phase consisting of validity tests conducted by the supervisor, small scale test by ten students and three teachers namely two Mathematics teachers at Junior High School of 1 Ungaran and one Mathematics teacher at IT Bina Amal Semarang High School, and a large-scale test using teaching materials in learning at Junior High School of 1 Ungaran.

This research was held at Junior High School of 1 Ungaran, Semarang district. The sample selection uses a random sampling technique by selecting students' classes, so the chosen study sample is 7A and 7H classes. The problem on the test consists of levels C3, C4, C5, and C6. Teaching and learning activities are carried out during four meetings and two meetings for pre-test and post-test.

Characteristics of teaching materials developed are the presentation of mathematics learning that begins with learning everyday problems (contextual problems) that can be supported by students then only discuss the problems being studied and find the concept of the material. The features of the teaching material are discussion, considering, asking questions, student activities, and practice questions. This teaching material enhances HOTS so that it includes HOTS type questions in the examples and exercises discussing students about the questions. So, the characteristics of this teaching material are started by introducing daily problems with some HOTS type problems and supported by HOTS type practice questions.

The results of the assessment of the appropriateness of instructional materials were also obtained input from the validators to improve teaching materials developed by researchers. Among the inputs are to increase the number of HOTS type assessments in teaching materials so that students are accustomed to solving the type problems, and there are ineffective sentences in several sentences. The results of the validity of problem-based mathematics teaching materials to increase HOTS are shown in Table 5.

Table 5. Validity Results of Problem Based Mathematics Teaching Materials

No	Validator	Percentage of Validity			
		Content (%)	Presentation (%)	Language (%)	Graphic (%)
1.	GR-01	84	90	84	90
2.	GR-02	92	98	92	93
3.	GR-03	84	92	84	87
Total		260	280	260	270
Average		86.67	93.33	86.67	90
Criteria		very valid	very valid	very valid	very valid
Average of Total Validity				89.07	
Criteria				very valid	

Assessment of the readability of teaching materials through the test method is a gap test with test subjects, namely ten grade VII students. The mortar test question consists of 45 items totaling eight pages. The number of pages is taken from 20% of the number of pages of teaching material that contains material. The results of reading Mathematics teaching materials based on Comparison material problems are included in the category of teaching materials easily understood because the average percentage obtained is 81.78%, which means the teaching materials are easily understood according to Bormuth criteria as quoted by Widodo (1995). When students are asked to solve problems in teaching materials with comparative material, students have no difficulty in understanding the questions given. The increase of HOTS shown in the difference between pre-test and post-test can be seen in Table 6.

Table 6. The difference between Pre-test and Post-test

Source of Variation	Class	
	Control	Eksperiment
Total	188.86	791.17
N	30	30
$\bar{x}$ (average of the difference of score test)	6.295	26.372
Variants (s^2)	139.617	253.088
Deviation Standard (s)	11.816	15.909

From the analysis that has been calculated using one-party t-test obtained t_{count} = 3.611 while known value of $t_{(0,95)(58)}$ = 1.671 with α = 0.05 and dk = 58. The conclusion is that the data shows the value of $t_{count} > t_{table}$ so that Ho is rejected and Ha is accepted, meaning that the increase in the average value of the experimental class test is greater than the increase in the average increase in the control class test value.

Based on the results of the gain test analysis, obtained g control class of 0.27, which belongs to the low category, while g for the experimental class is 0.59, which belongs to the medium category. This means that the high-level thinking ability of control class students has increased by 27%, and the experimental class has increased by 59%. Thus supplementing mathematics teaching materials based on problem comparison material can increase HOTS of students with moderate improvement categories.

The product developed by the researcher is a problem-based Mathematics teaching material comparative material that has a presentation concept that provides characteristics that indicate the problem-based teaching material. This teaching material prioritizes the existence of problems as an orientation to problems, problem analysis that guides in conducting investigations to gain knowledge. The features "Let's

Practice" and "Competency Test" to train students to solve problems and, of course, train students' higher-order thinking skills. Other features in this teaching material are "Let's Observe", "Let's Discuss".

The "Let's Observe" feature is one of the main features in teaching materials that are oriented to problems that are close to daily life to guide students to find the concept of material. In addition, the feature also presents illustrations that are intended for each problem example. According to Saragih & Napitupulu (2015), teachers are more expected to create and cause problems (learning material) that are very close to the daily lives of students. It will support and encourage students to be more involved individually or in groups in the teaching and learning process, especially in observing, investigating, and drawing conclusions from the data provided, or making hypotheses.

Teaching materials are very valid, with an average of 89.07. Even though overall, it shows a good assessment of the teaching material being developed, the inputs or suggestions from the validator are still heeded and then revised by the researcher to improve the quality of the teaching material. The following are revisions made by researchers in accordance with the input of the validator; one of the inputs is adding HOTS questions, so students are familiar with the typical questions. As stated by Thomas and Thorne in Widodo & Kadarwati (2013) states that HOTS can be learned, can be taught to students, and there are differences in learning outcomes that tend to memorize and HOTS learning that uses higher-order thinking.

Good teaching materials are teaching materials that pay attention to the level of understanding of the reader and age so that the reader can understand the contents of the material presented. As stated by Ayodele & Olagoke (2012) that the text material to be delivered to students must be adjusted to the level of understanding of the reader and their age to facilitate understanding. Therefore, teaching materials aimed at junior high school students must meet the level of understanding of junior high school level readers. This also influences the students' interest in reading teaching material. This problem-based teaching material is categorized as easy to understand, with an average score of 81.78.

Learning outcomes in this study are individual completeness and classical completeness in the experimental class. The KKM of Junior High School of 1 Ungaran is 80, and the proportion of KKM classically is a minimum of 75%. In the individual completeness test obtained data that has been tested concluded that students have met the KKM. This is based on the calculation and verification of existing hypotheses. Likewise, the classical completeness test shows that grade 7A meets the KKM.

Students' higher-order thinking skills are analyzed according to the results of pre-test and post-test on items with the ability to think at a higher level. In the control class, each aspect of thinking does not have a change in criteria, but only the nominal percentage tends to increase, but not too significantly. This control class also has a score with very good criteria in two aspects of higher-level thinking, namely analyzing and evaluating. The aspects of creating at the beginning of the test are included in both criteria, with a score of 58.34. The final test was not far from the previous results, and two aspects of thinking remained on the criteria very well, and the aspect of thinking also created remained on the criteria well, but the percentage increased to 67. The control class already had a mature preparation before the researchers entered the class. The material taught by researchers has been taught before, and this control class is among the most superior classes among all seventh grades in SMP Negeri 1 Ungaran.

While in the experimental class, each aspect of thinking had a change in criteria bigger than the initial test and, of course, nominally increased. Like the control class, the experimental class had already previously received comparative material by their teacher. However, this class is equipped to solve problems that tend to be minimal based on the pre-test scores. So it can be concluded that overall the initial test and final test with the results obtained in the control class criteria are higher than the experimental class.

In this study, an increase in students' problem-solving abilities is done by comparing the increase in the average test between the control class and the experimental class. The control class is a class that uses teaching materials used in schools, while the experimental class is a class that uses Mathematics Problem Based Teaching Material Supplements in Comparative Material.

The increase in HOTS data is taken from the pre-test and post-test values , which are then calculated to increase both the control class and the experimental class. The learning strategies and methods used during the learning process in the control class and the experimental class are the same, namely questions and answers, lectures, and discussions, which distinguishes only the types of Mathematics teaching materials used.

The increasing score in classes using problem-based math teaching supplements is higher than in classes not using. The teaching material lists the orientation of the type of HOTS problem. As stated by Wicasari

& Ernaningsih (2016) that habituation provides HOTS-oriented problems can improve students' high-level thinking skills where if previously only came to remembering or a little understanding because it was too dependent on the formula then with this new habituation, it is expected that students are able reached the creating stage.

The Gain test showed that the control class has a gain of 0.27, which belongs to the low category, and the experimental class has a gain of 0.59, which belongs to the medium category. Although the experimental class did not belong to the high category, the improvement was still bigger than the control class. The use of teaching materials has an effect on the habit of students solving problems on HOTS type questions. Therefore, most students in the experimental class are able to have a bigger improvement than the control class.

4. Conclusion

The development of problem-based Mathematics teaching material supplements has the characteristics of problem-based teaching material that is prioritizing the problem as an orientation to the problem that is a problem that is close to life (contextual problem), which aims to guide students in conducting investigations to gain knowledge. Some problem orientation sections list problems of type HOTS. The results of the validity test showed that the teaching materials developed were included in the very valid category, with the acquisition of an average percentage of the validity of 89.07%. While the readability level of teaching materials developed is classified as teaching materials that are easily understood with an average percentage of readability of 81.78%. An increase in HOTS after treatment using problem-based teaching materials this can be seen from the results of the experimental class tests that have an increase in the average test. The experimental class also gained a gain of 0.59, which was included in the medium category, while the control class gained an increase of 0.27, which was included in the low category.

References

Akbar, S. (2013). *Instrumen Perangkat Pembelajaran* (Learning Instrument). Bandung: PT Remaja Rosdakarya.

Anderson, L.W., & Krathwohl, D.R. (2001). *A Taxonomy for Learning, Teaching, and Assessing; A revision of Bloom's Taxonomy of Education Objectives*. New York: Addison Wesley Lonman Inc.

Ayodele & Olagoke, M. (2012). Readability of Basic Science and Technology Textbooks for Primary Schools. *Research Journal in Organizational Psychology and Educational Studies*, 1(1): 33-36.

Hidayati, A. U. (2017). Melatih Keterampilan Berpikir Tingkat dalam Pembelajaran Matematika pada Siswa Sekolah Dasar (Training Thinking Skills in Mathematics Learning on Elementary Students). *Terampil Jurnal Pendidikan Dan Pembelajaran Dasar*, *4*(20), 143–156.

Ibrahim, M. & Nur, M. (2002). *Pengajaran Berdasarkan Masalah* (Teaching Problem Based). Surabaya: Unesa University Press.

Learning and Teaching Support Network (LTSN). (2001). *Problem-Based Learning: An Introduction.* Primer 4, Version 1.

Lewy, Zulkardi, & Aisyah, N. (2009). Pengembangan Soal untuk Mengukur Kemampuan Berpikir Tingkat Tinggi Pokok Bahasan Barisan dan Deret Bilangan di Kelas IX Akselerasi SMP Xaverius Maria Palembang (Developing Assessment to Measure Higher Order Thinking Skills on Sequence and Series in 9th Grade Acceleration Students of Xaverius Maria Palembang JHS). *JURNAL Pendidikan Matematika* (3) : 15-28.

Murtiwi, W. (2015). Bahan Ajar Berbasis Masalah Untuk Meningkatkan Kompetensi Penyelesaian Masalah Matematis Siswa SMP (Teaching Materials Problem Based to Increase Problem Solving Competence). *FKIP Universitas Tanjungpura*, 1(2), 1–17.

Pratini, H. S., & Widyaningsih, R. (2018). Keterampilan Berpikir Tingkat Tinggi Calon Guru Matematika Dan Upaya Untuk Menstimulasinya (Higher Order Thinking Skills Mathematics Teacher Candidates and Its Effort to Stimulate). *Prosiding Seminar Nasional FKIP 2018*, *1*(1), 181–189.

Rahmadani, S., Harahap, F., & Hasruddin. (2016). Pengembangan Bahan Ajar Mikrobiologi Pangan Berbasis Masalah (Developing Food Microbiology Problem Based Teaching Materials). *Jurnal Pendidikan Biologi,* 5(3), 187–192.

Rajagukguk, W., & Simanjuntak, E. (2013). Pengembangan Bahan Ajar Matematika Berbasis Kemampuan Berpikir Kritis (Developing Critical Thinking Based Mathematics Teaching Materials) . *Penelitian Bidang Pendidikan*, 19(2), 105–111.

Saragih, S., & Napitupulu, E. (2015). Developing Student-Centered Learning Model To Improve High Order Mathematical Thinking Ability. *International Education Studies*, *8*(6).

Savinainen, A. (2004). *High School Students Conceptual Coherence of Qualitative Knowledge in the Case of the Force Concept.* Dissertation. The University of Joensuu.

Sugiyono. (2010). *Metode Penelitian Pendidikan : Pendekatan Kuantitatif, Kualitatif dan R & D* (Education Research Methods: Quantitative, Qualitative and R&D Approaches). Bandung: Alfabeta.

Wicasari, B., & Ernaningsih, Z. (2016). Analisis Kemampuan Berpikir Siswa Dalam Menyelesaikan Permasalahan Matematika yang Berorientasi pada *HOTS* (Analysis of Thinking Ability of Students in Solving Mathematics HOTS Problem Oriented. *Prosiding Seminar Nasional Reforming Pedagogy 2016*, 1(1), 249-254.

Widodo, A.T. (1995). *Modifikasi Teks Rumpang untuk Bahan Ajar MIPA* (Modification of Hiatus Text for Mathematics an Natural Science Teaching Materials. Kampus Bendan Ngisor: Lembaga Penelitian IKIP Semarang.

Widodo, T., & Kadarwati, S. (2013). Higher Order Thinking Berbasis Pemecahan Masalah untuk Meningkatkan Hasil Belajar Berorientasi Pembentukan Karakter Siswa (Higher Order Thinking Skills Problem Solving Based to Increase Students Character Oriented Study Result. *Jurnal Cakrawala Pendidikan*, *5*(1), 161–171.