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Development of STEM Integrated Project Based Learning Model to Improve Students' Creative Thinking Ability

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Abstract
This study aims to: (1) determine whether the STEM integrated project based learning model is valid, practical and efficient to improve students' creative thinking skills; (2) improve students' creative thinking skills by using the developed STEM integrated Project Based Learning learning model. This research is categorized into Research and Development research (research and development). This research includes development research using the ADDIE development model to develop an integrated STEM Project Based Learning learning model on Three Dimensional material and all required research instruments. This study used a limited trial to 24 students of class XI Accounting at SMK Negeri 1 Panyabungan. The results showed that: (1) The STEM integrated Project Based Learning interactive learning model that was developed found that the interactive learning model was declared valid, practical and effective; (2) Based on the normalized gain index, it was found that in the first trial there was an increase in the creative thinking ability of students with the "low" criterion with a score of 0.30 (g 0.3) and in the second trial there was an increase in the score with the "medium" criterion. ” with a score of 0.42 (0.3 < N-Gain 0.7).
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INTRODUCTION

In accordance with Permendiknas No. 23 of 2006 the Minister of National Education, the profile of SMK graduates is mastering the competence of expertise and entrepreneurship programs both to meet the demands of the world of work and attend higher education according to their vocational. The graduate profile can be interpreted that the mandate of education in SMK is to create or produce graduates who have special skills and are ready to enter the workforce according to market demands.

Gunawan (2000) suggests that vocational school graduates' work readiness is influenced by factors of knowledge, skills, and attitudes. So that vocational education has advantages, one of which is that students are not only equipped with cognitive competencies, but are also equipped with practical skills that support work readiness. To produce graduates who have work readiness, vocational education must form students who have hard skills and soft skills. A person's success in work is not only determined by hard skills, but is also determined by soft skills which determine whether a person is able to be accepted well in his work environment or not. Hard skills possessed by students are in the form of knowledge of vocational competence, while soft skills are in the form of skills and experience possessed by students. The learning model used should be project-based so that the vocational education target is achieved. Developing students' hard skills, one way that can be done is through practicum activities. The selection of learning models is very important for the success of practicum-based learning. One of the project-based learning models is Project Based Learning (PjBL).

PjBL is a learning model that organizes classes in a project (Thomas, 2000:1). According to the NYC Department of Education (2009), PjBL is a learning strategy in which students must construct their own content knowledge and demonstrate new understanding through various forms of representation. Meanwhile, the George Lucas Educational Foundation (2005) defines a dynamic learning approach in which students actively explore real-world problems, provide challenges, and gain deeper knowledge. Through this PjBL mathematics learning will be carried out with active projects to explore mathematical problems in the real world.

The results of observations made, teachers do not use PjBL in learning mathematics. Teachers conventionally explain to students learning mathematics. In the ongoing learning process, actually there is active student activity in the classroom, it's just that the activities carried out by most students are activities that should not be carried out in learning such as actively speaking when the teacher is explaining the material.

The importance of developing the PjBL model is that if the appropriate learning model is used, the learning implementation will be carried out effectively. PjBL is a suitable and effective learning model to be used in vocational learning. The use of PjBL which has been developed with the STEM approach is in accordance with the mathematics practicum in SMK. Using the PjBL learning model developed will be more effective in helping the learning process so that learning objectives are achieved.

The PjBL learning model is an innovative learning centered on students (student centered) and sets the

teacher as a motivator and facilitator, where students are given the opportunity to work autonomously in constructing their learning (Trianto, 2014:42).

Sumiran (2009:20) suggests that PjBL has the potential to meet the demands of learning. According to Daryanto and Raharjo (2012: 162) the PjBL learning model has the advantage of encouraging students to develop and practice communication skills and also provide students with experience in learning and practice in organizing projects, and making allocations.

In this 4.0 century, each science no longer has to work alone, but various branches of science can work together, not only within science, technology or social science and humanities groups, but in many ways between several groups (Khoiriyah, et al. 2018).). Changes in learning in the 4.0 revolution era are expected to collaborate between subjects. In line with this, the 21st century learning paradigm emphasizes the ability of students to find out from various sources, formulate problems, think analytically and collaborate and collaborate in solving problems which are often called 21st century skills (Trilling and Fadel, 2009). Based on Trilling and Fadel (2009), in general, 21st century skills are divided into three skills, namely Learning and Innovation Skills, Information, Model, and Technology Skills and Life and Career Skills. Life and Career). One of the lessons that can integrate 21stCentury Skills is STEM (Science, Technology, Engineering, and Mathematics).

STEM 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 (Winarni, et al., 2016). STEM 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 (Ostler, 2012).

STEM is a learning approach that stimulates and motivates students to think at higher levels, one of which is creative thinking through project-based learning, investigation and research (Apriliana, et al., 2017). Belland, et al (2017) stated that STEM is a problem-based inquiry approach that is applied through modeling or design visualization in learning. STEM is a learning approach using an authentic context that can train students to hone cognitive, creativity, innovation and manipulative skills in solving problems related to the environment by utilizing technology (Cahyaningsih & Roektiningroem, 2018). So that it is easier for students to understand mathematics and be able to improve their creative thinking skills.

The ability to think creatively is the ability to produce a variety of new ideas / ideas in solving problems as alternative solutions. This ability is an ability that must be possessed by students, because this ability is in accordance with the goals of national education and the objectives of mathematics education.

Based on the description above, the creative thinking ability of students is very necessary to be developed in schools. However, the reality on the ground shows that the ability to think creatively is not optimal. The low creative thinking ability of students is evidenced by the results of the Trend International Mathematics and Science Study (TIMMS) (Ismara, 2017) which states that the level of creative thinking ability of students in Indonesia is relatively low, because only 2% of Indonesian students can work on social problems. requires the ability to think creatively in solving it.

Researchers see that the existing problems will provide a development related to the learning model, namely the development of an integrated STEM project-based learning model. The development of the STEM-integrated PjBL model is expected to increase students' creative thinking in learning mathematics.

METHOD

Research Pattern

This research includes development research using the ADDIE development model to develop an integrated STEM Project Based Learning learning model on Three Dimensional material and all required research instruments. This study used a limited trial to 24 students of class XI Accounting at SMK Negeri 1 Panyabungan.

Subject

The subjects in this study were several students of class XI Accounting at SMK Negeri 1 Panyabungan, totaling 24 people. While the object in this study is the STEM integrated PjBL learning model on three-dimensional material.

Data Analysis

Analysis of the Validity of the PjBL-STEM Model and Learning Tools

Knowing the validity of the learning model used, the researcher conducted a descriptive statistical analysis based on the average score of the learning model that had been validated by a team of experts.

Practical Analysis of Learning Model

The practicality of learning tools is measured based on the results of the observer's assessment to state whether or not the device can be implemented in the classroom using the provided learning tools (intended-operational or io). The instrument used is an observation sheet on the implementation of learning devices that

have been developed.

Learning Model Effectiveness Analysis

The criteria for determining the achievement of the effectiveness of learning tools are based on four indicators of learning effectiveness, namely: (1) achievement of learning mastery if 80% of students who take the mathematical problem solving ability test have scored 75; (2) the achievement of complete learning objectives (at least 75% of the formulated learning objectives can be achieved by a minimum of 65% of students); (3) the time used in learning is efficient or does not exceed ordinary learning; (4) students' responses to learning.

Analysis of Students' Creative Thinking Ability Improvement

Increasing students' creative thinking skills can be interpreted using normalized gain (N-Gain). Increasing students' creative thinking skills in the learning process is not easy to state, using absolute gain (difference between initial and final test scores).

Data Collection Techniques

Creative Thinking Ability Test

The test of students' creative thinking skills will be managed by the data. The data from the students' creative thinking ability test results will be analyzed quantitatively to determine the increase in creative thinking skills after using the STEM integrated PjBL learning model on three-dimensional material. Aspects and indicators are arranged into a test grid which will be developed into a test of students' creative thinking skills and appropriate scoring guidelines.

Student Activity Observation Sheet

Observations of students are carried out from the beginning of learning activities until learning is complete by using student activity observation sheets. The student activity observation sheet is a sheet that contains guidelines in carrying out observations of student learning activities during learning in the classroom by giving a check mark (✓) in the indicator column being assessed. Observations were made on a random sample of students who would represent all students.

Observation Sheet Teacher Ability to Manage Learning

Observations were made by the mathematics teacher of class XI Mechanical Engineering at SMKN 1 Panyabungan. This observation aims to observe the learning carried out by researchers using the developed models and approaches. Data on the ability of teachers to manage learning were obtained by using observation sheets during teaching and learning activities. The observer writes down the categories of scores that appear by placing a check mark (✓) in the rows and columns of each assessed aspect.

Student Response Questionnaire

This questionnaire contains several statements to find out the opinions of students in response to the use of the STEM-integrated PjBL learning model. The student response questionnaire consists of 9 statements.

Learning Media Development Procedure

Analysis

At this stage of analysis, the researcher conducted an analysis for the development of learning models, feasibility and development requirements. The initial analysis of the development of the STEM integrated PjBL model starts from the learning problems that have been stated above.

Analysis of Student Needs

Analyzing the state of learning as the main information, providing tests of students' initial creative thinking skills and observing the availability of learning models that support the implementation of learning.

Character Analysis of Students

This stage is to determine the attitudes of students in learning mathematics and so that the development of learning models is in accordance with the character of students.

Curriculum Analysis

This stage is to pay attention to the characteristics of the curriculum used in the schools studied. Aims for the development of learning models in accordance with the demands of the curriculum. After that, the researcher examines the basic competencies to formulate indicators of learning achievement.

Formulation of Learning Objectives

This stage is an important reference in designing a learning model such as PjBL. This stage aims to describe indicators of achievement of learning outcomes into more specific indicators that are adjusted based on the results of the material and analysis of tasks that have been carried out previously. The indicators and learning objectives are adjusted to the core competencies and basic competencies in the 2013 curriculum.

Design

At this stage, the design of a stem-integrated pjbl learning model is carried out that is able to improve students' creative thinking skills which contains lesson plans, student worksheets, materials and examples of questions, and practice questions. Two steps were taken at this stage, namely: 1) further study and establishing the theories that underlie the content and construction of the stem-integrated PjBL model, and 2) designing the components of the learning model based on the supporting theories of the STEM-integrated PjBL model.

Development

After the product in the form of a learning model is designed, the product will then be tested for feasibility by the validators. This feasibility test is carried out to see whether the product developed is feasible to use in learning. The expert validators who test the feasibility of the developed product consist of material experts and model experts who aim to measure product feasibility in terms of content quality and objectives, learning/instructional strategies, and model design. At this stage, revisions are also made to things that are not perfect according to the criticism and suggestions from the validator.

Application of Learning Model

At this stage is the application of the integrated pjbl stem model that has been designed in the design phase. The stem-integrated PjBL model is a real product of the development of this PjBL-STEM learning model. The main components of the model book compiled are the rational development of the PjBL-STEM model, supporting theory, the stem-integrated PjBL learning model which contains the characteristics and components of the STEM-integrated PjBL model and instructions for implementing learning with the PjBL-STEM model. This PjBL-STEM model development product will be included in the student handbook.

Application of Learning Tools

The product in this phase is the initial script of learning tools that are in accordance with the PjBL-STEM model. Learning tools that are realized are learning implementation plans, teacher manuals, student books, student activity sheets and learning outcomes tests.

Evaluation

In the last stage, the final revision of the model, learning tools and instruments was developed based on the input obtained from the response questionnaire and the results of observations. It is intended that the models and learning tools developed are truly in accordance with the objectives to be achieved and can be disseminated (Mulyatiningsih, 2012).

RESULT AND DISCUSSION

Description of the results of the STEM-integrated Project Based Learning Model

The product of this research is a student handbook based on the STEM-integrated Project Based Learning model on building materials for students of SMK Negeri 1 Panyabungan class XI Accounting Department. This research design was carried out through 5 main stages, namely analysis, design, development, implementation, and evaluation as described as follows:

Analysis (Analysis)

Analysis of Student Needs

Some of the main problems that exist in the learning process are related to the implementation of mathematics learning. This problem has an impact on the low creative thinking ability of students. Thus, to overcome this problem, it is necessary to develop a mathematical learning model that meets the valid, practical, and effective criteria.

Character Analysis of Learners

From the results of the initial test analysis of students' creative thinking skills at SMK Negeri 1 Panyabungan, it is seen that students' creative thinking abilities are still relatively low. From the results of an interview with one of the mathematics teachers at SMK Negeri 1 Panyabungan, it is also known that there are still many students who have not achieved the KKM score (≥ 75) in the previous semester's math exam.

Curriculum Analysis

This curriculum analysis is shown to identify, detail, and systematically arrange the concepts that students will learn in the material Build space (cubes and blocks) into a concept map.

Formulation of Learning Objectives

The formulation of learning objectives obtained from this analysis stage can be seen in Table 1. below:

Table 1. Learning Objectives in Each Meeting

Topic	Indicator	Learning objectives
Analyze points, lines and planes in three-dimensional geometry	• Calculating the surface area and volume of a cube • Calculating the surface area and volume of a cuboid	1. Through discussion and analyzing students are able to apply the concept of the surface area of a building 2. Through discussion and analysis, students are able to apply the concept of volume and determine the relationship between the elements in cubes and blocks.
Presenting problem solving related to the distance between point to point, point to line and line to plane in three-dimensional geometry	• Create a project Props	

Design

The purpose of this stage is to design a student's book so that a prototype (initial design of the student's handbook) is obtained for building material (cubes and blocks).

Development

The definition and design phase resulted in the initial design of a student handbook called draft I. The first phase in the development phase was to validate draft I to experts and then conduct field trials. Expert assessment includes content validation which includes all student handbooks that have been developed at the design stage of draft I, resulting in draft II that is suitable for use. The results of the validation of the experts are used as the basis for revising and improving the student handbooks and instruments. Aspects that are validated include: quality of content and objectives, learning/instructional strategies, and design of student handbooks.

Implementation and Evaluation

After the learning model developed has met the criteria for validity (draft II), the research continues to the implementation stage. The learning model in the form of draft II and all learning tools were tested at the research location, namely class XI of the Accounting Department at SMK Negeri 1 Panyabungan, hereinafter referred to as trial I. If the research success criteria were met, the research was terminated. However, if it has not been achieved, the research will continue to trial II after improvements have been made**.**

Test Result Analysis I

The first trial was conducted in class XI of Computer and Network Engineering at SMK Negeri 1 Panyabungan with a total of 21 students. The first trial consisted of 2 meetings according to the lesson plan that had been prepared. In this trial phase, the researcher acts as a teacher who teaches. Learning is carried out individually because the teaching and learning process must continue to follow social and physical distancing programs to avoid the spread of the Covid-19 virus. The activities carried out can be seen in the Learning Implementation Plan (RPP) in the appendix.

Test Result Analysis II

From the analysis of the results of the first trial, the researchers found several weaknesses that must be corrected so that this research can produce student handbooks and tools that meet all valid, practical, and effective criteria. After the revision was completed, the second trial using the student handbook (draft II) and its equipment was carried out in class XI Accounting at SMK Negeri 1 Panyabungan with a total of 24 students.

Developed STEM Integrated Project Based Learning Model

Syntax

The STEM-integrated Project Based Learning syntax which was developed with step 1, the determination of the basic questions was developed to determine the basic questions related to scientific literacy which are (Scince) and mathematics (Mathematics). In step 2, namely identifying aspects of science, technology, engineering and mathematics in the project plan to be designed. Step 3, design a project planning based on technology and skills in designing a project. At this stage the teacher provides initial information on the use of technology and skills in designing a project. For students, the teacher ensures that students are able to determine technology and have the skills to design project implementation steps. In stage 4, draw up a schedule. The teacher and students make an agreement about the schedule for making the project. In step 5, monitor learners and project progress. In step 6, test the results. The teacher and students discuss about the project prototype. The teacher monitors the involvement of students and measures the achievement of standards. Step 7, Presenting the product results and the last step in the developed model is evaluating the experience**.**

Social System

Using the STEM approach can influence attitudes, perspectives, mindsets, interests, perceptions and skills to design something. This ability has an impact on individuals who are social in society. Furthermore, in terms of technology in the STEM aspect, in this STEM approach students can use technology positively. The use of

technology in the STEM approach is to facilitate learning and increase learning resources.

Reaction Principle

The principle of reaction relates to how the teacher pays attention to and treats students, including how the teacher responds to questions, answers, responses or what students do. The STEM-integrated PjBL model emphasizes learner-centered learning, so that the teacher functions as a facilitator, motivator, consultant mediator in teaching students.

As a facilitator, the teacher provides learning resources and provides assistance so that students are able to organize knowledge and skills to discover unknown rules, relationships and structures. As a consultant, the teacher is a place to ask questions when students have difficulty finding solutions to problem solving, encouraging students to keep trying to find solutions to problems. The teacher surrounds observing students work and provides opportunities for students to ask questions, express ideas freely and openly. As a moderator, the teacher leads the discussion, directing group discussions to run effectively. The teacher proposes alternative problem solving and ensures that all students carry out activities actively during the learning process.

Support System

The support system developed is the teacher setting up classes, instructional systems, learning tools, learning facilities and the necessary media so that learning is carried out effectively and efficiently. In this phase, the learning tools developed are learning tools that are in accordance with the STEM integrated PjBL model design. The tools developed are Learning Implementation Plans (RPP), Student Books, Student Activity Sheets, and Learning Outcomes Tests.

Instructional Impact and Accompaniment Impact

The STEM-integrated PjBL learning model emphasizes practicum-based or project-based learning that produces a real work. The PjBL model organizes the class in a project in which students must construct their own content knowledge and demonstrate new understanding through various forms of representation. Applying this PjBl model will have an impact on the ability of students to create contextual and useful works. The use of PjBL learning models can develop students' ability to solve problems, one of which is the ability to think creatively.

Results of the Validity of the STEM-integrated Project Based Learning Learning Model

Based on the results of the validation of the STEM integrated Project Based Learning learning model that was developed, it was found that the interactive learning model was declared valid or had a good degree of validity. Then the developed interactive learning model is also said to be feasible based on all aspects of the validity of the interactive learning model. Furthermore, the results of the validation of the learning implementation plan (RPP), Student Handbooks, Student Worksheets (LKPD), and creative thinking ability tests are also valid or have a good degree of validity. This shows that the STEM integrated Project Based Learning learning model that was developed along with the lesson plans, Student Books (BS), LKPD, creative thinking ability tests have met the validity criteria.

Practical Results of STEM-integrated Project Based Learning Learning Model

Through the observation sheet on the implementation of learning using the STEM integrated Project Based Learning learning model that was developed which was given to an observer at each trial meeting I and II, the results showed that the score for observing the implementation of learning did not meet the practical criteria in the first trial, namely with a score of 2.93. at the first meeting, the score was 3.13 at the second meeting, and the average was 3.03 ("Medium" category). While in the second trial, a score of 3.87 was obtained at the first meeting, 4.00 at the second meeting, and 4.27 at the third meeting. The average result of the observation of the implementation of learning in the second trial was 4.04 with the "High" category. This is supported by the opinion of Akker (2007: 66) which states that the criteria for the practicality of learning media are said to be practical if the observations of learning media in the classroom are included in the good or very good category. In the research of Marselina & Muhtadi (2019: 206) that the handbook learning media is easy to use and effective for improving student learning outcomes. Therefore, it can be concluded that the interactive handbook developed has met the practicality indicators**.**

Results of the Effectiveness of the STEM-integrated Project Based Learning Model

Based on the results of trial I and trial II, the learning model developed has met the effective category in terms of the achievement of students' creative thinking abilities, active activities of students, and positive responses from students.

The achievement of the final test of students' creative thinking skills in the first trial was 52% with 11 students declared complete. So, it can be concluded that in the first trial the application of the STEM integrated Project Based Learning learning model that was developed did not meet the criteria for achieving classical completeness (>80%). However, in the second trial, the achievement of the final test of students' creative

thinking skills had met the specified criteria, namely 83.3% with a total of 20 students who were declared complete. So, it can be said that the STEM integrated Project Based Learning learning model has met the effectiveness criteria in the aspect of achieving students' creative thinking abilities. This is supported by the research of Sonda, Alimuddin, and Asdar (2016) which states that the learning effectiveness criteria in terms of N-gain scores are in the medium category and classical student completeness is more than 80%.

Based on the results of the analysis of the achievement of learning objectives in the first trial, it was found that the achievement of the posttest learning objectives of students' creative thinking abilities in the first trial was only item 1 achieved, while item number 2 was not achieved. The achievement of the posttest learning objectives of students' creative thinking abilities in the second trial has been achieved for each item.

Based on the analysis of the results of observing student activities in the first trial, the average percentage of achieving the ideal time for student activities for two meetings in the first trial was 20.41%, 19.91%, 20.42%, 22.51%, 7.85% and 8.90%. While in the second trial, the average percentage of students' ideal time for three meetings was 22.57%, 18.40%, 23.26%, 23.26%, 7.29% and 5.21%. Based on these data, it can be concluded that all student activities in the second trial also meet the set ideal percentage of time.

Judging from the questionnaire response scores of students in the first trial of 90% and in the second trial of 94%. So it can be concluded that from the students' responses to the interactive learning model based on STEM integrated Project Based Learning that was developed effectively.

Improving Students' Creative Thinking Ability

Based on the results of the analysis of the creative thinking ability of students in the first and second trials, it showed that there was an increase in students' creative thinking abilities. Based on the average normalized gain, it was found that in the first trial there was an increase in the creative thinking ability of students with the "medium" criteria with a score of 0.3 (0.3 <g≤0.7) and in the second trial there was an increase in the value with "medium" criteria with a score of 0.42 (0.3 < N-Gain 0.7). So it can be concluded that the STEM integrated Project Based Learning learning model developed can improve students' creative thinking skills.

The results of this study are strengthened by several previous studies, namely research by Lani Meita Indah Furi, Sri Handayani and Shinta Maharani with the title Experimental Project Based Learning and STEM integrated project based learning to improve student learning outcomes and creativity in the basic competencies of milk management technology. at the Indonesian University of Education. The result of this study is that the creativity of students using the PjBL-STEM learning model on the basic competencies of milk processing technology has an average value of creativity that is higher than the creativity of students using the PjBL learning model.

CONCLUSION

The STEM-integrated Project Based Learning interactive learning model that was developed found that the interactive learning model was declared valid in terms of the validity results by the expert who stated that the learning device was categorized as valid with slight revisions. The interactive learning model based on the integrated Project Based Learning that was developed has also met the criteria for the practicality of the learning model in terms of the analysis of the results of the observation of the implementation of learning in the second trial, the score for the observation of the implementation of learning increased to 4.04 (category "High"). So that the learning model developed successfully meets the criteria for the practicality of the learning model. And the interactive learning model based on STEM integrated Project Based Learning that was developed that was developed has met the established effectiveness criteria in terms of: (1) In the second trial it was 83% (20 students); (2) The achievement of learning objectives has been achieved for each item in the second trial, namely question number 1 by 80.67% and question number 2 by 80.33%; (3) student responses in the second trial were 94%; and (4) the learning time used does not exceed the usual learning time set by the school.

Based on the normalized gain index, it was found that in the first trial there was an increase in the creative thinking ability of students with the "low" criteria with a score of 0.30 (g 0.3) and in the second trial there was an increase in the score with the "moderate" criteria with a score of 0.42 (0.3 < N-Gain 0.7). So it can be concluded that the interactive learning model based on the STEM integrated Project Based Learning that was developed can improve students' creative thinking skills.

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