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STEM Approach in Developing Natural Science for Junior High School Level in Order to Improve Students' Critical Thinking Skill and Scientific Process Skill

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***Abstract*—This research is aimed to discover the feasibility of the Natural Science subject teaching tools developed using STEM approach. It consists of lesson plans, worksheets, and assessment tools for evaluating critical thinking and scientific process skills. This research utilized the Research and Development (R&D) method. The Research and Development method used applies the ADDIE model (Analysis - Design - Develop - Implementation - Evaluation). The outcome of the research is the validated Natural Science subject teaching tools which were developed using STEM approach. The teaching tools were validated by academic experts (lecturers) and teachers of the Natural Science subject. The average of the validation results of the developed lesson plans was 97% which is categorized as very good. The developed worksheets were rated 3.36 which can be categorized as good. The data used for validation were analyzed using Linkert scale. The instruments used in the research were in the form of validation sheets from academic experts (lecturers), teachers of Natural Science subject, and worksheets rated by students. The feasibility of the observation sheets used to assess students' critical thinking and scientific process skills were each rated 95% and 88.9% which can be categorized as very good. The observation itself was carried out in SMP Stella Duce 1 Yogyakarta in November 2017. The results of this research show that the Natural Science subject teaching tools developed using STEM approach are feasible to use in the said subject teaching-learning processes.**

Keywords—STEM approach, critical thinking skill, scientific process skill

I. INTRODUCTION

In the era of globalization, it is necessary for the Indonesian students to be equipped with the 21st-century skills. This is aimed at ensuring that every student has the competence needed to compete in this modern era. This 21st-century learning paradigm emphasizes that students must have the ability to think critically, to solve problems, to connect the science they learn with the real world, to master information technology, to communicate, to collaborate with other people and to master skills that involve the cognitive, affective and psychomotor spheres [1]. The mastery of the 21st-century skills is carried out by understanding the characteristics, achievement techniques, and learning strategies.

Since 2015 the ASEAN Economic Community (MEA) Agreement or ASEAN Economic Markets has come into force. One of the consequences is that graduates of certain levels of education unit/school have the right to compete freely to be in job market in ASEAN countries. So, this agreement not only affects the economic sector, but also other sectors, including education or schooling, which is regarded as the locomotive of human development. Since Indonesia was elected to be the center of MEA free-trade, the government has to prepare all the needed programs focused on infrastructural sectors and human resources. The government have to make sure that the education makes all the citizens have sufficient and qualified professional skills.

Based on 2015 data from the Central Bureau of Statistics Badan Pusat Statistik [2], the absorption of manpower in Indonesia is still dominated by unskillful workers, who only study at Junior High School or elementary school. Based on the data issued by the Central Bureau of Statistics in February 2015, the number of workers whose educational background is of elementary school (SD) is 54.6 million; junior high school (SMP) is 21.5 million; and senior high school (SMA) 18.91 million. Meanwhile, the population of highly educated workers totally only reaches as many as 13.1 million people. The low number of graduates of higher education level is due to the fact that most of the people have not been able to reach higher education for economic reasons. Consequently, most workers consider that it is enough only to achieve the elementary educational level or junior high school.

Education has an important role in preparing human resources for facing the MEA. Generally, its role is to provide skills both soft skills and hard ones. So, qualified human resources are produced by the quality educational process. In fact, the high quality of education among community members has been a major problem to solve.

In the present time, all the stake holders are trying hard to improve the quality of education in Indonesia especially in the field of natural sciences (Ilmu Pengetahuan Alam/IPA). This effort is carried out by implementing reasoning, logical, systematic and critical thinking skills in the learning-teaching process.

The trending teaching method carried out the daily learning-teaching process is the student-centered learning

process. This process of learning is aimed to help students learn to construct their own knowledge to be able to realize meaningful learning. However, these field observations shows a different result, that is, the learning-teaching process in Indonesia's classrooms is still oriented towards the achievement of Graduate Competency Standards (Standar Kompetensi Lulusan/SKL). The success of students is still measured by the mastery level of teaching materials, not by how to explore and use all the skills and the materials. The impact of this educational practice is that the graduate of all the Indonesia's schools has no sufficient skills and competence in complying the demand of qualified workers in all fields.

In the present time, schools tend to apply the Low Order Thinking Skill (LOTS). The rarely use the Higher Order Thinking Skills in the learning-teaching activities. Consequently, the students are not familiar with higher order thinking skills which include the cognitive levels of C4 (analyze), C5 (evaluate), and C6 (create). In other words, if the teacher uses the Low Order Thinking Skill, the students will not achieve the higher order thinking skills.

The results of a preliminary study at State Junior High School (SMP Negeri) in Yogyakarta City showed that in the learning process students are not fully involved actively in the learning process and in building their own knowledge and skills. Thus, the ability of thinking creatively and critically is not well-developed. In other words, the students tend not to be able to design or develop ideas for solving problems scientifically and making an invention/innovation.

In order to improve the quality of human resources, critical thinking skills and the scientifically thinking process skills are seriously applied in education nowadays. In the 21st century, critical thinking skills and scientifically thinking process skills are ones of several inventions in learning-teaching processes whose aim is to prepare future qualified human resources. Lai in [3] defines critical thinking skills as students have several skill components including analyzing an argument, making inference using inductive or deductive reasoning, assessing or evaluating and making decisions or solving a problem. Students' critical thinking skills should be emphasized in the learning teaching process. Its aim is to produce more enjoyable and meaningful learning experience for both students and teachers. Natural science is not just a collection of knowledge, but involves how to discover, process and acquire a set of knowledge. A researcher who wants to do an experiment should master the required skills to acquire a piece of natural science, like thermodynamics [4]. Besides the ability to think, scientific process skills is to be developed so that knowledge obtained by students can be meaningful.

Project-based or problem-based learning connects students with their own problems and the ones they encountered in daily life. The two models of learning strategy which are based on problems which they have and possible problem-solving strategies, students continually learn the subject matter and competence in a structured way. In the project-based learning model, problem-solving is embodied in an actual product which is created by the students themselves. In the problem-based learning or the project-based learning model teachers encourage their students to inquire or investigate and invent or discover their own knowledge or solution. The project-based learning model is appropriate to develop communication skills, critical thinking skills, collaboration and creativity. This learning model is appropriate to develop some of the skills which must be possessed in the 21st century. Using the project-based learning model, the students are expected to build their own knowledge through a series of thinking processes in order that they can develop the critical thinking ability and science process skills continuously; and in the future they can prepare themselves to compete in international job market.

Youth manual [5] predicts the increase of employment needs in the world. It states that in the future Indonesia the projected need of employee in the health sector grows up to 16% from 2012 to 2024; the mechanic-technique sector is projected to increase up to 8%, and the information technology sector increases up to 7%. The whole sectors are in the domain of the so-called STEM interdisciplinary (Science, Technology, Engineering and Mathematics). Since most Indonesian students have weaknesses in the mastery of mathematics, problem-solving, computer-based skills, these have to be initiated as early as possible through an educational process. The effort to solve the problem of the increasing needs includes the internalization of attitudes, knowledge, and skills and career prospects in the future. This effort helps the students to prepare themselves to compete in the global job market.

Since the future job market demands the mastery of science, technology, engineering and mathematics, the STEM approach in the teaching-learning process can be one of the possible alternatives. This approach encourages teachers to integrate multiple disciplines, like science, technology, engineering, and mathematics. In short, this interdisciplinary approach leads the students to learn something holistically. The Education Council in [6] states that schools should support skill developments by means of interdisciplinary tools, like: sciences, critical and creative thinking, critical thinking skills, problem-solving skills and digital technology. These are the competence which the students have to master in the 21st century. These skills are the core objectives of STEM learning.

There are several reasons for the encouragement to apply the STEM-based approach in the teaching-learning process. One is the approach provides a broad overview to increase students' interest for their career in STEM field. In addition to improving the ability of the students in understanding the complexity when faced with problems in real life. The National Research Council (2010) presents a research on the success story of the STEM approach in the US. Based on the success story in the USA, many countries, including Indonesia, try hard to adopt the STEM-based learning approach. All these countries have modified and improved this learning approach to improve the quality of education.

Various researchers and innovations on the STEM approach show that this approach has been improved. One of them is the integration of the Project-Based Learning with STEM (science, technology, Engineering, and mathematics). However, the research on the STEM-based approach which integrates the Project-based Learning shows that the teaching and learning tools which support the approach have not

developed and improved properly, yet. Consequently, the STEM approach integrating the Project-based Learning model is not completely practiced in the classroom learning-teaching process.

Based on this arising problem, the researcher improves the learning-teaching process by improving and implementing the tools of the the STEM approach which integrates the Project-based Learning model. The tools are focused on the calorie that they can be use in the classroom context to improve the critical-thinking and scientifically process skills

The rest of this paper is organized as follow: Section II describes the proposed method. Section III describes the result and following by discussion. Finally, Section V concludes this work and highlights future work.

II. PROPOSED METHOD

This research is a development research, Research and Development (R & D). The R & D method used in this research is the ADDIE model developed by Molenda in [7]. This model consists of the following steps: Analysis - Design - Develop - Implementation - Evaluation. The location where the research was conducted is at SMP Stella Duce 1 Yogyakarta. Data collection techniques used in this study is in the form of questionnaires which are used to validate the feasibility of the learning tools of the natural science subject (*Ilmu Pengetahuan Alam*/IPA) with the STEM approach developed by the teachers. The data analysis is conducted by analyzing the feasibility of learning tools by two expert lecturers, three natural science teachers, and fifteen students who were told to give their responses to the student-work-sheet composed by the teachers. The tools to validate the questionnaire on the Lesson Plan (RPP) consist of all the elements required to make the standardized lesson plan as Widoyoko in [8] and the 4-scale conversion is used to validate the student-work-sheet. The analysis of critical skills assessment and science process is based on the decided categories [8]. The learning tool in the form of RPP is feasible to use if the validation score is in either category with the percentage of more than or equal to 75% as Borich in [9]; and the student-work-sheet is feasible to be used in science learning in school if the average validation score of developed devices is more than or > 2.5. The assessment tools of critical thinking skill and science process skill are said to be appropriate if the validation score is at a percentage of more than or equal to 75% [9].

III. RESULTS AND DISCUSSION

The natural-science teaching-learning tools with the developed STEM approach is allowed to use in the classroom teaching activities after being assessed of validators. The team of validators who assess the learning tools consists of two expert lecturers, one natural-science teacher, and fifteen students. This team is to determine whether the teaching-learning tool is feasible to use or not. The lecturers consist of an expert who masters the core teaching materials and another masters the teaching media. The natural-science teacher is also asked to assess the teaching tools and review to make the tools are feasible to teach. The students are asked to review whether the work-sheet which is composed on the basis of the advanced STEM approach make them learn easier or not. The questionnaire or tool of the validation is prepared by the researcher.

The results of the RPP validation assessment by expert lecturers and IPA teachers are presented in Table I.

TABLE I. SUMARY OF ASSESSMENT DATA ON TEACHING TOOLS

Assessment Data	Percentage	Criteria
Stage 1	83%	Good
Stage 2	97%	Very Good

The assessment of the lesson plan with the STEM approach is carried out through two stages. The average assessment result of the lesson plans from the expert lecturers and natural-science teachers in the first stage reaches a percentage of 83% with good criteria. This criterion is sufficient to categorize that the developed lesson plans are feasible to use, since the assessment results ≥75% than the demanded requirement. However, there are several aspects that need to revise. So, the lesson plans will be re-evaluated by the validators through the second assessment stage. The revision of the lesson plans includes the following sections: (1) the learning objectives should be in accordance with the ABCD guideline, that is, Audience, Behavior, Condition, and Degree; (2) the learning method used should be explicitly stated, (3) the activities emphasizing the STEM approach must be focused only on students. Teachers must design learning activities that can trigger students' curiosity to learn the material, even, enrich the standardized material as stated in the compulsory text book (*Buku Teks Pembelajaran*/BTP); (4) learning materials have to be designed much more complete, (5) the formula has to be written according to the standardized versions; and (6) some typing errors have to be corrected.

The revised lesson plans are given back to the validator and science teacher for reassessment. The result of the second validation stage reached a percentage of 97% which is categorized as in the very good category. The result of the lesson plan assessment at this stage have proved that the developed lesson plans with the STEM approach is feasible to be used in the lesson teaching-learning activities. The lesson plans are feasible to use because they have been designed on the base of the criteria arranged to improve the skills of critical thinking and science process skills.

The teaching-learning tools which must be designed in the next step is the student-worksheet. It must be designed based on the STEMP approach, since it is expected to improve students' thinking and science-process skills. The student-worksheet which is designed using the STEM approach is validated through a two-stage review by expert lecturers and natural-science teachers. The result of the student-work sheet validation results is presented in Table II.

TABLE II. SUMMARY OF THE STUDENT-WORKSHEET VALIDATION

Assessment Data	Average	Criteria
Stage 1	2.6	Good Enough
Stage 2	3.36	Good

Based on the Table II above, the average score of the validation in stage 1 results 2.6. This score shows that it is in

the good enough category. This means that the student-worksheet which is designed using the developed STEM approach is not feasible to use yet. Consequently, it needs to be reviewed and revised to the expected criteria. After the review and revision, the student-worksheet is given to the validators to review and decide whether it is feasible to use or not. In this process of review and revision, the focus is on the design to improve students' critical thinking skill and science skills.

The result of the assessment by the validator shows the validation score of 3.36. It means that it is the good category. These results indicate that the developed student-worksheet has been feasible to use to improve the skills of students' thinking and science process.

The limited field validation of the student-worksheet has been done. This validation was conducted by involving a limited number of the targeted students. The number of the students involved in this validation is 15 persons. The criteria of the validation consist of the following components: linguistic components, the presentation components and the components of graphic, materials, and skills which are expected to develop in the teaching-learning process. The result is presented in Table III.

TABLE III. SUMMARY OF THE LIMITED VALIDATION OF THE STUDENT-WORKSHEET

No	Festivity Aspect	Student Score	Category
1	Linguistic Aspect	3.72	Very good
2	Presentation Aspect	3.41	Very good
3	Material Aspect	3.6	Very good
4	Material Aspect	3.6	Very Good

Some parts of the student-worksheet must be revised because of: (1) the lay out is still less attractive; (2) charts and drawings are needed to add on certain parts; (3) the sentences in the student-activity steps are made much communicative; and (4) the font type is much varied. The teaching-learning tool which is assessed next is the form which is used to observe the students' critical thinking skills. Critical thinking ability, according to Moon in [10], is the ability to think deeply as indicated by expecting something in the form of inaccurate information or the one which needs to evaluate further. While Lai in [3] defines the skills of Critical Thinking as a mental process, strategy, and representation for a process in problem-solving, making decisions and learning new concepts. Critical thinking skill is a process of thinking in learning that includes six indicators of thinking ability. The six critical thinking skills are interpretation, analysis, evaluation, inference, explanation, and self-regulation. The feasibility of the critical thinking observation sheet also goes through two stages of revision. Questionnaires which is used to assess this critical thinking observation sheet include several indicators that correspond to the critical thinking aspects to be measured. The validator will assess whether the indicator is formulated in accordance with the aspect of critical thinking to be measured or not. The summary of the validation on the tool to evaluate the critical thinking skills is presented in Table IV.

TABLE IV. THE SUMMARY OF THE VALIDATION ON THE FORM TO EVALUATE THE CRITICAL THINKING SKILLS

Assessment Data	Average	Criteria
Stage 1	86.4%	Good
Stage 2	95.5%	Very Good

Based on the Table IV above, in the first stage, the validation score on the observation sheet to assess the critical thinking skills reached 86.4% with the good category. Although the score has reached the appropriate standard, the tool should still be reviewed and revised, based on the recommendation and feedback provided by the validators. The second stage of assessment, the tool is much better, since it reached the percentage of 95.5% which is in the very good category. This means that. according to the experts, some of the formulated indicators have been in line with the critical thinking aspects to be measured.

After the measurement tool of the critical thinking skills, the form of the questionnaire used to measure the students' science process skill is validated. The science process skill is inherent in the learning process of natural science (IPA). One of the uses of studying natural science is to improve students' understanding of the nature of science. The most important dimension of the nature of science is the way to gain knowledge by using the scientific method. Science learning aims to train students to be active in acquiring knowledge or science concept by integrating their skills, knowledge and scientific attitudes. IPA is closely related to how to find out or discover or create something. Science is not just about a collection of knowledge; but it also involves a kind of scientific knowledge or a process of discovery. Researchers who want to do the experiment should have skills like the science process skills [4]. The feasibility of questionnaires on the science process skill is also determined through two stages of revision. The validators will assess whether the indicator formulated is in accordance with the science skill aspects to be measured or not appropriate. The summary of this validation is presented in Table V.

TABLE V. SUMMARY OF THE VALIDATION OF THE SCIENCE PROCESS SKILL QUESTIONAIRE

Assessment Data	Average	Criteria
Stage 1	83.4%	Good
Stage 2	94.5%	Very Good

The Table V above shows that, in the first stage, the score of validation on the questionnaire on the science process skill obtained a percentage of 83.4% in the good category. The tool should still be reviewed and revised, based on the suggestions and inputs from the validators. In the second validation stage, the score on the questionnaire of the science process skill increased to 94.5% with the very good category. Based on the validation assessment which was done, the assessment tool in the form of questionnaires to measure the students' attitude on the science process skills is feasible to be used in the teaching-learning activities.

IV. CONCLUSION AND FUTURE WORK

Based on the results of research and discussion we can conclude that the learning tools of the natural science subjects (IPA) with the developed STEM approach can be

categorized appropriate to be used in the teaching-learning activities after they are reviewed, and revises based on the recommendation and inputs from the expert lecturers and science teachers.

Suggestion from this research is that the student-worksheet should be well-designed with selected colorful charts and drawings, since they can motivate the students in using the developed worksheet.

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