Available online at http://journal.uny.ac.id/index.php/jrpm

Jurnal Riset Pendidikan Matematika 9 (2), 2022, 191-200

Development of learning tools based on realistic mathematics approach that oriented to high school students' mathematical generalization ability

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ARTICLE INFO

Article history

Received: 27 Juli 2022

Revised: 30 Okt 2022

Accepted: 30 Nov 2022

Keywords

Realistic Mathematics Approach, Generalization, Mathematical Generalization Ability.

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ABSTRACT

Learning mathematics needs to encourage generalization skills to enable students in expanding and transfering knowledge to practical knowledge. This research aimed to develop learning material based on a realistic mathematical approach that is oriented to generalization ability. The learning materials developed were lesson plans and student worksheets. This was research and development with an ADDIE model. The instruments used were the evaluation sheets, response questionnaire for teachers and students, and tests of mathematical generalization ability. The data analysis technique used was descriptive qualitative and quantitative. The design of the learning materials focuses on aspects of the mathematical generalization ability of high school students by presenting real problems. Student activities were designed to solve real issues related to pattern analysis, focus on student contributions to find conjectures, and design interactions so students can proceed to the abstraction stage using the concept of linkage. So, students can make conclusions regarding the given concept in response to such issues. The results show that the validity qualifications of lesson plans and student worksheets were good and very good, and the practical qualifications were very good. The learning materials complied with effective based on completeness tests of the generalization ability of 82.26 with good qualifications

How to Cite: Hayuningrat, S., Rosnawati, R. (2022). Development of learning tools based on realistic mathematics approach that oriented to high school students' mathematical generalization ability**.** *Jurnal Riset Pendidikan Matematika, 9*(2) 191-200. doi:https://doi.org/10.21831/jrpm.v9i2.52197

INTRODUCTION

Generalization is the ability to develop a learned concept to a certain skill and apply it to new issues in a different context. Generalization gives a broader picture of student knowledge concepts (Tall, 1991). Generalization is a process that makes math live (Mason, 1996), hence generalizations strongly support math learning (Dumitrascu, 2017) and (De Ley, 2016:2). Generalities are essential to mathematical thinking and learning (Iordache, 2019). Generalization is a main component of math in searching for a common formula, where the students generalize the next formula into some pattern (Sosa Moguel et al., 2019). The generalization methods help students to cover the gap between previous knowledge and new ideas, then make connections from previous knowledge to achieve a new concept (Stacey, 1989). So, generalization is an important aspect of mathematical performance, and as a primary component of mathematical teaching at all levels (Ellis et al., 2017).

Isoda & Katagiri (2012:24-25) expresses generalities in mathematical learning teaches about the type of situations where the students are encouraged to look for a certain situation that they can apply to solve problems. The generalization abilities of students affect their mathematical thinking ability (Weinberg, 2019). Generalization ability is an essential aspect of mathematical thinking process, using generalization may influence students in building an understanding of good mathematical concepts (Aprilita et al., 2016:2). According to Mullis et al., (2013) the impact of students' generalization skill is so large in expanding the domains that math thinking or problem-solving has been created and it can be applied more generally and broader. This explains that generalizing ability is essential for students to understand mathematical concepts (Mullis et al., 2013; Hashemi, et al, 2013).

NCTM (2000) describes a generalization process as a record of the order and a project formulation. Generalization is thought to enable students take a skill or concept learned in one context and apply it to a new problem in a different context (De Ley, 2016:2). As an example, trigonometry which is a branch of mathematics focused on the measurements of the sides, and angles of triangles, in which the understanding of sin, cos, and tan, is presented in lateral patterns in the elbow triangle, and in turn, this contrast is presented in Cartesians coordinates to the observable and interconnected effects of trigonometry function. El Mouhayar (2022) research indicates that relational and diverse aspects of patterns help students to be objective during generalization. Generalization of mathematics can take different forms and be built on various kinds of reasoning (Yao & Elia, 2021). Improving and developing students' generalization abilities requires a proper learning process, which involves facilitating students to use patterns, and train abstractions and actions. In math study, activity patterns, contours, and abstractions can be made when learning activities employ the principle of reinvention. One of the learning approaches that use those principles is a realistic mathematics approach.

Gravemeijer (1994:91) presents three key principles of the realistic mathematics approach : (1) guided reinvention (finds back)/progressive mathematizing, according to the principle of reinvention, students must be allowed to experience a similar process to mathematics found; (2) didactical phenomenology, the situation in which the given mathematical topic applied should emphasize the contextual problem, which is originating from the real world or problems that students can imagine; (3) self-developed models (developed models), model of development for students that is set from the contextual problems to math solutions. The realistic mathematics approach is worked based on real-life circumstances, or the probability of real-life conditions (Güler, 2018). It is such an advantage that every Indonesian math teacher must know that the realistic mathematic approach is very worthy to use in the process of learning mathematics. (Putri et al., 2019).

A realistic mathematics approach allows students to reinvent (Ulandari et al., 2019). The realistic mathematic approach comes because of the number of students who experience learning difficulties and apply them in the real world (Nguyen et al., 2020). Students who have difficulty in understanding mathematical ideas and concepts need guidance from adults and this can be done through exploratory activities of real-life situations and problems. The main idea of the realistic mathematics approach is that students should be allowed to re-invent mathematical concepts and principles under adult guidance (Gravemeijer, 1994). Students are allowed to come up with a mathematical idea or concept based on the child's experience in interacting with his environment. The question may be about a school, family, or community environment that the student knows well. The process of realistic mathematics approach study uses contextual problems as a starting point in learning mathematics. Students were allowed to organize problems and try to identify the mathematics aspects that existed in the problem.

Hadi (2017:38) explains that the realistic mathematic approach could improve mathematical education in Indonesia, which is dominated by the issue of how to increase the student's understanding of mathematics and develop reasoning. Nugraheni & Sugiman (2013:104) also explains that realistic mathematics is an approach that has an opportunity to improve the quality of education in Indonesia. Other factors include students who can grow in their knowledge and mathematical understanding. It is explained that students can reconstruct discoveries in the field of mathematics through the activities and exploration of the various problems in their daily life. Further, Hadi (2017:39) adding the advantage the student gets with a realistic mathematic approach is: (1) the student has an alternative concept of an idea - a mathematical idea that is useful for studying the next one; (2) students acquire new knowledge by shaping knowledge for themselves; (3) the new knowledge built by the student comes from a body of varied experiences; (4) each student without looking at race, culture, and gender can understand and do the math. Based on the above points, the benefits of a realistic mathematic approach can be obtained by both teacher and student. In mathematics instruction, teachers can use contextual problems to make it easier for students to analyze patterns and conjectures where students

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

identify and discover mathematical concepts. Based on the experience of students, it is expected that the analysis of patterns and conjectures is carried out naturally through the model-of and the model-for. The principle of self-developed models is hoped to assist students in the projects and abstractions of students can explore design projects until they find their model for problem-solving (Nirawati et al., 2021).

The realistic mathematics approach is rich in mathematical content covered with students' daily activities, the content provides for facilitating and motivating students in the initial process of generalizing the mathematical problem. The teaching materials that students can imagine, will stimulate them to begin their initial generalization process. At the stage of the project, it requires finding connections based on the facts of the mathematics problem (Nurhasanah et al., 2019:65). Realistic mathematic approach didactical phenomenology principle presents phenomena to find specific problem situations that can be generalized and can be used as a basis for generalization of abstractions (Nugraheni & Marsigit, 2021). This principle provides opportunities for students to generalize mathematical concepts. The learning device used for the learning process is a module in the form of worksheets. Effective learning tools can improve student activities in learning (Astawa, 2015; Marlina, 2013; Tiro, Jamal & Mastuang, 2015). To improve generalization skills in learning with a realistic mathematics education approach, learning tools containing aspects of generalization and adapting the realistic mathematics education are needed.

METHOD

This research is development research using ADDIE development models adapted by Robert Marine Branch. The product in this study is a learning material based on a realistic mathematics approach that is oriented to generalization skills. The learning materials developed were valid qualifications, practical and effective lesson plans, and student worksheets.

Validity suggests that the developed learning materials have been developed referring to the theory and guidelines of the learning development device (Akker al., 2013:28). In this case the design agreement is seen in the formation of the lesson plans component and student worksheets component, the quality of the set indicators of competence and purpose of learning, material truth, and fit all learning activities with the appropriate approach, the selection of learning resources, the appropriateness of learning results, and the use of language. Whereas the lesson plans and student worksheets design correlation are viewed from consistent activity goals with the purpose of learning, material content truths, and activity matches with generalization aspect, language, presentation, and graphics. Practicality is viewed in two areas: easiness of product use, which can be applied in the field (Nieveen, 1999). Effectiveness is linked with tooling that can affect the results of formative evaluations for generalization abilities (Nieveen, 1999). Here's the assessment table used for validation and effectiveness of the product, where it is valid and effective with minimum good assessment (Widoyoko 2009: 238).

Table 1. Research Measurement Category

Percentage	Category
$84\% < X \leq 100\%$	Strong good
$68\% < X \leq 84\%$	Good
$52\% < X \leq 68\%$	Enough
$36\% < X \leq 52\%$	Low
$0\% < X \leq 36\%$	Strongly low

Data collection methods through questionnaires, observations, and tests were used to measure the reliability of research products according to valid, practical, and effective qualifications. The type of data used in the development of this learning device was qualitative data and quantitative data. The instruments used were product evaluation sheets, observation sheets, questionnaires, and tests of students' generalization abilities. In this study, generalization mathematical ability is defined as the process of drawing conclusions where students have made patterns, contours, and abstractions in solving mathematical problems. As for the lattice of instruments generalized ability is as follows.

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Table 2. Generalization Ability

No	Aspect	Indicator
1	Pattern Analysis	Identify patterns and determine pattern structure
2	Conjecture	Determine pattern relationships/relationships, use pattern linkages to carry out planning in solving problems
3	Abstraction	Formulate plans into mathematical formulas, apply mathematical calculations, and draw conclusions from calculations performed

Product evaluation design using one-shot case study. Where the product test was implemented in SMA Negeri 9 Yogyakarta, with 34 participants as a research sample. To test the effectiveness of learning tools reviewed from learners' generalization ability is broader than using one sample t-test with a test limit of 75 for generalization ability.

RESULT AND DISCUSSION

Based on the curriculum analysis, high school mathematics, the objects of study in school include facts, concepts, procedures, and principles. For the student in X class of senior high school, the concept of trigonometry studies the measurements of the sides, sides, and angles of triangles and the value of the trigonometry ratio at a special Angle. The concepts are abstract ideas that enable students to classify an object. Trigonometry concepts that are following basic competencies are the definition of sine as the ratio between the opposite side of the angle and the hypotenuse, the definition of cosine as the ratio of adjacent sides to the hypotenuse, cosecant as the ratio of the hypotenuse to the lateral side, cotangent is the ratio of side to angle to side before the angle. The special angle is a particular Angle in which the comparative value of trigonometry comparisons can be sought without the use of mathematical tables or calculators.

Based on the time allocation of the trigonometry for comparison, the five and the four times meeting for materials with 50 minutes for each meeting, one meeting for daily reviews. In mathematics instruction there is one focus on mastering the trigonometry materials for comparison using generalization, so students will be accustomed to generalizing the given mathematical concepts. Thus, the students can develop their generalization ability especially to learn new concepts and resolve the problem provided.

The ages of students in high school range from 15-18 years, which based on the cognitive development of Piaget, are on formal operational, which believes the age are in a concrete operational transition to formal mathematics. Students at formal levels can already formulate hypotheses, combine possible proportions, and have reflective thoughts (Dahar, 2006:39). These high school students will certainly be the basis for a student's centered curriculum approach. Through the entrance, students are allowed to express experiences of an event as a means to understand the math problem (Shadiq & Mustajab (2010:7). Students can be allowed to re-invent (reinvent) mathematical concepts and principles and associate relationships between matter (Gravemeijer, 1994).

In the design stage, the activity of designing lesson plans and worksheets is based on the results of the analysis stage. The lesson plans design consists of identity, formulation of indicators and learning objectives, preliminary activities, main activities, closing activities, and assessment. In the main activities, a realistic approach is designed for covering the generalization processes including patterns, conjectures, and abstractions. In using contextual problems, the focus is designed to facilitate students to carry out pattern analysis to find conjectures or interrelationships of the patterns presented in the contextual problems that exist around students and can be imagined by students. The contextual problems presented are the distance of the eye's sight and the blind spot of the eye to see the angles in a right triangle. Hanging plane logging path to determine the tangent ratio. The choice for this problem encourages students to use models-of and models-for, schemes, diagrams, symbols and so on which might use as bridges for students from concrete to abstract situations. The design presented is designing patterns from the contextual problems and makes students look for further patterns and their interrelationships so that students can develop them to carry out the abstraction process. Lingefjärd & Hatami (2020) claims that abstractions in generalization are the beauty of the human mind in which mathematical abstractions can be linked to some examples of connections between patterns, algebra, and geometry.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

After analyzing design patterns, the group discovers the latest patterns and maximizes student contingencies to develop both individually and collectively. These will be ideas from pattern links to develop students' abstraction abilities. The activity designed is to facilitate students in training to find contour or connectedness patterns from simple patterns to trigonometric ratios patterns. The patterns presented in the first to fourth meetings with contextual problems according to levels and the goals of learning in the meeting. To that end requires both student interaction with teachers and student with the student to view the abstraction process that is happening according to Lingefjärd & Hatami, 2020.

The activity is designed to give students spaces to discover the targeted concepts and to make sure that students' generalization processes were accomplished. Surely the results will be confirmed by teachers regarding the structure and concepts of mathematics connectedly so the conclusions that students will produce will fit the purpose of study in each meeting. This suggests that learning units will not be achieved separately but that interconnectedness and integrity should be exploited in problem-solving. Students will be able to stimulate concepts learned after analyzing patterns, discovering contingencies, and continuing the abstraction steps.

The design of student worksheets is customized with realistic mathematic approach characteristics that could train the student's mathematical ability to conclude the analysis of patterns, adjectives, and abstractions in each meeting. During student activities, researchers can monitor whether students have generalizations according to the design developed. Through observation researchers observe student activities using worksheets and activities carried out according to the concept of trigonometry as a comparison and how students develop solutions to solve problems using generalizations abilities. The granting of context is the line of sight and the eye blind point in viewing the sampled objects designed to enable students to use patterns to form the sense of sin, cos, and tan, through the size of the elbow triangle or not (figure 1.a). To facilitate the scale of the outer rim of a sampan cliff is approached by a geometric building, creating a long spindle and an enormous angle (figure 1.b). Another context used in these trig topics is a glider landing, visibility on a cliff, and blind spot.

Figure 1a. Luweng Sampang Cliff Side

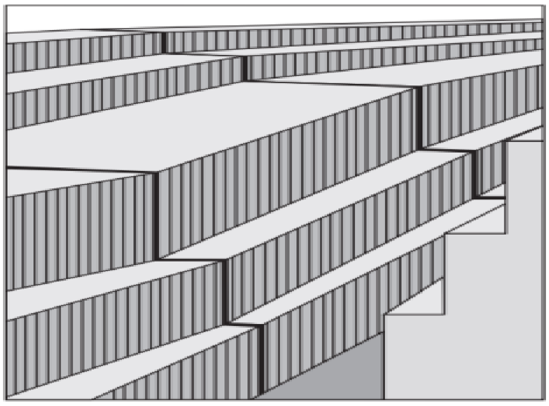

Figure1b. Luweng Sampang Cliff Side Schematic

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

The following are the results of the assessment of lesson plans and student worksheets by experts.

Table 3. Rating result lesson plans

No	Assessment Aspects	Score	Classification
1	Identity formulation/ learning objectives	96,7%	Strong good
2	Material selection	86%	Strong good
3	Learning approaches selection	80%	Good
4	Learning activities with realistic math approaches	82,3%	Good
5	Learning source selection	86,7%	Strong good
6	Learning outcome assessment	80%	Good
7	Vocab and grammar	80%	Good
	Average	86,3%	Strong good

Tabel 4. Rating result student worksheets

No	Aspek Penilaian	Score	Classification
1	Competence	90%	Strong good
2	Material	85%	Strong good
3	The relevance between task book with realistic math learning activity	85%	Strong good
4	Language	83,3%	Good
5	Presentation	83,3%	Good
6	Display	85,4%	Strong good
	Average	87,9%	Strong good

Widoyoko (2009: 238) explains that product development is classified to be valid with an average rating for a minimum category of "Good" from the experts' assessment results, which states that the learning tools developed are valid and can be tried out. Furthermore, learning materials are tested by seeing how students follow the student activities that have been provided. In student class activities show that students have carried out a generalization process following the designs that have been developed. From the stimulus of a luweng sampang context which was observing patterns, students discover how the influence of angles on the sides of a triangle. The results of the study (Sitorus & Sutirna, 2021) explained that the choice of context influences the initial understanding used to make the initial basis for receiving material. The following is the context presented in the comparison of sides in a right triangle (Figure 4)

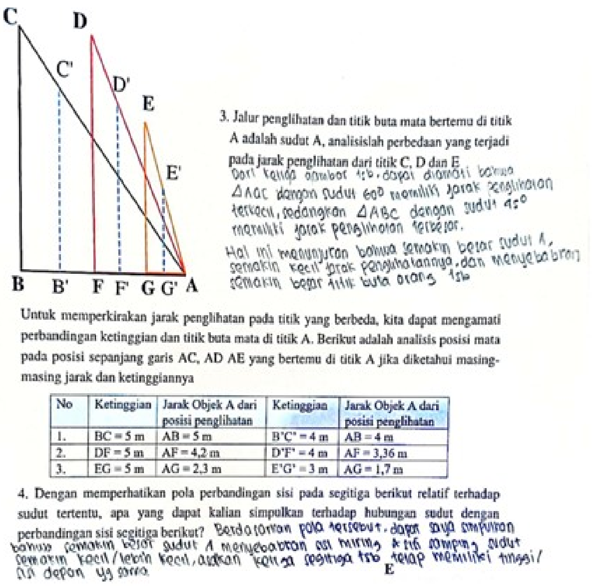

Figure 4a. The effect of the size of the angle on the sides of the triangle

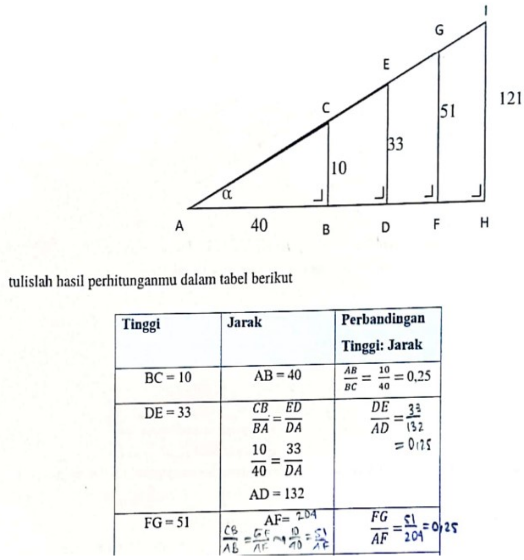

Figure 4b. Comparison of launch path heights and triangle congruence sketches

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

Furthermore, the generalization process is carried out by providing a stimulus in the form of contextual problems on the hang-gliding landing strip in activities, where this application is one of the visualizations used in studying the congruence of right triangles and the ratio of the height of the launch path to the landing distance (Figure 4b). The implementation of learning that presents a generalization process is also supported by student response questionnaires that show good responses to student worksheets. In other words, worksheets are very good in terms of legibility, and updating, that are interesting can provide assistance, and (Table 5)

Table 5. Student Response Questionnaire Results

No	Assessment Aspects	Score	Classification
1	Legibility	86,2%	Strong good
2	Recency	86,3%	Strong good
3	Supporteness	85,5%	Strong good
4	Attractiveness	85,5%	Strong good
	Average	85,9%	Strong good

Based on the average student assessment in the " Strong good " category, it can be concluded that the product is in the "Practical" category for facilitating mathematical generalization abilities. Likewise with the good response given by the teacher towards the lesson plans used during the implementation of learning activities and lesson plans as a design that guides the implementation of learning activities (Table 6)

Tabel 6. Teacher Response Questionnaire Results

No	Assessment Aspects	Score	Classification
1	Lesson plans	80%	Good
2	Student worksheets	92,8%	Strong good
	Average	88,1%	Strong good

The practicality assessment carried out by the teacher on the learning device showed that the device received an 85% presentation in the " Strong good " category so the device was declared practical from the assessment carried out by the teacher. The assessment of the effectiveness of this learning device is seen from the results of the student's mathematical generalization ability tests which are presented in Table 7.

Table 7. Recapitulation of Mathematical Generalization Ability Test Results

Description	Value
Total students	34
Maximum Value	100
Minimum Value	57,14
Average value	82,26
Students whose scores are more than the Matthews correlation coefficient (MCC)	29
Students whose grades are less than the Matthews correlation coefficient (MCC)	5

The learning device with material on trigonometry ratios developed for class X high school students showed 85.29% classical completeness result on the generalization ability test. Furthermore, effectiveness analysis was also carried out by testing the hypothesis. Before carrying out the hypothesis test, the prerequisite test that must be carried out is the normality test with statistics test using the one-sample Kolmogorov-Smirnov with the results in Figure 5 below.

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Hasil_Belajar	.115	34	.200*	.972	34	.520

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Figure 5. Normality Test Results

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

Figure 5 shows a significant result of 0.200. It can be concluded that because the significance is greater than the value, which is 0.05, the data is declared to be normally distributed. Then tested the effectiveness of the test results of mathematical generalization abilities using a one-sample t-test statistical test. The results of the effectiveness test of students' mathematical generalization ability tests are presented in Table 8 below.

Table 8. Statistical Test Results

	Value
t_{count}	5,316
$t_{table}(t_{0,05})$	1,706

Based on Table 8, the value of $t_{count} > t_{table}$ ($t_{0.05}$) is obtained. It can be concluded that h_0 is rejected. So, mathematics learning materials with a realistic mathematics approach are effective in facilitating students' generalization abilities. The design of the learning device developed in this study focuses on aspects of high school students' mathematical generalization ability through realistic problem presentation, student activities were designed to solve real problems related to pattern analysis, focus on student contributions to find conjectures and design interactions so that students can proceed to the abstraction stage using related concepts to solve problems.

CONCLUSION

Lesson plans and student worksheets designed with a realistic mathematics approach to learning present the problem of such incidents as the luweng sampang contexts, the jumping off the fly, as the entrance to activities that force students to use pattern analysis for generalization, focusing the students' contour to find contour and design interactions so that students can continue to the abstraction point using concept links to solve the problem on trigonometry topics. The developed lesson plans and modules for worksheet products have valid, practical, and effective qualifications. Valid under the "Strong good" category for lesson plans and module for worksheets assessments based on a total score of 87.91 and 88.00. Practical with the "Strong good" category based on the accession of student activity and the teaching observational observations that led to the realization of activities by 95% (more than 80%); Teacher practical assessment of the learning device with a score of 97; And the student assessment of module for worksheets with an average score of 102.05 in the highly practical category.

Effective based on classified test results of generalization mathematical capability tests over 80%. With an average value on a student's generalization ability test is 82.26. This result is supported by the results of a t-test one-specimen statistical test which states that a mathematical learning device is effective to facilitate students' generalization capability. This achievement is also supported by the results from a statistical one-sample t-test analysis stating that $t_{count} > t_{table}$ and thus suggests that this mathematical learning device is effective in facilitating students' generalization capabilities.

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ISSN 2356-2684 (print), ISSN 2477-1503 (online)

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ISSN 2356-2684 (print), ISSN 2477-1503 (online)