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Effectiveness of the Guided Inquiry Model Integrated with STEM to Improve the Student Critical Thinking Skills in Chemistry Learning

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Abstract:- This research is conducted to know the effectiveness of the guided inquiry model integrated with STEM to enhance the student critical thinking skills. This reseach is begun with development of chemistry learning device for thermochemistry topic using the 4-D model. The subject of reseach are the fifty seven students of XI grade divided in two classes (MIA-1 and MIA-2) at Muhamadiyah 10 Senior High School, Surabaya, Indonesia. The results of study showed that validity of the learning device developed were very valid category. The guided inquiry model integrated with STEM was effective to increase the student critical thinking skills with gain score of medium category for the MIA-1 class and high category for MIA-2 class, respectively. There was significant difference between pretest score and post test score for two classes based on t-test analysis. The critical thinking skills of students changed from very less critical category to critical category, in both classes studied.

Keywords:- *Guided Inquiry, STEM, Critical Thinking Skills, Thermochemistry.*

I. INTRODUCTION

Recently the science and technology had developed very fast so students are re-quired to master some skills in order to compete globally. Therefore, 21st century skills had integrated in learning activities as student's provision in facing globaliza-tion. Based on the study result of PISA in 2013, Indonesian occupies a position of 64 from 65 countries. There are three student ability in this review namely mathematics, reading and scientific abilities [1]. Based on the data, it showed that students did not get much motivation in developing their critical thinking. As the result, they can only remember something they studied but they do not understand how the knowledge is applied.

In learning process, it is true if students are directed to be active in having critical thinking. The student activities in learning process have an important role in building students thinking and also one of constructivism learning fundamentals. The students build their knowledge actively not only infiltrate the ideas from the teachers [2]. Mas-tering the critical thinking skills is not enough to be used as main process that sustains students to overcome their uncertainty future. The critical thinking skill is used as a basis for problem-solving. Through the ability to think critically, someone can assess strengths and weaknesses of a development. Therefore, critical thinking skill is essen-tial for 21st-century society [3]. There is a positive correlation between concept mas-tery with critical thinking skills, therefore critical thinking can help students in building their knowledge to master the concept [4].

One of the learning model that fit to Indonesian curriculum-2013 is guided inquiry model. It can make the students to find a concept, utilizing any kinds of information source and idea to advance the perception about problems, topics or issues.The use of guided inquiry model in learning process give positive impact for students concept mastery [5]. Inquiry process can also develop some student skills, including critical thinking such as skill of discovering information, making decision smartly and also being able to solve problem creatively [6]. Therefore there are some weaknesses in guided inquiry model, namely 1) when the students are organized in heterogen group, they are not active 2) The problems given are not about daily life 3) students who are used to study using conventional learning model sometimes get difficult in giving motivation even they are rather difficult to be required to study by themselves [7].

The weaknesses in guided inquiry model can be overcame by using STEM (Sci-ence, Technology, Engineering, and Mathematics) approach. This approach is appli-cate the learning based on the problem solving through the scientific investigation and mathematics application with the background of technology design as the form of problem solving. The benefits of STEM are 1) giving many chances for developing the critical thinking 2) increasing learning interest in science 3) technical component in STEM emphasizes in process and design or product planning and can use technic in order to explore, discover and solve the problem 4) One of STEM education parts that can absolutely help to understand others is technology in which it help students to apply what they learn [8].

Learning based on STEM can increase the student motivation, creativity and also student understanding about science concept and the effective in exercising student motoric skills in order to develop the product [9]. The STEM integration in learning can enhance the dominant role of students in the learning process [10]. The focus of

guided inquiry model integrated with STEM is students are involved in solving the problem investigation and other meaningful activities, giving learning chances, work-ing independently, constructing student knowledge and creating real product which help student in understanding the concept [11, 12]. Chemistry learning with STEM approach is conducted by planning the design and technology to solve real problems. Therefore, teacher has a importan role in giving real support in order students can build the knowledge and interdisciplines skills [13].

Based on the preliminary study, thermochemistry topic was one of the chemistry topic that was considered difficult by students at the Muhamadiyah 10 Senior High School, Surabaya, Indonesia. Many students were not complete in mastering the thermochemistry concepts so they needed to be remediated. This phenomena was suitable with Nasrudin, Suyono &Ibrahim (2015) that in learning thermochemistry topic, many students are poor in understanding about counting enthalpy reaction, determining enthalpy changes based on Hess Law, determining enthalpy changes based on bond energy [14]. In general, students still have misconception and difficult to understand the correlation between bond enthalpy and bond energy using phenomena. The students understanding on thermochemistry concepts such as enthalpy, calor, work, and chemical reaction will be lost when they study mathematic problems in thermochemistry [15].

It proves that students do not realize about the linkage between scientific disci-plines with thermochemistry topic. Therefore, it is needed an approach like STEM in learning the thermochemistry topic. Learning integrated with science, technology, engineering and mathematics and connected with science, skills and attitude shows higher score in posttest than pretest [16]. In this paper we reported the effectiveness of the guided inquiry model integrated with STEM to improve the students critical thinking skills on the thermochemistry topic.

II. METHODOLOGY

The type of this reasearch is pre-experimental reseach with one group pretest post-test design [17]. This reaseach begins with development of the learning device for thermochemistry topic refers to the 4-D models [18]. There are four kinds of learning device developed using guided inquiry model integrated with STEM namely lesson plan, student book, student worksheet, and test of critical thinking skills. All learning devices were validated by expert before implemented in chemistry learning. This research was carried out at Muhammadiyah 10 Senior High School Surabaya, Indonesia, in academic year of 2018/2019. The research subject was 28 students of XI MIA-1 class and 29 students of XI MIA-2 class. The learning process was carried out for three meeting with the materials of exotermic and endotermic reaction, determination of enthalpy reaction using calorimeter, and the use of Hess law, formation enthaly data, bond energy data to determine the reaction enthalpy, respectively. The data were collected by three techniques namely validation, test and questionnaire.

III. RESULT AND DISCUSSION

A. Validity of Learning Devices

Four types of the learning device were developed namely lesson plan, student book, student worksheet, and test of critical thinking skill. The validity of learning device were assessed by three experts as validator. The results of validation were presented at Table 1.

Type of learning device	Validation score			Average	Categories
	V1	*V2*	*V3*		
Lesson plan	3.89	3.43	3.84	3.69	Very valid
Student worksheet	4.00	3.52	3.71	3.63	Very valid
Student book	3.26	3.59	3.71	3.53	Valid
Test of critical thinking skills	3.25	3.75	4.00	3.60	Very valid

Table 1:- Validation Results of the Learning Devices

Table 1 showed that all type of the learning device developed were very valid cate-gory. The Lesson plan had fulfilled the validity. The learning outcomes had been adjusted with competence indicator, fulfilled ABCD rules, such as audience, beha-vior, condition, and degree [19]. Lesson plan was planned completely and systemati-cally so the learning process could run interactively, inspirative, joyful, challenging, efficiently in motivating students to have active role in learning process.

Student worksheet was feasible to be used as means of interaction between stu-dents in solving the problems assosiated with guided inquiry model integrated with STEM. The interaction occurred could enable students to complete each other and understand together, hearing good conversation and enable to learn the way others being success to solve the problems [20]. As the manifestation from constructivism, student worksheet was designed to make students learning easily through practice, information and evaluation. Students were given chance to correlate the thermoche-mistry topic with phenomenon in daily life, analyze observation result and discuss it so students can understand concept studied [21].

Student book was used to increase the efficiency and effectivity of learning pro-cess, adjusted with students need and used to as source of information to solve the problem given in worksheet. The use of student book could cause new eagerness and motivation to envolve in learning process and also gave good psychology effects to the students [20].

Test of critical thinking skills was designed to measure four critical thinking skill indicators namely interpretation, inference, explanation, and analysis [22]. It had fulfilled the construct and content validity as well as the language used was easy to be understand by students.

B. Students Critical Thinking Skills

Critical thinking skills assessed in this research were interpretation, inference, explanation, and analysis. Test of critical thinking skills developed was consisted of four questions in essay. Based on the reseach, it could be stated that guided inquiry model integrated with STEM could increase student critical thinking skill. The student book and worksheet with consisted of scientific investigation based on science, technology engineering and mathematic (STEM) to design technology as the manifestation of problem solving. Training of critical thinking skill in each phase of guided inquiry model integrated with STEM can be explained as follows.

Phase 1: Initiation. Teacher gave problems that connected to daily life phenomenom. The phenomenal at student book and worksheet was one of manifestation of STEM. Science that had role as research about phenomena or problems would involve students in scientific investigation. Statement of the problems toward the phenomena could train students to one of critical thinking skills indicator such as interpretation [22]. It could increase students motivation in learning process so it was influence to information saving in the long term memory and increased the concept mastery [21, 23].

Phase 2: Selection. It was important phase because students get the main subject of thermochemistry. Students involved in discussing with friends in their group to find the accurate source or information to formulate the hypothesis. The students could use the student book or other source including from internet. Finding the information motivated the students to do investigation to solve the problems [7, 23]. This condition can train the student's interpretation skills as an indicator of critical thinking skills [22]. Learning process is occurred if the students relate to the problems that are still in their range, commonly called ZPD (zone of proximal development). Level zone of higher mental function development usually occur in discussion or cooperation among the individuals before higher mental function enter in individuals [22].

Phase 3: Formulation. Teacher directed the students to formulate the relevant hypothesis with the problem, choosing hypothesis as research priority and formulating research variable by implementing the STEM component, namely science. It is used as the scientific knowledge and also the process to understand the problems and the ability to join and participate in making the decisions [12]. Finding relevant information to formulate hypothesis and useful variable in training students critical thinking skills, especially for indicator of interpretation (identifying the relations between statements and questions and also concepts that would be assimilated by students in their concept structure.

Phase 4: Collection. The students conducted experiment by implementing all part of STEM, such as science, technology, engineering and mathematic. The experiment at fourth phase would train one of the indicators of critical thinking, namely analysis dan inference. It made the students more active in participating to gain the concept mastery. Beside students were easy to get useful experience and also to prove the concept truth [24]. Science, technology, engineering and mathematic were applied when students designed the equipment related to exoterm and endoterm reaction, namely the ice gel product made from baby diapers, simple thermos, simple calorimeter from styrofoam and emergency bottle lighter.

Phase 5: Presentation. Students were analyzed the research results by implementing the STEM approach. Science had role as basic concepts to formulate the conclusion relating to problem statement. Technology was an innovation that made students easy to understand the solution of problems [16]. Students were trained about critical thinking skills in analysis, inference, and explanation indicators. It was skill to know and get factors needed to make a reasonable conclusion. It was applied when the result of research was concluded through students working and then communicating the research result in front of class [25].

Phase 6: Assesment. In **t**he last phase of guided inquiry model integrated with STEM was very important for the teacher to give chance to train the critical thinking skills and concept mastery through questions so it will deepen their concept understanding and their critical thinking skills

The profile of student's critical thinking skill after implementation the guided inquiry model integrated with STEM in thermochemistry topic could be seen at Figure 1 for MIA-1 class and Figure 2 for MIA-2 class.

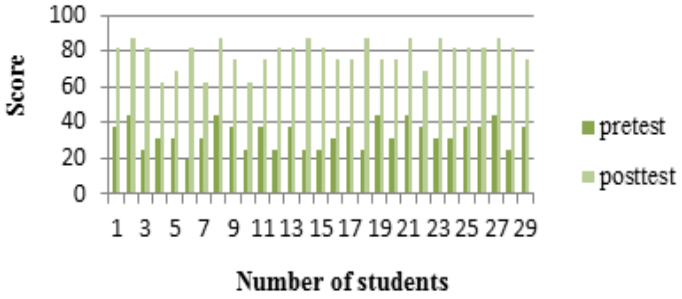

Fig 1:- The Pretest and Posttest Score of Students Critical Thinking Skills for MIA-1 Class

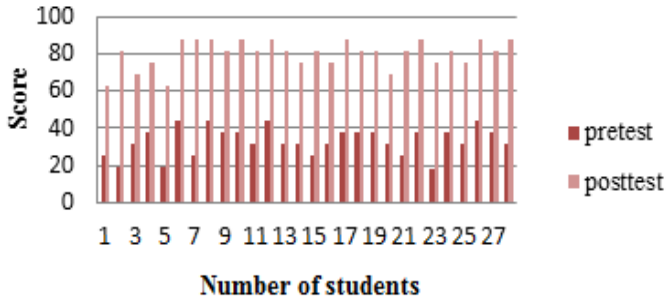

Fig 2:- The Pretest and Posttest Score of Students Critical Thinking Skills for MIA-2 Class

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The average pretest score of student critical thinking skills for MIA-1 class and MIA-2 class were 33.40 and 33.48, respectively, with very less critical category because both scores were smaller than 43.75 [26]. While the average posttest score of student critical thinking skills for MIA-1 class and MIA-2 class were 77.58 and 77.68, respectively, with critical category because both scores were at score intervals of 62.50 – 81.25 [26]. Based on t-test analysis for pretest and post test score, it was obtained the p-value of 0.00 (< 0.05). Therefore there was significant difference the student critical thinking skills before and after implementation guided inquiry model integrated with STEM at both class, MIA-1 and MIA-2 [27].

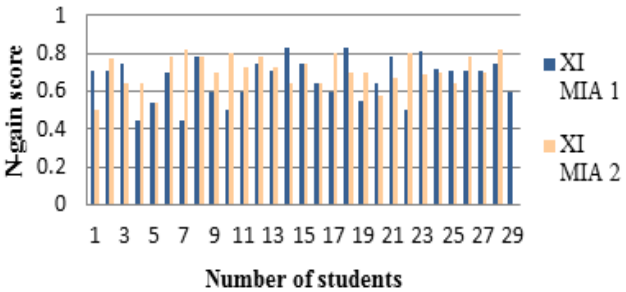

Fig 3:- N-Gain Score f Student Critical Thinking Skills for MIA-1 and MIA-2 Class

The increasing of student critical thinking skill before and after implementation guided inquiry model integrated with STEM were analysis based on n-gain score. The average n-gain score of student critical thinking skills for MIA-1 class and MIA-2 class were 0.68 (medium category) and 0.71 (high category), respectively [28].

Based on the above data, implementation of guided inquiry model integrated with STEM was effective to increase the student critical thinking skills on thermochemistry topic. This learning model caused the increasing of students motivation during learning process so the score of students critical thinking higher [25]. It was supported by results of students response questionnaire stating that 86.2% of students were interested in learning process, 96.55% of students felt easy to understand the teacher's explanation, and 89.7% of students were interested in learning atmosphere and the learning devices. The process of critical thinking skills formation to students did not appear coincidentally but it was gradually and needed preparation such as through critical questions, question with words arrangement and deeply concept construction was possible to produce students with high level thinking [22].

The result of students critical thinking skills could also be connected with constructive theory. It explained that the cognitive development was a process when students formed meaningful system and reality interpretation actively through their experience and interaction. By using critical thinking skills, students could form long term memory relating to material studied so students could attain the learning achievement [16, 21].

IV. CONCLUSION

The guided inquiry integrated with STEM is effective to enhance the student criti-cal thinking skills. Implementation this model cause the significant difference be-tween pretest and post test score of student critical thinking skill at both two classes (MIA-1 and MIA-2). While the n-gain score of critical thinking skills at both classes showed good category, namely 0.68 (medium category) and 0.71 (high category) for MIA-1 and MIA-2, respectively. The critical thinking skills of students in both classes studied changed from very less critical category to critical category.

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