

Design and Validation of STEM-based Lesson Plan to Empowering Student's Critical Thinking Skill in Stoichiometry

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Abstract. Science, Technology, Engineering, and Mathematics or STEM is a learning model can improve student's critical thinking in the 21st century. STEM is a paradigm that can create interdisciplinary learning and can improve student's critical thinking skills when using the STEM model. The aims of this research is to determine the STEM-based indicators in empowering the critical thinking skills of students provided in Senior High School. This research methodology is descriptive case study approach, with observation and interview, and an introduction of STEM model for teacher and student by using small class application. The participants in this study are 8 experts, and students. The technique of assessing lesson plan using Delphi technique with 8 experts as an evaluator of STEM-based Lesson Plan. Before and after studying with the STEM model, the results show: (1) Lesson Plan expressed by the teacher can be used in the learning process; (2) Instruments introduced, lesson plans based on the STEM learning model can be introduced and can empower students' critical thinking skills in trials observation; (3) The learning process experiences a cultural change by teachers and students.

Keywords: Critical Thinking Skills, Learning Process, Interdisciplinary Learning, Lesson Plan, STEM

INTRODUCTION

Science, Technology, Engineering, Mathematic or STEM, is a growing learning model today across the country. One of the countries that developed this learning model is America. This is because STEM learning is able to overcome the challenges experienced in various fields. The progress of research development with the STEM model is used to address global challenges, this is because this learning model has overcome the concerns and brought attention to the need for improvement in STEM education[1], besides the use of STEM model learning is required for the demand for training on Science skills a consideration in the development of STEM model research [2]. The largest impact on STEM entrance is reported to be the intent to major in STEM, which is directly affected by high school students' exposure to and achievement of mathematics and science courses[3].

STEM is a science approach with has four aspects in it. The four aspects are Science, Technology, Engineering and Mathematics. These four aspects constitute an ongoing unity between real-world problems, and also problem-based learning [4]. The STEM model is a learning model that can create a cohesive and active learning. The process of STEM learning is the use of skills and knowledge simultaneously by learned [5].

Learning STEM model is good used at the level of basic education, intermediate to college level, even this learning is good to be used until doctoral level [6]. The importance of the use of learning model is done early,

because the use STEM learning model in the field of education has a goal to prepare learners in order to compete and ready to work according to the field that occupied. In addition, the objectives of learning with STEM model in primary and secondary education are as follows: (1) having knowledge, attitude, and skills to identify questions and problems in their life situations, explaining natural phenomena, designing and drawing evidence-based conclusions on issues - related STEM; (2) to understand the specific characteristics of the STEM discipline as forms of knowledge, investigation, and design initiated by humans; (3) have an awareness of how STEM's disciplines form a material, intellectual and cultural environment; and (4) have a desire to engage in the study of STEM-related issues (eg energy efficiency, environmental quality, natural resource constraints) as constructive, caring, and reflective citizens using science, technology, engineering and math ideas[7].

One of the objectives of research with STEM model is developed to compete globally, that is by improving society's ability in science and innovation. Kennedy Dan Odell, pointed out that learning high-quality STEM models should include (1) integration of technology and engineering into science and mathematics; (2) putting forward the scientific process by means of scientific investigation and engineering design, including math and science instruction; (3) a collaborative learning approach to learning, by connecting students and educators with STEM learning models; (4) provides a global and multi perspective; (5) can combine strategies such as project-based learning, providing formal and informal learning experiences; and (6) may use appropriate technology to enhance learning [8].

The use of the STEM learning model is used because of the demand for 21st century education development. This is because the 21st century curriculum demands a change of learning process, where learning is not only seen in terms of the output but from how the knowledge process was obtained [9]. So to obtain qualified human resources, then learning with this model also needs to be developed to face the era of global competition and the demands of 21st century education. In addition to the development of the 21st century, one of the obstacles to science learning is the skill of the process of science, which is seen from the low ability reading and interpreting, logical, rational and systematic thinking ability of students[10], as well as low student communication skills[11]. In learning science that is taught should pay attention to the process, attitude and technology. Because by looking at these three things it will be able to develop aspects of cognitive, affective and science process skills of students [12]. From these factors, what we will do from this research is to make STEM-based lesson plan instruments to empower critical thinking skills of students in Senior High School.

METHODS

The methodology of this research is descriptive case study approach. The process of this study consists of four steps: (1) Observation and interview of teacher and student about learning process in School; (2) Review and make STEM-based lesson plans empower students' critical thinking skills; (3) evaluating the instruments that have been made by involving 8 experts; (4) Applying the already created instrument, this application is to know whether the instrument can be used in High School.

Object of research in this research is experts and students. Expert consists of 7 teachers and 1 lecturer. The purpose of the expert and the teacher is to evaluate the already created instances using the Delphi technique [17]. Delphi technique is a method used to collect information in the form of opinions from several experts through a questionnaire. Whereas the students aims to seek information about the instrument that has been created and evaluated.

The lesson plan refer to STEM-based learning, so it consist of four disciplines. The disciplines are; Science, Technology, Engineering and Mathematic. The design of STEM-based lesson plan were developed will be an example for stoichiometry matter on STEM education. The activities in each discipline can be seen below:

1. *Science Discipline:*

- a. Students divided into 4 groups, and then students in each group discuss about stoichiometry. For the evaluation in this phase, students are asked to share their thoughts about the case and various examples of stoichiometry from their daily lives.
- b. Teacher give the students 3 chemical solution, are: NaOH, CuSO₄ and HCl. From that solution, students must looking for stoichiometry reaction precipitation and Stoichiometry of Acid-Base Systems.

2. *Technology Discipline*: Students are taken into a computer laboratory to watch Stoichiometry animation or real experiment. For the real experiment students upload it in to social media or youtube. And for clarity in student labs can edit videos obtained at slow speeds.
3. *Engineering Discipline*: Students work in groups in the laboratory. They use their newly acquired knowledge about stoichiometry.
4. *Mathematic Discipline* : Students can write a reaction and after that the student can determine the mass and the mass ratio in a reaction.

Trial to students conducted during 3 meetings. The first meeting of the students is to provide a pretest and be given material using the evaluated lesson plan. For the second meeting is to evaluate the tasks and problems provided by a teacher, and at the end teacher gives post-test to the students.

RESULTS AND DISCUSSION

Observation and Interview

Observations and interviews have an important role in a research, to dig as much information on the object to be studied[13]. Observations and interviews in this study are used to: (1) Know the instruments used by teachers and the learning process in the School; (2) Find out what problems are faced in school and to find out whether STEM model learning should be used in the School or not; (3) Environment, facilities and infrastructure in the School. The process of observation and interviews involves several teachers and some high school students in Kediri.

The results of the observation and interviews in the school found that: (1) It appears that teachers use traditional and didactic learning systems; (2) Chemistry lessons are considered the most difficult lessons by students; (3) Student's activity is still lacking in the learning process and the lack of sample use of the taught material is still lacking; (4) Children's skills in disclosing or communicating science are lacking; (5) The classroom environment supports the complete and yet untapped facilities and infrastructures, namely LCD, laptop, internet and laboratory; (6) The assignment is given only from books used in the School only, that is in the form of problem-solving; (7) Instrument owned by teachers have not been able to empower students' critical thinking skills, (8) The level of completeness at the stoichiometric material in high school is low, this can be seen from the school data on the completeness of stoichiometric material in the academic year 2016/2017. Lack of utilization of facilities and infrastructure in this School due to: (1) Time and ability of teachers in making Power Point so that LCD utilization is not maximized; (2) The laboratory in the learning process with the lab is still lacking; (3) Utilization of IT or internet with Laptop on learning process Virtual laboratory also not yet exploited, on the other hand by using virtual laboratory can support result of learning process [14]. So by observing the results of observations and interviews, researchers want to create and use a lesson plan based on STEM in deceiving critical thinking skills.

Lesson Plan Design

Lesson plan instruments are made with STEM-based to empowering critical thinking skill. The lesson plan made attention to the 2013 curriculum and the syllabus used in the School in stoichiometric material. Stoichiometry material is chosen because it is seen from the unfinished student in this material and the stoichiometry is considered difficult by the students. One of the difficulty is the students can't connect the stoichiometry material with daily life. Because of that, the lesson plan instrument made with STEM-based can be used to solve student problems.

The STEM-based lesson plan is demonstrated by the start of learning using several examples of images related to stoichiometry (battery, calorimeter, heating or boil water, water capillarity symptoms, etc.). But before students are given examples of such images, at the previous meeting, students were asked to learn stoichiometric material and teacher give pretest to the students. The purpose of giving the example image is to empowering students' thinking skills.

At the meeting using the STEM model, teachers will divide the learners into 4 heterogeneous groups. Each group will create media (in the form of videos, posters, podcasts, or other media) with different of theme in each group.

Teacher must introduce to students that each student in a group must know very well about material that will present. Teachers should note that each child will play an active role in the process of completing the task. Furthermore, students will present their group work results, and the results of media that have been made students will be uploaded in social media.

Lesson Plan Evaluation

A gradual evaluation is required to provide a good and applicable product of lesson plan in the School. Evaluation of lesson plan is done with Delphi Technique, the questionnaires were given to 8 experts in their field. The 8 experts who has been competent in chemistry subject, consist of 7 teachers and 1 lecturer. The first session of the evaluation is the introduction of the STEM learning model and evaluation with the development of lesson plan that has been made by the researcher. In the first session it is hoped that the teachers and experts will give input and criticism to the result of the lesson plan that has been made. But in 1st session the teacher meeting the teacher asked what STEM is and how the model goes, because it's a new for them. These practitioners are expected to provide input, suggestion and criticism to the developed lesson plan in the form of a questionnaire and the input sheet provided (Figure 2). In 1st and 2nd meeting some of suggestion still many suggestions. Meanwhile in the 3rd session with 8 experts stated that the developed lesson plan is already valid, so from expert and teacher claim that it can be tested to the class.

Activities	Activity Description	Time (minute)
Preliminary	<ol style="list-style-type: none"> 1. Teachers give pre-test to students. 2. The teacher gives apperception to the learner by showing some sample images of stoichiometry (battery charging, capillary, syphon, in water, kinetic gas theory, calorie meter, water cooking) using PowerPoint. The teacher asks the students to name the displayed image and ask the relationship between the images and the material to be studied. 3. Teachers remind and associate new material with prerequisite materials about stoichiometry. 4. Teacher conveys the objectives and learning step that will be done. 	45
Core	<ol style="list-style-type: none"> 1. The teacher discusses the outline of the material that has been given in WordPress (https://chimicaedu.wordpress.com) using a given thermochemical example. 2. Teachers divide learners into 4 heterogeneous groups and ask students to sit in groups. Each group is given different problems. 3. Each group is given a solution to search 	45

Fig 1. Lesson Plan Instrument with STEM Learning Model

Trials or Experiment of Lesson Plan

After lesson plan with STEM model declared valid by the teacher and assessment instrument have been made, then the teacher apply in class. Researchers here act as observers. From the results of observations made by researchers can be seen that: (1) Participants (students) look active and communicative; (2) Teachers are more communicative to students; (3) The appearance of student creativity during the learning process; (4) Student can find the conclusion about the material; (5) Students are active in providing questions; and (6) The skills of the students 'science processes are shown by the students' ability to explain simply, draw conclusions, and choose the right strategy or action to solve the problem. These skills are shown during the learning process. While that needs to be considered in this learning model teachers should be able to assess which students are working to solve problems and not. Results of these studies allow for a change in the science process skill. It is because from another literature, There are 10 indicators on science process skill: (1) Observing, (2) Classifying, (3) Looking for Conclusion, (4) Predicting, (5) Questioning, (6) Hypothesis, (7) Planning experiment, (8) Manipulating materials and equipment, (9)

applying, (10) Communicating[15]. From that indicators, the result of research can influence the developing the science process skills. Science process skill is one essence of thinking and research in science, it is because science process skill could reflect the true behavior of scientists when solving the problems and plan experiments [15].

By used STEM-based in learning, this learning makes learning process more effective. The effectiveness of this method can be seen in table 1. One of the goals of STEM education is to raise interdisciplinary thinkers[18]. Four disciplines of STEM education is combined to teach a science subject. The results of this study are consistent with the study conducted by Becker and Park[19]. But on the other hand the teacher also revealed, for STEM-based learning change takes time for full use. because for the change using this method requires time and learning style applied in Indonesia now has become a culture, while the teacher believes STEM-based learning is a new culture in the learning system for teachers and students.

ASSESSMENT SHEET OF LESSON PLAN

Name :
 Instance :
 After reviewing PPP Stoichiometry, please gives the comment

No	Skill Component	Indicator	Score				Note
			1	2	3	4	
1	Clarity of subject identity	a) The name of the subject is mentioned				v	
		b) The subject matter is mentioned				v	
		c) Name of school grade of education and class mentioned				v	
		d) Semester, duration of learning is mentioned				v	
		e) The author's name is mentioned				v	
		f) Formulation of KI and KD in accordance with the curriculum				v	
2	Clarity of indicator formulation and learning objectives	a) Clear indicator formulation (measurable)				v	
		b) Indicator measures KD complete and clear				v	
3	Clarity of topics and learning materials	a) Selected topics support the achievement of KI and KD				v	
		b) Topic of topic according to formulated indicators and time allocation				v	

4	Conformity of method/strategy approach learning step, with topic and learner	a) In accordance with the objectives of learning, material, time allocation, and learner.				v	
		b) The design of learning activities, focused on learning objectives.				v	
		c) Contains the design of student learning activities that require interaction with learning resources.				v	
		d) Contains material summaries with indicator and time allocation				v	
		e) Make use of prior knowledge				v	
		f) The design of learning activities in accordance with student development				v	
5	The suitability of the selection of tools, media and learning resources with topics, learning strategies, and learner.	a) In accordance with the objectives of learning, material, and learner.				v	
		b) Using media and learning tool.				v	
		c) Allow student to engage in the use of media prop.				v	
6	Conformity assessment with indicators and learning objectives	a) Clear, complete technique, procedure, and instrument.				v	
		b) Instrument appropriate indicator				v	
		c) The formulation of the question clearly according to the expected answer				v	
		d) Problem/question; encourage student to develop chemical communication				v	
		e) The instrument has an answer key and a scoring guide				v	

Fig 2. Validation of Lesson Plan with STEM Learning Model

Table 1. Data of Pretest and Posttest Students on Stoichiometry

No	Pretest	Posttest	Pre-test Mean	Post-test Mean
1	20	90	18	94.5
2	20	100		
3	20	100		
4	10	90		
5	20	90		
6	10	100		
7	30	90		
8	10	90		
9	10	90		
10	20	100		
11	20	100		
12	20	100		
13	10	90		
14	30	100		
15	20	90		
16	20	90		
17	10	90		
18	10	100		
19	20	90		
20	30	100		

CONCLUSION

The results of lesson plan review by some experts in STEM-based learning, then the STEM-based lesson plan can be tested in the classroom. The results of this good study can also be seen from the results of pretest and posttest obtained from research and learning process. The pretest and posttest results indicate a good improvement of the students with STEM-based learning. While in the change of learning process, give a good result. Activity, habits, and behaviors between teachers and students are change. This positive effect is characterized by cultural changes experienced by teachers and students, teachers become more communicative and students become more active and confident in providing information. In addition, students better understand about the relationship between science stoichiometry material in class and students know science in everyday life. Thomas and Watters argue that STEM learning models will have good results if in the classroom still use traditional learning models [16]. And the result of pretest and posttest indicate that the learning process contained in the lesson plans; liveliness, curiosity of students, the ability to observe and give conclusions, can make students' cognitive value will be better [12]. So this learning can be used as one of the models that can be applied and introduced in Indonesia.

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