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The Development of Project-Based Learning Method to Increase Students' HOTS in Mathematics

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ABSTRACT

The highest level of the cognitive process hierarchy is Higher-Order Thinking Skill (HOTS). HOTS allows students to solve challenges, but time for processing is limited. Based on the findings in the field, many students do not have the skills related to HOTS. Based on these findings, developing a learning model that can increase HOTS in students is necessary. One of the learning models that can improve HOTS is the project-based learning model (PjBL). This study aimed to produce a project-based learning model for improving HOTS. This type of research is on developing a 4-D model developed by Thiagarajan, Semmel, and Semmel with modifications. The subject of this research is a project-based learning model. The instruments used were a needs analysis sheet, material analysis and PjBL model validation sheets. Methods of data collection by observation, questionnaires and interviews. The research results show that the project-based learning model has met the valid criteria for increasing HOTS.

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1. INTRODUCTION

Thinking abilities are closely related to a person's ability to use cognitive and affective abilities. These abilities include the ability to obtain or provide information, solve problems, and make decisions for a variety of active activities (Yee et al. 2015) (Yustina, Syafii, and Vebrianto 2020) (Zhao, He, and Su 2021) (Purnomo et al. 2022). Thinking skills combine cognitive processes and the ability to complete a given task. Thinking skills consist of critical thinking skills, creative thinking skills and problem-solving thinking skills. These three thinking skills are known as higher-order thinking skills or HOTS (Saraswati and Agustika 2020) (Pratiwi, Dewi, and Paramartha 2019) (Faridah and Artono 2019). HOTS occurs when a person acquires new information, keeps it in memory and organizes it, relates it to existing knowledge, and generates it to achieve a goal or solve a complex situation. (Fleury et al. 2020).

Based on the results of research studies, many students do not have HOTS abilities. This makes it difficult for students to solve problems. The difficulties felt by students when completing mathematics

are the lack of understanding of the problems posed and the inability to use the correct strategies. This is because students are not used to solving problems during the problem-solving stage (Schoenfeld 2016) (Zakaria and Salleh 2015) (Ayebo, Ukkelberg, and Assuah 2017). So that in, solving the problem is not optimal, which causes difficulties in solving HOTS questions (Karimah, Kusmayadi, and Pramudya 2018), (Abdullah, Abidin, and Ali 2015), (Susanto and Retnawati 2016). Problem solving ability is still low (Hidayat and Irawan 2017) (Kusuma et al. 2017) (Yeni, Wahyudin, and Herman 2020) (Amir 2015). Problem-solving with HOTS category with Analyzing, Evaluating, and Creating (Anderson et al. 2001)(Wilson 2016). Students need HOTS ability in studying Mathematics subject.

Mathematics subject (PDGK4108) is a compulsory subject that must be taken by students of the Elementary School Education Department (PGSD) department. This subject covers mathematical logic concepts, mathematical reasoning and systems, linear and quadratic equations and inequalities, sets of relations and functions, opportunity, social arithmetic, introduction to statistics I and II, problem solution, transformation and congruence and similarity (Sukirman et al., 2012). Based on observations and interviews, many students have difficulty in studying this Mathematics course. Students' abilities are still in the category of low-level thinking skills. Based on that, it is necessary to develop a learning model to increase student HOTS.

One of the learning models developed to improve HOTS is the PjBL learning model. (Yulianti, Hartono, and Santoso 2015)(Hayati, Utaya, and Astina 2016)(Fitri, Dasna, and Suharjo 2018) (Rini and Cholifah 2020). PjBL is an innovative learning model or approach which emphasizes contextual learning through complex activities (Rethusa, Lusa, and Hasnawati 2020)(Maros et al. 2021) related to real-life (Yulianti et al. 2015) and provides opportunities for students to work independently (Anggi Permana Putra dan Ismet Basuki 2018) and work with the team (Indarti 2016). The PjBL model can connect students' higher-order thinking skills (Hayati et al. 2016), creative thinking (Yustina et al. 2020) improve transferability (Fernández-Samacá, Ramírez, and Orozco-Gutiérrez 2012). Project-based learning has the potential to provide students with a more engaging and meaningful learning experience. (Yulianti et al. 2015) (Maros et al. 2021). Because it incorporates the 4C principles, project-based learning is an excellent model for meeting 21st-century educational goals (Fitri, Dasna, and Suharjo 2018; Dewi, 2022).

The student-centered PjBL method will provide students with a meaningful learning experience through the products created during the project-based learning process. PjBL has the characteristics that students will be faced with concrete problems, find solutions, and work on projects both individually and in teams to overcome these problems. (Jazimah and Septianingsih 2021). Project-based learning methods are used to create a constructivist learning environment in which students will build their knowledge and insights (Gresalfi, Barnes, and Cross, 2016; Dewi 2022). Students are also expected not only to understand the context of the material, but also to cultivate higher-order thinking skills that are used to solve real-life problems (Rusydiana, Nuriman, and Wardoyo 2021; Fitriyah and Ramadani 2021)

PjBL has advantages compared to other learning methods according to (Maspufah et al. 2022) namely 1) Students are encouraged to use their problem-solving abilities in real-world situations, 2) Students can expand their knowledge through group discussions and individual learning activities, 3) scientific activities occur in students through group discussions, 4) individual student difficulties can be overcome through group discussion activities so that solutions can be found to solve the problem. PjBL also has weaknesses or shortcomings including 1) it takes a lot of time to solve problems, 2) students are less active in group discussion activities, 3) if the topics presented to each group are different, students cannot understand the topic as a whole.

Research related to the PjBL method has been carried out by several researchers including: (Pham Duc 2018) with the research title "Project-Based Learning from Theory to EFL Classroom Practice" it was concluded that project-based learning has characteristics as cooperative learning, student-centered, lifelong learning, independent learning and increasing student motivation and creativity in learning. (Ali Mufti 2022) in his research entitled "Project-Based Learning to Improve Higher-Order Thinking

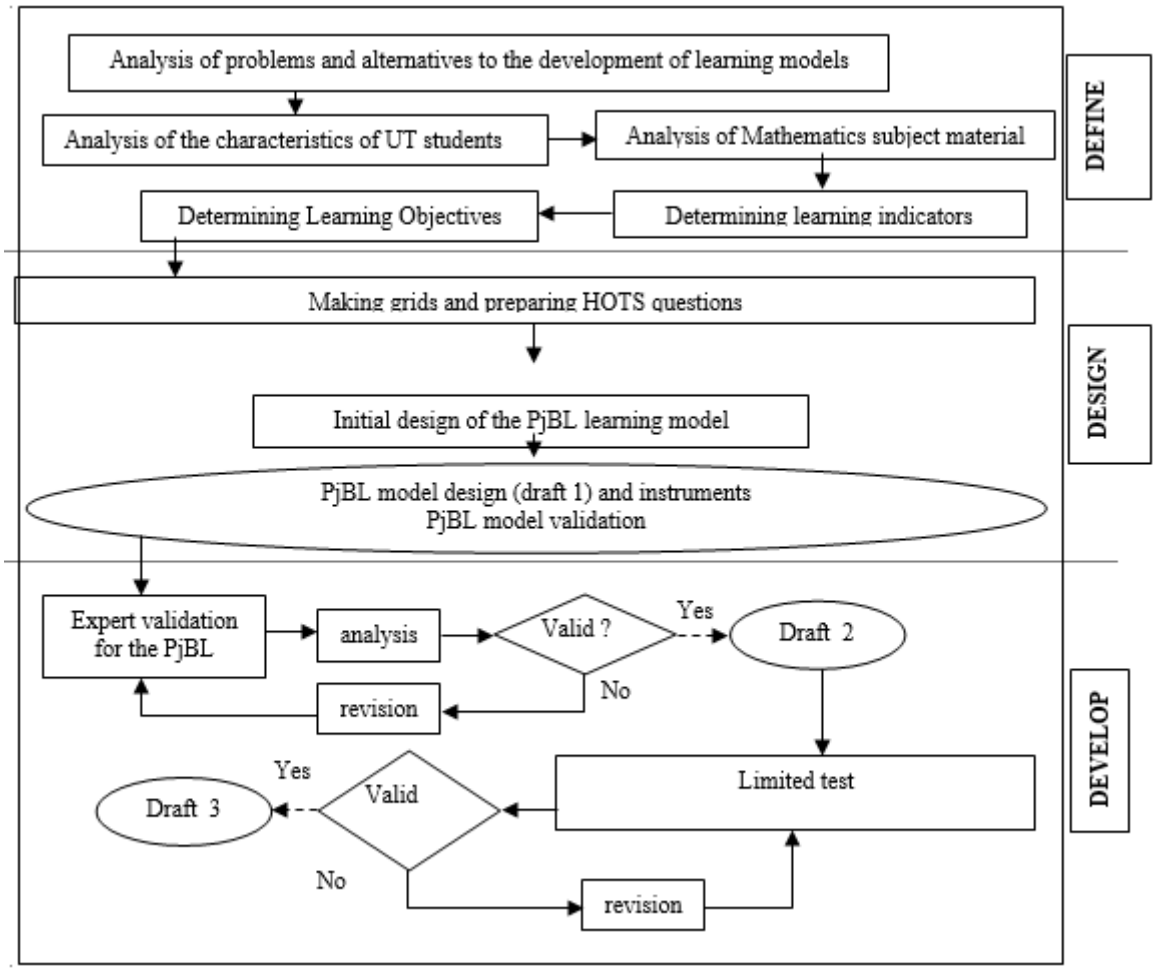
Skills in Arabic Subjects, it can be concluded that project-based learning is the right learning method to achieve the criteria of 21st-century learning and HOTS level learning. (Takiddin, Jalal, and Neolaka 2020) and (Harun 2020) in his research revealed that the application of project-based learning methods can improve students' higher order thinking skills.

Transitioning from traditional learning models to project-based learning necessitates a shift in the fundamental learning approach from lecturer-focused to student-focused (Chu et al. 2017) (Maros et al. 2021). Implementing project-based learning can significantly improve both lecturers' and students' classroom experiences. It has the potential to alter the way lecturers teach, students learn, and lecturers and students interact. Project-based learning has the potential to alter how students respond to common learning processes. Based on the foregoing, this study intends to develop a project-based learning model to improve student HOTS.

2. METHODS

This type of research is research on developing a modified 4-D model developed by Thiagarajan, Semmel, and Semmel. The 4D model was developed considering that this model is programmed with a systematic and structured sequence of activities to solve tutorial problems according to the characteristics of Elementary School Education Department (PGSD). This research consists of stages that can be repeated until a new theory is discovered, which is the result of a revision of the tried learning theory and can change and develop during the learning process, demonstrating that there is an iterative cycle of processes from thought experiments to experiments. Learning (instruction experiment).

The subject of this research is a project-based learning model in Mathematics. The instrument consisted of a needs analysis sheet, material analysis and PjBL model validation sheets. Methods of data collection by observation, questionnaires and interviews. Data processing uses data triangulation, namely observations, questionnaires and interviews (Creswell 2012) (Sukestiyarno 2020). Based on the development results, a project-based learning model for mathematics subjects will be made. The stages of the research can be seen in Picture 1 below.



Picture 1. 4-D Modified PjBL Model Development Steps (modified from Thiagarajan)

All stages in the 4-D development model were done in this study. In the 4th stage, namely, disseminate, there should be three steps that must be carried out: validation tests, packaging and diffusion of adoption, but in this study in the 4th stage, only validation tests were done. Packaging and diffusion of adoption have not been implemented because they will be implemented later. The data obtained on the validation sheet assesses the validator on the PjBL learning model. Validation sheets aim to make it easier for validators to assess learning tools with assessment criteria. Table 1 shows the criteria for the validity of the PjBL learning model.

Table 1. Criteria for the validity of learning tools

Value Range	Information
$1 \leq x < 2$	Invalid (cannot be used yet)
$2 \leq x < 3$	Fairly Valid (can be used with many revisions)
$3 \leq x < 4$	Valid (usable with minor revisions)
$4 \leq x \leq 5$	Very Valid (can be used without revision)

Information: x = PjBL learning model validation scores

3. FINDINGS AND DISCUSSION

During the development stages of the PjBL learning model, a modified 4-D model from Thiagarajan, Semmel, and Semmel is used. The modified development model is divided into three stages: define, design, and development. The stages of developing the PjBL learning model are as follows.

a. Define (definition)

This stage of defining consists of 1). Problem analysis, 2). Analysis of student characteristics, 3). Analysis of Mathematics course material, 4). Determine learning indicators, 5). Determining Learning Objectives. The results of the problem analysis in implementing the Mathematics course tutorial are that many students find it difficult to take Mathematics courses. When students are given HOTS questions, many students cannot do them. In addition, there is a lack of student activity and low motivation to attend lectures. Many students have not studied the material before the lecture occurs. Many students do not understand mathematics lecture material due to limited student learning time. In addition, students only use one learning resource, the module.

Based on the analysis results, a lesson will be designed to cover the existing deficiencies. Through this learning, students are expected to learn correctly and get maximum results. One of these learning alternatives is to apply the PjBL learning model. Students are indirectly asked to work on or complete a project in lectures through this PjBL. The learning model includes not only adequate time but also student activities, cognitive ability development, autonomy, and creativity. Effective teaching is widely regarded as being oriented and focused on students and their learning. Students will be able to develop HOTS skills through this PjBL.

b. Design (planning)

After the definition stage, the next step is designing learning models and learning media. The developed learning model is a project-based learning model with a 4-D development model. Table 2 shows the design of the learning design using the project-based learning model.

Table 2. The stages of the project-based learning model's design

PjBL Stages	Learning Experience	Student Activities
Start with the big questions	Stimulate students' interest in problem-solving in elementary school	Students in elementary school analyze the difficulties of their peers by working on questions in the form of stories.
Drafting plans for projects	Determine and find project designs, namely making a problem-solving-based lesson plan (RPP)	In elementary school, students choose the mathematics subject matter that will be covered in the lesson plan (RPP)
Drafting a solution plan	Develop authentic inquiry skills	Students analyze the stages of problem-solving and are associated with the selected material
Monitor student and project progress	To emerge analytical skills	Designing lesson plans (RPP) for elementary mathematics problem solving
Assess project results	Delivering project results	Students present the outcomes of their lesson plans (RPP).

Evaluating experience project	Develop the ability to analyze project results	Students provide feedback related to the results of the lesson plan (RPP) design Students improve the lesson plan (RPP) as a result of input from other students

The project-based learning model is implemented in six stages, with one of the implementation designs being in problem-solving material. In this design, a project made by students is in the form of a problem-based learning design for elementary mathematics. In the first stage, students were asked to analyze elementary school students' difficulties in working on problems in the form of stories. Through this activity, students are expected to develop thinking skills at the fourth stage in Bloom's taxonomy. This activity is also dos to provide the right solution to the difficulties experienced by students in working on the story form questions.

The second step is that students are asked to determine the material to be made for project assignments. In the third stage, students are asked to analyze and evaluate the stages of problem-solving and are associated with the selected material. This is done to find out at which stage students found problems. In the fourth stage, students were asked to design lesson plans (RPP) based on solving elementary mathematics problems using the PjBL learning model. In the fifth stage, students are asked to present the results of their designs. In the sixth stage, students revise the learning design that a learning device with the PjBL learning model will be produced.

c. Develop (development)

After designing the PjBL learning model, the next step is validation by an expert validator. This is done to determine the level of validity of the PjBL learning model. The expert validator consists of 3 experts: media experts, mathematicians, and evaluation/learning experts. Experts provide assessments and input by revising learning tools with the PjBL learning model. The next step is revising the learning device with the PjBL learning model by taking input from experts. The validation results can be seen in Table 3 below.

Table 3. Results of Expert Validation on the PjBL Learning Model

No.	Validator	Skills/ Expertise	Average Results	Validation
1	Validator 1	Mathematics	3,91	
2	Validator 2	Learning Media	4,05	
3	Validator 3	Evaluation/Learning	4,1	
Average			4,02	
Category			Very Valid (can be used without revision)	

Based on expert validation, it can be seen that mathematicians with a score of 3.91 good categories, media experts with a score of 4.05 very good categories, and evaluation/learning experts with a score of 4.1 very good categories. The average validation results, with a score of 4.02, on the other hand, are extremely valid. Several material-related changes were made during the evaluation. The material emphasizes more on contextual problems and can be implemented in learning. The questions have not fully emphasized the HOTS ability. The material presented still focuses on the ability to understand concepts. The evaluation experts emphasized the pretest and posttest, and evaluation questions did not vary. Changes in the variety of questions will make students more challenged in working on the

questions. Based on these results, the PjBL learning model is valid and can be implemented in learning activities.

PjBL is an innovative learning approach that involves project work and requires students to design, solve problems, make decisions, conduct investigations, and work independently. Students in the Project-based Learning model are faced with concrete problems, must find solutions, and work on projects in groups to overcome these problems. The development of the PjBL learning model can be implemented in learning which can increase student HOTS after validation by expert validators

Validation activities by expert validators complete the design that has been made. Through input from expert validators, the quality of the PjBL learning model will be even better in increasing student HOTS. The valid PjBL model can be applied in the learning process (Yahya, Ummah, and Effendi 2020)(Yuwono and Syaifuddin 2017). The design of project-based learning models and supported by e-module learning media can increase competence (Rethusa et al. 2020), independence (Anggi Permana Putra dan Ismet Basuki 2018), ability to work together (Indarti 2016), critical thinking (Hayati et al. 2016) student HOTS ability (Fitri et al. 2018) (Purnomo, E.A, Suparman, & Kadarwati, 2020).

Student learning experiences in the development of PjBL learning models include students being invited to care about problems in around environment (Indarti 2016) (Fitri et al. 2018) (Maros et al. 2021). This learning model can be used by educators to condition active student-centered learning in which students have a more interesting, active, innovative, creative, independent learning experience and produce work based on real (contextual) problems encountered in everyday life. This project's products are learning designs created by each group. Project-based learning is an extremely effective learning model that promotes the highest level of teacher didactic abilities (Maros et al. 2021). Project-based learning is not only effective, but it also promotes critical thinking and problem solving, interpersonal communication, information and media literacy, collaboration, and leadership (Duchovicova et al. 2018). In this study, project-based learning will be more effective than traditional teaching (Chu et al. 2017)(Duchovicova et al. 2018). Students implementing the PjBL learning model can improve students' HOTS abilities.

The PjBL model learning process requires active students to search independently. In line with Hadi and Ramadhana (2022) and Fitriyah and Ramadani (2021) PjBL can create a good learning environment for students that encourages students to construct knowledge and skills independently. PjBL can connect material in Mathematics courses with real-world contexts, in this case, projects can generate motivation for students to participate in learning activities. The PjBL model requires students to be active in solving problems by initiating an idea that can be generalized into a product as a result of project activities. (Gresalfi et al. 2016; Rusydiana et al. 2021; Fitriyah and Ramadani 2021). In this activity, students can practice their higher-order thinking skills.

The use of PjBL learning methods conducted by Fitriyah and Ramadani (2021) According to his research, using PjBL methods in the learning process can improve creative thinking skills and HOTS. Research conducted (Hadi and Ramadhana 2022) also obtained results, namely the increase in the average score of students who have HOTS abilities after implementing PjBL in the learning process is in the very category. The PjBL model can also improve students' creative thinking skills, this is evidenced by the research conducted by (Mulyana et al. 2022) which leads to the conclusion that there are differences in students' creative thinking abilities before and after treatment, in this case the implementation of the Project Based Learning (PjBL) model. Based on several studies that have been carried out by previous researchers, it can be concluded that the PjBL method is very important and capable of improving students' HOTS abilities needed in everyday life so that PjBL learning methods can be developed by the expected skills.

4. CONCLUSION

The development of the PjBL learning model with an expert validation score of 4.02 was declared very valid (can be used without revision). Through project-based learning designs, this PjBL learning model can be implemented in the learning process. The outcomes of the project-based learning design

are divided into six stages, including starting with big questions, designing plans for projects, drafting completion plans, monitoring students and project progress, assessing project results, and evaluating project experiences.

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