Development of mathematical teaching materials based on project-based learning to improve students’ HOTS and character

S Sofiyan¹, R Amalia¹ and A B Suwardi²
¹Department of Mathematics Education, Universitas Samudra, Kota Langsa, Indonesia
²Department of Biology Education, Universitas Samudra, Kota Langsa, Indonesia
E-mail: rizkiamalia@unsam.ac.id

Abstract. This study aims to develop mathematics teaching materials based on a project-based learning model, that help improve students’ Higher-Order Thinking Skill (HOTS) and character. This type of research is developmental research that adheres to the ADDIE development model, which includes analysis, design, development, implementation, and evaluation. The participants were 25 preservice teachers enrolled at the basic mathematics course in one of university in Aceh, Indonesia. The study results showed that the teaching materials that had been developed were appropriate to use in learning and the feasibility of content, design, and language met the valid criteria. Students’ responses to the teaching materials were very good to support and accomplish lectures. The teaching materials tested were able to improve students’ HOTS, based on the pre-test results with an average score of 67 and the post-test results with an average score of 88. Besides, the average score of student character increased by 20% in the good category and by 16.67% in the very good category. To sum up, the mathematics teaching materials based on the project-based learning model are considered valid, practical, and effective.

1. Introduction
The challenges of higher education in the global era are marked by the development of science and technology which are full of competition. The Faculty of Teacher Training and Education as a unit of higher education also participates in the development of education, especially at schools. Students of mathematics education as teacher candidates are required to master aspects for global demands.

The minimum qualification criteria for graduates include attitudes, knowledge, and skills [1]. The important knowledge and skills that must be possessed by professional mathematics teachers and prospective teachers are essential knowledge, reflection and problem solving, as well as essential skills [2]. Reflection and problem solving are the processes of higher-order thinking skills or known as HOTS.

Higher-order thinking skills (HOTS) is the ability to connect, manipulate, and change the knowledge and experience owned critically and creatively in determining decisions to solve problems in new situations [3]. HOTS requires students to manipulate information and ideas in ways that transform their meaning and implications, such as when students combine facts and ideas to synthesize, generalize, explain, hypothesize, or arrive at some conclusions or interpretations. Manipulating information and ideas through these processes allows students to solve problems and understandings. When students engage in HOTS, an element of uncertainty is introduced, and...
instructional outcomes are not always predictable [4]. The process of manipulating information and ideas enables students to solve problems and improve their understanding.

Today, HOTS is needed by students. Students are required not only to apply what they have learned, but also to analyze, evaluate, and synthesize the knowledge they have gained to solve problems in everyday life [5]. HOTS connects problem findings and creativity through planning activities, self-observation of problem development, and adjusting the problem-solving strategies themselves [6].

In addition to the ability to think at a higher level, students also need to have character values as provisions for social life. Character is defined as a combination of emotional, intellectual, and moral qualities that distinguish a person [7]. Character education covers the cognitive, affective, and behavioural aspects of morality. Good character consists of good knowledge, good desires, and good deeds [8]. Lectures become one of the means of integrating cognitive abilities and strengthening character education. This is in accordance with the function of national education, which aims to develop the potential of students to become human beings who are faithful and pious to God Almighty; who have good morals; who are healthy, knowledgeable, competent, creative, independent; and as citizens, are democratic and responsible [9]. These skills or characters are indeed highly required for individuals to be able to survive in a competitive global era. Students are prepared to have not only skills associated with thinking and reasoning but also personality, integrity and good character. It is easy to understand and be able to imagine what would happen to someone having good knowledge and skills, but not having a good attitude and moral character.

However, based on observations of lectures at the mathematics education department, there is no optimization of HOTS-based learning and character integration. One of them is in a basic mathematics course. Basic mathematics is a course that contains mathematical contents for the secondary school level. HOTS needs to be provided for prospective teachers to help them teach students at schools. The teachers’ understanding and knowledge of HOTS are still lacking [10]. Lack of teachers’ understanding of HOTS hinders the learning process at schools based on HOTS. Whereas, the purpose of mathematics subject is to equip students with the ability to think logically, analytically, systematically, critically, and creatively, and the ability to work together [11].

Moreover, there are several problems related to students' moral degradation, such as, student brawls, adolescent misbehaviour and other negative phenomena among students like cheating during exams, not doing homework and being less confident in learning mathematics [12]. This issue is reinforced by the results of interviews with mathematics teachers in junior high schools that in addition to low student creativity, sometimes highly capable students are also anti-social. For this reason, prospective mathematics teachers need to be habituated to lectures integrating character values that later on could be applied at schools when teaching their future students.

The importance of integrating HOTS and character values can be carried out through the development of teaching materials. Students need to be trained and taught HOTS, one of the ways, through textbooks in learning mathematics [5]. Teaching materials are all materials including information, tools, and texts that are arranged systematically, which present a complete set of the competencies expected to be mastered by students and used in the learning process, for example, textbooks, modules, handouts, worksheets, audio teaching materials, interactive teaching materials, and so on [13].

In addition to teaching materials, the learning process also requires a learning model that can improve students’ HOTS and character. It means that the prepared teaching materials must be able to develop students’ thinking abilities and skills in problem-solving so that they become more independent. For this reason, it is highly necessary to have attractive, both print and non-print, teaching materials. One of the learning models that has a goal in which students can develop their abilities and skills is a project-based learning (PjBL) model. The steps of the PjBL model start with posing the essential questions, designing a plan for the project, creating a schedule, monitoring students and progress of the project, assessing the outcome, and evaluating the experience [14].
The learning model uses problems as an opening in gathering and uniting new knowledge based on real-life experiences. Then, the problems are solved as a group has been formed. The application of PjBL helps to increase the HOTS of students [15]. In this kind of learning, the students will find the completion of a given task or question and create a product. Such learning is expected to be able to foster a level of teamwork in a group and make it easier to work in a group. Working in groups can help the students to perform better than working individually. Math projects open the door for other subjects and disciplines to be integrated into a mathematics classroom and the students quickly recognize that mathematics is interwoven into many parts of their lives. Math projects also give the students the opportunity to work cooperatively; as previously mentioned, collaborative working assists them to get better than working independently. In the PjBL activities, the students with their abilities have the opportunity to contribute to the solution [16]. Therefore, teaching materials integrated with the PjBL model are expected to be able to assist the students actively develop their HOTS and characters.

Based on the explanation above, this current study aims to produce a valid, practical and effective project-based learning mathematics teaching materials to improve students’ HOTS and character.

2. Method

This research objective is to produce teaching materials using a valid, practical and effective project-based learning (PjBL) model to improve students’ HOTS and character. The development of teaching materials based on the PjBL model employed the ADDIE development model that consists of five stages of development, namely analysis, design, development, implementation, and evaluation [17].

The research procedure carried out at the analysis stage was analyzing the needs, curriculum, and characteristics of students. Aside from going through literature studies, the instrument used in the analysis stage was an interview guide. In the design phase, the researchers began with designing a geometry of space module for basic mathematics course based on the PjBL model, followed by making HOTS questions for the pre-test and post-test, character questionnaires and observation sheets. In the development stage, the module and other instruments were validated by two experts, i.e., mathematics education lecturers from Universitas Samudra. The instruments used were module validation instruments, character questionnaires, and HOTS assessment instruments, including an assessment of aspects of content selection and structure, language feasibility, and design/presentation. This validation was continued until the product developed was declared eligible to be tested in the next step. The next activity was a formative revision; namely, one-to-one trial then continued by a small group trial until the field trial produces the module to be implemented. In the implementation phase, the module developed was used in the basic mathematics course in the 2018/2019 academic year, which amounted to 25 students. In the final stage, an evaluation was carried out to analyze the quality of the product and lecture process using the PjBL-based module. The instruments used to analyze the practicality of the module were the questionnaire sheet/student response questionnaire and the observation sheet of module implementation in lectures. Furthermore, to analyze the effectiveness of the module on students’ HOTS and characters, test sheets and character questionnaires were given before and after the course.

The data analysis technique used in this study was to add the scores obtained from the experts’ assessment and then convert the data into a qualitative five-scale form, with data conversion criteria as follows.
Table 1. Conversion of quantitative data to qualitative data on a Likert scale

| Score Range                     | Criteria       |
|---------------------------------|----------------|
| $\bar{X} > \bar{M}_t + 1.8SB_i$ | Very good      |
| $\bar{M}_t + 0.6SB_i < X \leq \bar{M}_t + 1.8SB_i$ | Good           |
| $\bar{M}_t - 0.6SB_i < X \leq \bar{M}_t + 0.6SB_i$ | Good enough    |
| $\bar{M}_t - 1.8SB_i < X \leq \bar{M}_t - 0.6SB_i$ | Less good      |
| $X \leq \bar{M}_t - 1.8SB_i$    | Not good       |

$\bar{X} =$ Validated score

$\bar{M}_t =$ Average ideal score = $\frac{1}{2}$ (ideal maximum score + ideal minimum score)

$SB_i =$ Ideal standard deviation = $\frac{1}{6}$ (ideal maximum score - ideal minimum score) [38]

Based on Table 1, the interval used to determine the criteria depends on the maximum and minimum scores. The maximum and minimum scores depend on the number of grading points. Next, the formula in Table 1 was used to measure the validity of teaching materials in the form of PjBL-based geometry of space module, HOTS-based test questions, and character questionnaires.

The mathematics teaching materials developed are declared practical if the teaching materials with the PjBL model are easy to apply in the course. In brief, the implementation of the teaching materials is included in the category of ‘good’ based on the assessment/response of students and observation sheet of the learning implementation. The teaching materials are said to be effective if, at the final calculation, the percentage of students who have a minimum good character increases at least 15% compared to the initial measurement based on self-assessment. In terms of aspects of HOTS, the effectiveness of the teaching materials was measured using the HOTS test. The test was carried out twice, namely pretest and posttest with the same instrument. Furthermore, the teaching materials are said to be effective if the percentage of students who complete the test at least 68%. A student is said to have completed the test if he reaches a score of more than or equal to 70. Thus, at the end of the trial, it is expected that the percentage of the number of students who get a post-test score of more than or equal to a minimum of 70 is 68%.

3. Result and discussion

3.1. Analysis

Based on the analysis results, it was obtained that:

3.1.1. Analysis of student characteristics. The subjects of this study were students of mathematics education at Universitas Samudra, who took the basic mathematics course in the 2018/2019 academic year. To find out the initial abilities of the students, the researchers conducted an unstructured interview. Some of the questions asked were "Do you know what HOTS-based questions are?", "Have you ever worked on HOTS-based questions?", "What character stands out most from you and what are your weaknesses in the learning process?", "What is the ideal course, in your opinion?" and others. Based on the results of the interviews, we gained some information about the students’ characteristics, which we summarized into some important points: lack of knowledge about HOTS, the variety of learning styles, missing assignment deadlines or cheating on assignments, lack of confidence, and getting more interested in lectures with group discussions than traditional lectures.

3.1.2. Curriculum analysis. The curriculum analyzed in this study is the curriculum based on the Indonesian National Qualification Framework (or known as KKNI) of Mathematics Education Department, Universitas Samudra. Curriculum analysis carried out was oriented towards achieving competence which includes cognitive aspects, attitudes, and skills. In this study, the material focused on the development of the geometry of space module on the basic mathematics course.
3.1.3. Needs analysis. Based on the results of unstructured interviews with lecturers in the basic mathematics course, it was found that the students’ level of thinking ability was still low in solving problems in the basic mathematics course, especially geometry. Besides, some characters that need to be developed are honest, disciplined, confident, caring, persistent, tolerance, creative and responsible. The developed geometry of space module made use of the PjBL model and is expected to improve students’ HOTS and character.

3.2. Design

Based on the results of the analysis, the researchers then designed the module. The module was designed according to the characteristics of the PjBL model. The module format design consists of identity, learning outcomes, description/study materials, enrichment of material through project assignments, assessment indicators (knowledge, attitudes and skills), discussion and reflection, and bibliography. Evaluation sheet that covers HOTS questions and character questionnaire was developed based on indicators of achievement of basic competencies that have been formulated in the material for the geometry of space. In the process of developing teaching materials with the PjBL model, the researchers took into account the following matters: (1) Geometry of space presented in the module contains theories/concepts, contextual problems, proofs of theorems, sample questions, activities to be discussed in group or individually and the reflection section; (2) Teaching materials were also developed based on the syntax of the PjBL model [14]. Teaching materials include independent activities, group discussions or projects that students must work on. For a project assignment, each student will find how to draw, identify properties and elements, prove the shape of the nets and obtain the formula for surface area and volume in each shape; (3) Characteristics of HOTS expressed by Resnick [19] are non-algorithmic, complex, multiple solutions, involving a variety of decision making and interpretation, application of multiple criteria, and effortful. Based on those characteristics, the developed module contains HOTS questions in the concepts, proofs, sample questions and independent assignments, groups or projects. Later on, mathematics education students as teacher candidates will teach their students HOTS problem-solving at schools. For this reason, training or habituation is needed for the prospective teachers in answering HOTS questions in the course. Thus, through this lecture assignment, the students are expected to be able to design student worksheets, learning tools, media as well as HOTS-based learning evaluations; and (4) The cultivated character has three interrelated parts: moral knowing, moral feeling, and moral behaviour [20]. The operational basis of character education is mentioned in the 1945 Constitution article 31 paragraph 3 and 5, as well as the National Education System Law No. 20 of 2013. There are 18 values of character education that can be applied in learning, namely, religious, honest, tolerant, disciplined, hard-working, creative, independent, democratic, curiosity, the spirit of nationalism, love of the motherland, appreciate achievement, friendly/communicative, peace-loving, like reading, care about the environment and society and responsibility [21]. The developed module contains character values adjusted to the syntax of the PjBL model so that the students can integrate them into learning.

3.3. Development

In this stage, the product framework is embodied in a product that is ready to be implemented. Besides, expert validation on the module for space geometry, HOTS questions, and character questionnaires were carried out by two mathematics education lecturers from Universitas Samudra. Furthermore, based on expert advice, product revisions were carried out to achieve the expected goals.

Table 2 shows the results of expert validation on the teaching materials. The expert validation was carried out by two mathematics education lecturers from Universitas Samudra.
### Table 2. Validation of the teaching materials

| Aspect    | Score | Score Average |   |
|-----------|-------|---------------|---|
|           | Lecture 1 | Lecture 2 |   |
| Content   | 65 | 60 | 62.5 |
| Language  | 10 | 9 | 9.5 |
| Design    | 17 | 15 | 16 |
| Total     | 92 | 84 | 88 |

Based on scores on each aspect, an average score for the validity of the PjBL-based teaching materials developed to improve students’ HOTS, and character is in the category of very valid or feasible to use.

### 3.4. Implementation

After validated by the experts, the teaching materials were then tested for students by implementing them in the classroom. When the researchers carried out this trial, two mathematics education lecturers from Universitas Samudra observed the learning process and the students responded to the teaching materials. After the learning process ended, then HOTS-based tests and character questionnaires were given to 25 students.

### 3.5. Evaluation

In the evaluation stage, the analysis of the quality of the product produced was carried out. The researchers analyzed and described the validity, practicality, and effectiveness of the teaching materials developed with the PjBL model to improve students’ HOTS and character.

The practicality of the teaching materials was examined based on the assessment/response of students to the teaching materials and learning observations. Table 3 shows the students’ responses to the teaching materials used.

### Table 3. The students’ responses to the teaching materials

| Aspect                | Module | HOTS Test | Character Questionnaire |
|-----------------------|--------|-----------|------------------------|
| Content eligibility   | 86     | 85        | 85                     |
| Language eligibility  | 86     | 84        | 85                     |
| Design eligibility    | 87     | 80        | 85                     |
| Total                 | 259    | 249       | 255                    |
| Average               | 86.33  | 83        | 85                     |
| Category              | Very good |          |                        |

The students’ responses to the teaching materials in terms of content, language and design are in the very good category. Furthermore, the practicality of the teaching materials is also supported by the results of lecture observations. The researchers lectured the basic mathematics course for four meetings on the topic of space geometry. Table 4 shows the results of observations on the learning implementation.

### Table 4. The observation results on the learning implementation

| Lecture | Observer 1 | Observer 2 | Average | Percentage |
|---------|------------|------------|---------|------------|
| 1       | 55         | 58         | 56.5    | 94.17      |
| 2       | 57         | 57         | 57      | 95         |
| 3       | 58         | 58         | 58      | 96.67      |
| 4       | 58         | 60         | 59      | 98.33      |
| Average | 57         | 58.25      | 57.625  | 96.04      |
| Category|            |            |         | Very good  |
The observations focused on the aspects of completeness and suitability of the contents, presentation, and implementation of the teaching materials using the PjBL model. The maximum observation score for each meeting is 60. The average score from two observers is 57.625 or 96.04%, considered in the very good category. Based on these results, it can be concluded that the developed teaching materials are practically used.

Furthermore, the effectiveness of the teaching materials was measured based on the HOTS test results and character questionnaires. The researchers provided a pre-test and post-test with the same type of questions related to the space geometry topic. The questions given were non-routine and HOTS based. Table 5 shows the students’ HOTS test results.

| Variable                  | Pre-test | Post-test |
|---------------------------|----------|-----------|
| Average                   | 67       | 88        |
| N Complete                | 6        | 18        |
| Completeness (%)          | 24       | 72        |

Based on Table 5, the percentage of completeness for the pre-test is 24% and for the post-test is 72% of 25 students who took the HOTS test. Since the percentage of completeness for the post-test is more than 68%, the teaching materials are considered effective. The average score for the pre-test is 67 while for the post-test is 88. Therefore, PjBL-based teaching materials could increase students’ HOTS.

To assess the character of students, the researchers provided the questionnaire as self-assessment to 25 students. Table 6 shows the results of the questionnaire for finding out the character values of the students before and after using the teaching materials.

| Character Category | Early |   | End |   |
|--------------------|-------|---|-----|---|
|                    | The Number of Students | % | The Number of Students | % |
| Very good          | 6     | 24| 7   | 28|
| Good               | 10    | 40| 12  | 48|
| Good enough        | 7     | 28| 6   | 24|
| Less good          | 2     | 8 | 0   | 0 |
| Not good           | 0     | 0 | 0   | 0 |
| Total              | 25    | 100| 25  | 100|

Based on Table 6, the percentage of the students who have a minimum good character increases by more than 15% compared to the initial measurement on the self-assessment. As such, the teaching materials developed were effectively used to improve students’ characters. The characters focused in this assessment are honest, disciplined, confident, caring, persistent, tolerant, creative and responsible. The ‘disciplined’ character reaches the highest score of 83, and the ‘creative’ has the lowest score.
Teaching material for spatial geometry projects that will be given to students taking basic mathematics courses is as follows on Figure 1:

**Figure 1. Project on Geometry of Space**

Project-based learning (PjBL) is a learning model that makes use of a project or activity as a learning tool to achieve competency, attitudes, knowledge, and skills [22]. The PjBL employs authentic, real-world projects based on highly motivating and engaging questions, tasks, or problems to teach students academic content in the context of working cooperatively to solve the problems. This learning is a collaboration between student activities both independently and in groups in discovering the concept of the material taught through contextual project assignments.

Based on the steps of the learning implementation, the PjBL was effective in enhancing students’ HOTS and character. In the *start with the essential question* phase, the students were given a stimulus to answer the prerequisite questions for further material development, and confident and persistent characters began to be developed. In the *design a plan for the project* phase, the lecturer formed five groups consisting of five students with heterogeneous abilities, guided the group democratically, was tolerant and responsible for choosing the leader and described the tasks for each group member. Furthermore, the lecturer gave the students a project assignment to create a unique and interesting school or park design using varied spaces in geometry. In the *create a schedule* phase, the lecturer and students made an agreement as to when to submit the project assignment and presentation; in this phase, honesty, discipline, perseverance, and responsibility were developed. In the *monitor the students and the progress of the project* phase, the lecturer monitored the progress of the project assignments, guided and helped to deal with problems faced by the groups. In the *assess the outcome* phase, the students were randomly appointed by the lecturer to present the work of their group. Thus, each member of a group should understand their group work thoroughly. Furthermore, the question and answer session was given after the presentation. In the session, other groups were welcome to
pose HOTS questions on the space geometry related to the project being presented. As the students engaged in the discussion to explain and justify their thinking in the collaborative task, they recognized the importance of mathematical confidence as an important mindset for a mathematics learner [23]. Confidence, care, persistence, tolerance, creativity and responsibility were characters developed in this phase. The final phase is to evaluate the experience; the students reflected on the material that had been discussed. The lecturer gave HOTS questions concerning the space geometry for students.

The PjBL trains not only cognitive aspects but also affective and psychomotor aspects of students. Previous research agrees that "the module based on project-based learning can optimize students' life skills" [24]. Another study also shows that project-based learning models encourage students to be actively involved in statistical learning [25]. Mathematical learning tools with PjBL can improve critical thinking skills [26]. This is because the project is authentic learning and involves tangible, visible, and personally tailored projects for students. Besides, project-based learning provides inviting and productive learning experiences [27]. Research has claimed that as students participate in collaborative learning and practice social skills, they have the opportunity to develop core virtues such as leadership, responsibility, and cooperation [28].

The developed PjBL-based teaching materials focus on not only improving students' higher-order thinking skills but also internalizing character values. Well-designed mathematics teaching and learning can be used to develop students' character, such as, critical thinking, creative thinking, logical thinking, to think coherently, to think systematically, and being consistent in attitude, as well as to develop human values [29].

4. Conclusion
Based on the results, it can be concluded as follows. The PjBL-based teaching materials that have been developed are feasible and good to use in learning and, based on the validation test, the components of content, design, and language met the criteria of very valid category. The practicality of the teaching materials is very good, based on the students’ responses and observations on the implementation of the teaching materials in the basic mathematics lectures on the space geometry topic. The teaching materials tested in learning could improve students’ HOTS and character. It was indicated from the results of the pre-test with an average score of 67 and the post-test with an average score of 88. Besides, the average score of student character in both categories increases by 20% in the good category and 16.67% in the very good category, based on student self-assessment through questionnaires. Thus, the teaching materials are considered effective for increasing students’ character and HOTS.

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