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Development of Stem-Based Learning Tools to Increase the HOTS of Class X SMA Students on Environmental Change Materials

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ABSTRACT: Pery Jayanto, Development of STEM-Based Learning Tools to Increase HOTS of Class X SMA Students on Change Material. Yogyakarta: Faculty of Mathematics and Natural Sciences Yogyakarta State University, 2021. The objectives of this research are (1) to produce STEM-based learning device products in the form of RPP, LKPD and valid assessment instruments so that they are feasible to be applied in learning activities, (2) produce practical STEM-based learning device products that are easy to apply in learning activities, and (3) produce effective learning equipment products to increase the HOTS of class X SMA students on Environmental Change Material.

This research is a research and development (R&D) using the ADDIE model which consists of the stages of analysis, design, development, implementation, and evaluation. STEM-based learning tools developed are evaluated for the validity of the learning tools developed determined from the opinions of experts. Experts in this case are UNY Postgraduate lecturers, material experts and instrument experts who will provide suggestions and assessments related to the validity of the learning tools developed and then tested for practicality on the developed learning tools that can be determined through teacher and student assessments. This assessment is used to determine the responses of users of the learning tools developed. This assessment is about how suitable and easy the learning device is to apply and test its effectiveness on class X SMA students using a quasi-experimental pretest-posttest control group design. Data collection used interview guides, needs analysis questionnaires, validity assessment questionnaires for material experts and learning experts, practical assessment questionnaires by biology teachers and students and students' HOTS tests. The data analysis technique used n-gain and independent sample t-test.

The results obtained based on the research that has been carried out show (1) according to the results of the validation of material experts and instrument experts, the STEM-based learning tools developed are declared valid and suitable for use in terms of construction, material and language aspects (2) the use of STEM-based learning tools in activities practical learning to use according to the teacher's assessment which is assessed from the material aspects, lesson plans and student worksheets, while the practicality of learning tools by students is assessed from the aspect of ease and assistance of students in using LKS, and (3) learning using STEM-based learning tools can increase participant HOTS SMA XI class students on environmental change material with a value <0.05.

KEYWORDS: Learning tools, STEM, HOTS, Environmental Change

INTRODUCTION

Learning tools are tools that are prepared and used to carry out learning activities in the form of a syllabus, learning implementation plan (RPP), teaching materials, and assessment instruments that refer to the content standards (Qamar, 2020). Learning tools are prepared by the teacher referring to the principles of their development and contain components that have been minimally stipulated in the referenced education ministerial regulation (Syakila et al., 2021). Higher Order Thinking Skills (HOTS) is a complex thinking process in describing material, making conclusions, building representations, analyzing, and building relationships involving the most basic mental activities (Misrom et al., 2020). HOTS involves cognitive skills, namely skills to analyze, synthesize (Wijaya & Andriyono, 2020). Students who have HOTS are more open to differences or diversity, are not easy to accept information without evidence or grounded reasons, are not easily influenced or carried away, they are independent in thinking and acting, can distinguish important things and priorities so that they can produce work (Ichsan et al., 2019). In the end, HOTS is needed to improve the quality of human life (Sidiq et al., 2021).

STEM education is an approach in education where Science, Technology, Engineering, Mathematics are integrated with the educational process focusing on solving problems in real everyday life as well as in professional life (Stohlmann et al., 2012). STEM education shows students how concepts, principles, science, technology, engineering and mathematics (STEM) concepts

are used in an integrated manner to develop products, processes, and systems that are beneficial to human life (Kennedy & Odell, 2014). Learning tools that are applied in learning activities are applied in the form of a syllabus, lesson plans, LKPD and question instruments. LKPD is a sheet that contains a summary or instructions or steps for implementing work that must be done by students which refers to the competencies that must be achieved. LKPD is developed by applying the STEM pattern known as EDP (Engineering Design Process) or the process of designing a work or machine (Liu et al., 2020).

In this study, the topic of Environmental Change was chosen using the STEM approach because based on the results of the study it contained the scope of knowledge or science related to certain technologies that could be engineered by considering mathematical calculations (Kaleci & Korkmaz, 2018). From a scientific perspective, this topic will discuss factual knowledge about environmental damage/pollution and environmental conservation; conceptual knowledge includes hazardous substances in environmental pollution and recycling processes; procedural knowledge that can be learned includes testing various environmental pollution wastes; and metacognitive knowledge about how to prevent environmental pollution disturbances. In terms of technology, this unit will discuss "Waste Treatment Technology" using a simple water filter or filter. From the engineering side, students will be asked to design filters to minimize environmental pollution by performing some mathematical calculations related to the volume of the designed filter and the required budget. With the STEM approach to biology learning, it can stimulate the creativity and soft skills of students, as has been mandated in the 2013 curriculum.

In implementing the 2013 curriculum in the field, there are still several obstacles in its implementation in schools, one of which is SMA Negeri 1 Wates. From the results of an interview with one of the biology teachers at SMA Negeri 1 Wates who teaches in class X, some of the obstacles expressed include the teacher not being able to make a learning device that is in accordance with the procedures and mandated in the 2013 curriculum, where the learning tools used by the teacher are: obtained by downloading without modifying or developing it first, and the learning is still unsatisfactory in the range of less than 70, namely 63,43 in emphasizing the reasoning level so that it has not been maximized in generating HOTS students in accordance with the 2013 curriculum mandate. 2019 at SMA 1 Wates, the material that is of concern in this research is the subject of biology on indicators of environmental change which is still relatively low with the percentage of students who answered correctly 59,43, while the percentage of students who answered correctly at the provincial level was 68,92 and un for the National level 60,09.

Based on these problems, the researchers tried to conduct a study entitled, "Development of STEM-Based Learning Devices to Improve HOTS for Class X Students of SMA Negeri 1 Wates on Environmental Change Materials". From this research, it is expected to produce products that are suitable for use in order to improve the skills of students in SMA/MA.

METHOD

This research is a Research and Development (R&D) using the ADDIE model which consists of the stages of analysis, design, development, implementation, and evaluation. The developed STEM-Based Learning Toolkit was evaluated for the level of validity of the developed learning device which was determined from the opinions of experts. The experts in this case are UNY Postgraduate lecturers who are material experts and instrument experts who will provide advice and assessments related to the aspects of the validity of the learning tools developed and then tested the level of practicality on the learning tools developed can be determined through teacher and student assessments. This assessment is used to determine user responses to the developed learning device. The assessment was about how suitable and easy the learning tools were to apply and tested their effectiveness on class X SMA students using a quasi-experiment pretest-posttest control group design. Collecting data using interview guides, needs analysis questionnaires, validity assessment questionnaires for material experts and learning experts, practicality assessment questionnaires by biology teachers and students, and students' HOTS tests. The data analysis technique used n-gain and independent sample t-test.

RESULTS AND DISCUSSION

A. Initial Product Development Results

1. Analysis Phase
   a. Field Study Analysis
      1) The school has implemented the 2013 curriculum in class X, so the teacher has also understood the application of the PjBL model as a learning activity which will be presented using the STEM approach.
      2) The low ability to analyze, evaluate, and create students in the conceptual, procedural, and metacognitive domains because biology teachers' knowledge of HOTS is still lacking, this can be seen from the learning tools previously used by teachers that did not contain HOTS.
      3) Learning activities that emphasize the relative increase in HOTS have not been carried out.
      4) Cognitive aspects of remembering and understanding are prioritized in applied learning activities compared to cognitive aspects of analyzing, evaluating, and creating.Sekolah telah menerapkan kurikulum 2013 di kelas X, maka

guru juga telah memahami penerapan model PjBL sebagai kegiatan pembelajaran yang nantinya akan disajikan dengan menggunakan pendekatan STEM.

b. Literature Review

In learning activities regarding learning approaches and skills that need to be possessed by students, it is necessary to conduct an assessment of the development of learning tools in ongoing learning activities. The results of the study show that the learning tools implemented by the teacher in learning activities can increase the HOTS of students.

c. Analysis of Research Needs

Analysis of research needs is based on the results of the analysis of field studies and literature reviews conducted. Based on the results of the study conducted, STEM learning activities can increase students' HOTS. The HOTS of students is improved by training students to use their abilities to try to solve the problems they face independently so that learning objectives are achieved.

2. Design Phase

a. STEM-Based Syllabus Design

The syllabus design refers to Permendikbud Number 22 of 2016 which at least contains subject identity, school identity, KI, KD, subject matter, learning, assessment, time allocation, and learning resources. Based on the components of the syllabus, it is adapted to STEM aspects, especially in terms of material that applies the concepts of science, technology, engineering, and mathematics then learning activities that apply EDP or engineering engineering processes which are important components that must exist in STEM learning which is applied to the syllabus and assessment of learning activities is carried out by measuring tests and non-tests, namely tests are used to measure students' HOTS, while non-tests are used to measure students' attitudes and skills.

b. STEM-Based RPP Design

The design of the RPP refers to Permendikbud Number 22 of 2016 at least containing school identity, subject identity, class/semester, subject matter, time allocation, learning objectives, KD and GPA, learning materials, learning media, learning resources, learning steps, and assessment of learning outcomes. Based on the components of the syllabus, it is adapted to STEM aspects, especially in terms of material that applies the concepts of science, technology, engineering, and mathematics then learning activities that apply EDP or engineering engineering processes which are important components that must exist in STEM learning which is applied to the syllabus and assessment of learning activities is carried out by measuring tests and non-tests, namely tests are used to measure students' HOTS, while non-tests are used to measure students' attitudes and skills.

c. STEM-Based LKPD Design

As one of the learning tools that contains problems where there are natural phenomena that are designed based on everyday life with the help of a STEM approach that is able to assist students in identifying and finding solutions that are realized through EDP or engineering design processes in STEM activities that play a direct role in solving a problem in real life to train students' HOTS to improve.

B. Product Trial Results

1. Development Phase

a. Learning Tool Validation Results by Instrument Experts

The results of the assessment were analyzed statistically using Microsoft Excel, so the average value obtained was 3.38 with very good criteria. The mean value obtained indicates that the STEM-based learning device is valid and feasible to use for this study.

b. Learning Tool Validation Results by Material Experts

The results of the assessment were analyzed statistically using Microsoft Excel, so the average value obtained was 2.69 with good criteria. The mean value obtained indicates that the STEM-based learning device is valid and feasible to use for this study.

c. Limited Trial Results

1) Practicality of STEM-Based Learning Devices according to Biology Teachers

The data on the practicality of STEM-based learning tools were obtained from two biology teachers, then statistically analyzed using Microsoft Excel. Based on the recapitulation of data acquisition from two practitioners in a limited trial, the results obtained an average of 3.65 which in general the product is categorized as very good.

2) Practicality of STEM-Based LKPD according to Students

The results of student assessments regarding the practicality of STEM-based worksheets were tabulated for statistical analysis using Microsoft Excel. Based on the recapitulation of student assessments in the limited trial, the results obtained with an average value of 3.78, in general the product was categorized as very good.

2. Implementation Phase

a. Field Trial

1) Student HOTS Analysis

a) Statistical Descriptive Data Results

Table 17. Statistical Descriptive Data Results

	Pretest		**Posttest**	
	Experiment Class	Control Class	Experiment Class	Control Class
The highest score	67.50	62.50	90.00	83.75
The lowest score	41.25	41.25	70.00	60.00
Deviation Std.	7.502	6.499	6.193	7.242
Average	55.43	48.70	81.42	71.99

2) Prerequisite Test Analysis Results

a) Normality Test

The experimental class data showed normality test results were normally distributed with p-value (sig) = 0.200 > 0.05, while control class data showed normality test p-value (sig) = 0.107 > 0.05, so it was declared normally distributed. Table 18 below presents the results of the normality test.

Table 18. HOTS . Normality Test Results

		Kolmogorov-Smirnov[a]		
	Class	**Statistic**	**df**	**Sig.**
HOTS	Experiment	,129	29	,200*
	Control	,148	29	,107

b) Homogeneity Test

The results of the homogeneity test of the two classes based on the mean (table test of homogeneity of variance) show the probability results of homogeneous value. Table 19 below presents the results of the homogeneity test.

Table 19. HOTS . Homogeneity Test Results

		Levene Statistic	**df1**	**df2**	**Sig.**
HOTS	Based on Mean	,650	1	56	,423
	Based on Median	,310	1	56	,580
	Based on Median and with adjusted df	,310	1	49,703	,580
	Based on trimmed mean	,631	1	56	,430
	Based on Mean	,650	1	56	,423

c) Test Independent Sample T-test

Table 20. Results of Analysis of the Independent Sample T-test HOTS

		T-test for Equality of Means			
		T	**Df**	**Sig. (2-tailed)**	**Mean Difference**
Posttest	Equal Variances assumed	5,328	56	,000	9,43103

Tests on the independent sample t-test obtained the results of tcount is 5,328. When comparing ttable with a significance level of 95% and df = 56, namely 2,003, then tcount = 5,328 > ttable 2,003 and it can be seen from the significance level of 0.000 < = 0.05. The analysis results obtained indicate that H0 and Ha are accepted, which means that there is a significant difference between the two classes. Draw the conclusion that the HOTS of students in the experimental class increased because learning biology using STEM-based learning tools on environmental change materials was more active than the control class that did not use STEM-based learning tools.

C. Product Revision

1. Evaluation Phase
   a. Post-Validation Product Revision
      Based on the purpose of validation to get revisions from expert validators. Expert validators provide suggestions for improvement in the STEM-based syllabus, lesson plans, and LKPD sections. Revision in detail at this stage is as follows:
      1) Three-dimensional learning from STEM has not been shown on the question instrument grid and LKPD.
      2) The questions do not meet the HOTS
      3) The material is not presented in the syllabus so it is not possible to assess the breadth and depth in accordance with KD or not.
      4) The material does not exist so that the validator cannot assess the material related because it is not explained in the syllabus or lesson plans.
      5) The questions should be in accordance with the learning indicators, lesson plans and LKPD.
   b. Test Result Product Revision
      Product revisions in the form of input generated at the stage of trial results sourced from teachers and students which are described in detail as follows:
      1) The time allocation given to make the product is not enough, so the product is not optimal
      2) Should be given a limit on the costs incurred
      3) The language used in writing instructions for learning activities should use a simpler language
      4) It is necessary to add a little more information, for example the processing time, so that students can know the time limit.

D. Final Product Study

1. The Validity of STEM-Based Learning Devices in the Process of Biology Learning Activities
   After obtaining validation data according to two expert lecturers, then conducting an analysis to determine the validity of the product developed. Most of the results of the analysis stated that the product components had been validly used but a small part of the product components had to be revised before being used. Based on all the results of the analysis data obtained, the product developed in the form of a valid STEM-based learning device is implemented in the process of biology learning activities.
2. Practicality of STEM-Based Learning Devices in the Process of Biology Learning Activities
   The results of the data analysis of the practicality of the product based on the assessments of teachers and students in a limited trial got a very good category. Based on all the results of the analysis data obtained, the product developed in the form of STEM-based learning tools is practically implemented in the process of biology learning activities. Based on the results, according to two biology teachers and students, they stated that the STEM-based learning tools that had been developed obtained very good criteria, which means that the products developed were practical to be implemented by teachers and students during biology learning activities that took place in class.
3. The Effectiveness of STEM-Based Learning Tools to Improve Students' HOTS
   The results of increasing the average pretest and posttest scores of students referring to the KKM standard of the school in the experimental class and control class prove the effectiveness of the product developed. The results of the analysis on the HOTS result variable, namely the average value of students compared to the standard KKM score so that it can be seen whether there is an increase in the average pretest and posttest scores of students in the experimental class. Based on the results of the analysis, the use of learning tools in environmental change materials is effective in increasing the HOTS of students in the experimental class to a higher level. The average value of N-gain in the experimental class is 0.587 with moderate criteria, meaning that there is a significant change but the value of N-gain is not higher, this can be caused because there are several items with Sensitivity Index (IS) values. with sufficient criteria, so that there are some students who are unable to answer the prettest and posttest questions.

CONCLUSIONS

Regarding the elaboration of the discussion in the previous chapter regarding the research that has been carried out, it is concluded that:

1. The developed STEM-based learning device is valid because it has fulfilled the material, construction and language aspects based on the validation results by material expert lecturers and learning expert lecturers.
2. STEM-based learning tools that are developed are practical for students to use by obtaining an average result of 3.65 which in general the product is categorized as very good according to the teacher's assessment and LKDP obtains results with an average value of 3.78 so in general the product is categorized as very good according to the assessment of students.

3. Learning using STEM-based learning tools on environmental change materials effectively helps increase students' HOTS with a value <0.05. This happens because the STEM stage is able to train students' analytical skills in asking critical questions about what they want to create at the ask stage, practice brainstorming skills and develop solutions as much as possible at the imagine stage, and train to evaluate the best ideas in the plan stage. training to create by building products at the create stage which makes ideas come true, and training to evaluate to make products better at the improve stage.

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