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THE PROFILE OF XI GRADE STUDENTS' SCIENTIFIC THINKING ABILITIES ON SCIENTIFIC APPROACH IMPLEMENTATION

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ABSTRACT

This study aimed at analyzing XI grade students' scientific thinking abilities on the implementation of the scientific approach. 82 students of XI grade science class at three state senior high schools in Surakarta involved in this study. The students' scientific thinking abilities illustrated as the students' competence in seven aspects: the purpose of science; science question, science information, science interpretation, science concept, science assumption, science implication (Paul & Elder, 2003). The data on students' scientific thinking abilities were collected using essay test on worksheet and interview methods. The instrument had been validated by expert judgement and students as a user. The scores were used to represent the students' scientific thinking abilities in three categories (low, middle,high). The results of the study showed that students' competence in seven aspects of scientific thinking abilities: purpose of science (62,00%); science question (36,6%), science information (39,66%), science interpretation (41,00%), science concept (43,33), science assumption (38,33%), science implication (21,33%). Therefore, it concluded that the XI grade students' scientific thinking abilities on the implementation of scientific approach was at the low category. It was suggested that the learning model based scientific approach be conducted for the students' scientific thinking abilities improvement.

Keywords: scientific thinking abilities, scientific approach, 2013 curriculum

INTRODUCTION

There are 4 skills demanded for 21st century generation called the 4C (creativity and innovation, critical thinking and problem solving, communication, and collaboration) (Osman et al., 2013; Manzon, 2017; Howard et al., 2015). Hence, the 21st century education is required to empower the students' scientific abilities (Osborne, 2013). Scientific thinking is a form of knowledge seeking that involves the process of thinking to increase knowledge or intellectual; thereby, scientific thinking ability is not what already in a person's mind but the process of thinking that must be habituated to encourage the increase of knowledge (Kuhn, 2010; Paul & Elder, 2003). Scientific thinking ability is the result of the scientific discovery method applied in problem-solving by proving a theory (Zimmerman, 2007). Scientific thinking is obtained through inductive and deductive reasoning to find answers through explorations of factual scientific investigation, problem formulation, hypothesis, design, evaluation of evidence, hypothesis testing with experiment, and conclusions (Thitima & Sumalee, et al., 2012). Scientific thinking ability can be considered as part of critical thinking through claims and arguments about persons' behavior from a scientific view. Thus, scientific thinking is a form of logical reasoning in a scientific paradigm (Kagee et al., 2010; Stevens & Witkow, 2014).

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According to Paul & Elder (2003) there are 8 characteristics of scientific thinking: (1) the purpose of scientific thinking. Scientific reasons always have a purpose, therefore the delivery of scientific objectives to be achieved must be realistic and clear; (2) the emergence of scientific questions is usually related to the issues discussed. Generally, the questions are sub-questions to clarify the purpose and scope of the problem; (3) scientific assumptions obtained by clearly identifying the problem considering how the assumption is built on a particular point of view; (4) scientific point of view. Assumptions are built on views, therefore, it needs to be identified initially to ensure the scientific view. Once the scientific points are found, further identification of the strengths and weaknesses is required; (5) scientific information. Scientific thinking is always based on data, information, and scientific evidence. Not all claims are used, but limited only for the clear, accurate and relevant data to the question of the problem; (6) the scientific concepts. Scientific thinking is built on scientific concepts and theories. The concepts or theories used must be accurately and carefully identified, since only scientific and clear concepts and theories are used; (7) scientific interpretations and inferences. Scientific thinking will lead to scientific conclusions referring to the inferences or interpretation that gives meaning to scientific data. Conclusions are drawn only on the basis of the obtained data, thus, conclusions need to be checked for consistency with the existing data and identify which assumptions underlying the conclusions; and (8) scientific implications and consequences. Scientific thinking always has both negative and positive implications and consequences, both of which can be found by tracing them through data and thought. Referring to the characteristics of scientific thinking, then scientific thinking can be trained. This is relevant to Kuhn (2002) that training scientific thinking can be done through 4 phases of activities including: (1) investigation; (2) analysis; (3) inference; and (4) argument. Moreover, Koerber, et al. (2015) argued that scientific thinking can be developed through activities such as hypothesis testing, systematic experiments, data interpretations related to hypotheses, and a more general understanding of the nature of science. In nurturing scientific thinking ability, it is necessary to change the paradigm of learning from the teacher center to the student center, from learning that emphasizes the content to the process, the textual approach to the contextual and the scientific approach, the transfer of knowledge toward problem solving. Efforts to optimize the implementation 2013 curriculum in stages show that the Indonesia Government commits to responding the challenge of globalization era in order to meet the demands of 21st-century skills of human resources. One of the important changes as contained in the science curriculum (Indonesia Minister of Culture and Education Regulation No.103 of 2014) is a shift from a textual approach to a scientific approach.

A scientific approach is a learning approach adopted from scientist steps in building knowledge through the scientific method by using inductive reasoning rather than deductive reasoning. Inductive reasoning starts by looking at a specific phenomenon or situation to then draw the overall conclusion. Inductive reasoning puts specific evidence into a wider relationship. Scientific methods generally originate from a unique phenomenon with specific and detailed studies to then be drawn conclusions in general through investigative activities. To be scientific, the method of inquiry should be based on the evidence, observable, empirical, and measurable objects with specific principles of reasoning. The scientific approach is the organization of learning experiences in a logical sequence comprising observing, questioning, gathering information, reasoning, and communicating. Learning with a scientific approach is a learning process designed in such a way that learners actively construct concepts, laws or principles through a series of data collection activities such as observation, identifying problems, formulating hypotheses, testing hypotheses through investigation (experimenting), processing data or information, gathering and analyzing and by various techniques, drawing conclusions and communicating concepts, laws or principles found (Hosnan, 2014; Daryanto, 2014).

The characteristics of a scientific approach are: (1) The substance or subject matter is based on facts or phenomena which can be explained by certain logic or reasoning, not just imagination, story, reading, alone; (2) Teacher explanation, student response, and interaction between teacher and student are free from subjective thinking or reasoning that deviates from the logical thinking flow; (3) Encourage and inspire students to think critically, analytically and appropriately in identifying, understanding, solving problems and applying substance or subject matter; (4) Encourage and inspire learners to be able to think hypothetically in view of differences, similarities and links to one another from the substance or learning material; (5) Encourage and inspire learners to be able to understand, apply and develop rational and objective thinking patterns in

response to substance or learning materials; (6) Based on empirical concepts, theories and empirical facts that can be accounted for; (7) Learning objectives are formulated in a simple, clear, and interesting presentation system. Referring to the characteristics of the scientific approach, it can be argued that the scientific approach not only views learning outcomes as the final estuary, but the learning process is considered very important. Since the scientific approach emphasizes on the process skills, so it is believed to be a golden bridge for the development of attitudes, skills, and knowledge, especially in the empowerment of students' scientific thinking. Departing from the description above, this research was conducted to analyze the XI grade students' scientific thinking abilities with regard to the implementation of the scientific approach.

METHODS

The study involved 82 students of XI grade science class at three state senior high schools in Surakarta. The students' scientific thinking abilities illustrated as their competence in seven aspects: the purpose of science; science question, science information, science interpretation, science concept, science assumption, science implication (Paul & Elder, 2003; Dejonckheere, 2009; Dilekli & Tezci, 2016). The data on students' scientific thinking abilities were collected using essay test on the worksheet by formulating a hypothesis, determining variables and analyzing the results of the investigation (Ghojazadeh et al., (2014) and interview methods. Interviews with students focused on students 'difficulties in filling out worksheets related to students' scientific thinking skills (Kong, 2015). The instrument had been validated by expert judgment and students as a user. The scores were used to represent students' scientific thinking abilities in two categories (low and high category); $\leq$ 50% for the low category and > 50% for the high category.

RESULTS AND DISCUSSION

The students' competence in seven aspects of scientific thinking abilities: purpose of science (62,00%); science question (36,66%), science information (39,66%), science interpretation (41,00%), science concept (43,33%), science assumption (38,33%), science implication (21,33%) is shown in Figure 1. The percentage of each aspect was obtained from the score of the students, which were divided by the maximum score that students can get from certain aspects and then multiplied by 100%. Among those abilities, the students demonstrated moderate ability in the purpose of science, whereas in the other six components, students had the low ability of scientific thinking.

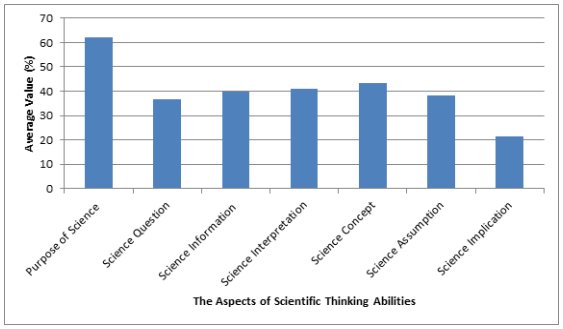


Figure 1. The Students' Competence in Seven Aspects of Scientific Thinking Abilities

The data analysis showed that the students' scientific thinking ability profile could be categorized as low. Meanwhile, from the observation data showed that teachers have not implemented a scientific approach to learning optimally. The teachers remained dominating the learning process and tended to be teacher centered. This was supported by the results of interviews with teachers that 75% of them declared a lack of understanding of scientific approaches, especially with regard to its implementation. This condition was also supported by the research done by Restami et al., (2013) which showed the average score of teachers' ability to implement a scientific approach was between 45% -50%. The teachers explained that they required more training, especially in terms of scientific approach concept and its practice in teaching and learning. Thus, it argued that the lack of teachers' competence in implementing of the scientific approach would results in a weak students' scientific thinking ability empowerment, since learning is a system that includes: input, process, output. A learning environment that merely involving the transfer of knowledge from the teacher to the students would not provide meaningful experience to students; thus, it encourages students toward rote learning.

Meanwhile, according to Ausubel, learning through experiences with contextual and meaningful activities, could make learning become engaging and having longer retention (Ratna, 2011; Jensen et al., 2014). The process of learning through observation has a high significance (Ary et al., 2018; Jewett & Kuhn 2016). The data observation showed that the activity of "asking" was generally initiated by the teacher rather by the student. Thus students' scientific

thinking ability was not developed. This is relevant to Sa'ud (2011) opinion that the activity of asking questions (asking) can be viewed as a reflection of the curiosity of an individual, while answering questions is reflecting of students' thinking ability. If the activities to tackle the scientific thinking (investigation, analysis, inference, arguments) through a series of scientific process stages such as hypothesis testing, systematic experiments, data interpretation related to hypothesis, and a more general understanding of the nature of science are not properly planned and extrinsically implemented, then do not expect students' scientific thinking ability to thrive (Kuhn, 2002; Koerber et al., 2015; Underwood, 2015). This is supported by Osman et al. (2013) and Collin (2014) opinion that inquiry learning can train students to improve their ability to explore, so they can find their own knowledge. By not accustoming the students to learning through inquiry, the students' scientific thinking skills are low. The followings are examples of the students' work that evidenced the students' low scientific thinking skills.

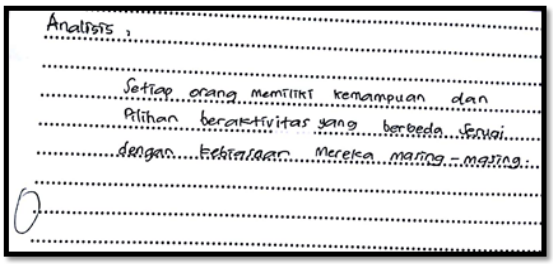


Figure 2. The Example of Student Work on Scientific Purpose Aspect

The data in Figure 2 shows that the students were careless in analyzing the presented images. It should be based on the presentation of observed images that could guide the students to understand the purpose of the specified activity. This supported the fact that the students' scientific purpose was low.

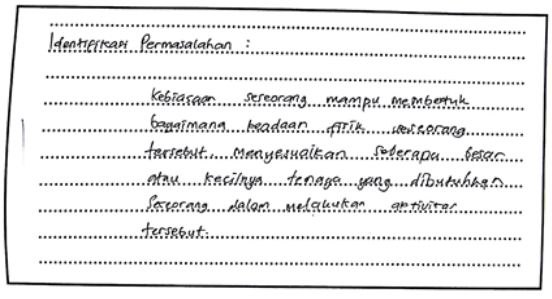


Figure 3. Examples of Student Work on Aspects in Formulating Problems

The data in Figure 3 informs that the students were inattentive in identifying problems based on the image presentation. The problems raised by the students have not used the question sentence, but in the form of narrative. This showed that students were less able to make scientific questions.

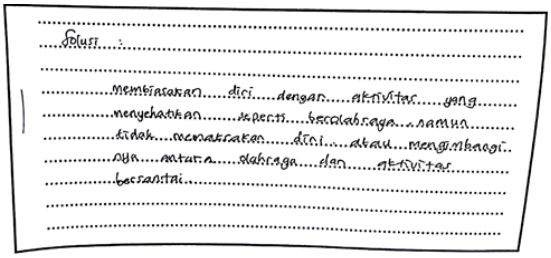


Figure 4. The Example of Student Work on Aspects of Developing Hypotheses

The data in Figure 4 describes the solutions proposed by the students did not answer the problems they have formulated previously. Ideally, the hypothesis made must be relevant to the formulation of the proposed problems.

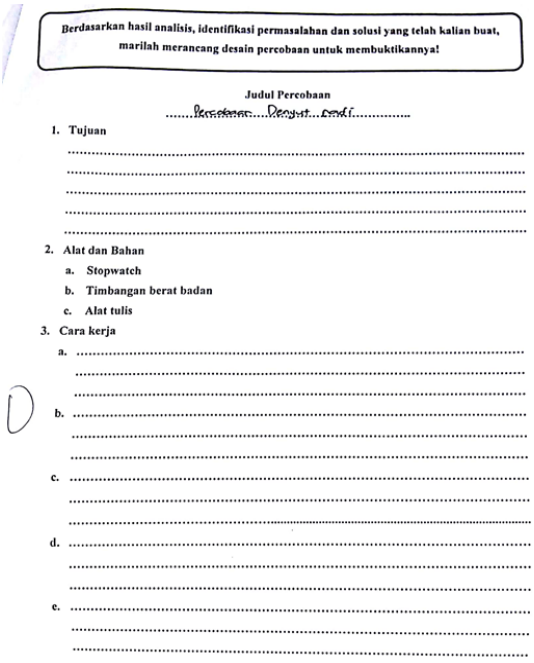
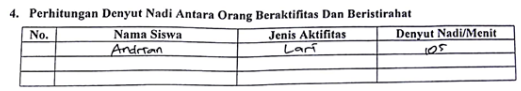


Figure 5. Example of Student Worksheet in Designing Experiments

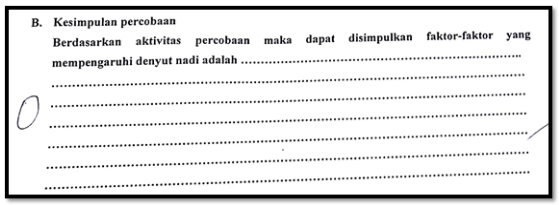
The data in Figure 5 indicates that the students have not been able to make experimental designs well even though they have been given clue. The students worked on an empty worksheet. This pointed out that the scientific concept aspect of the students was low.


4. Perhitungan Denyut Nadi Antara Orang Beraktifitas Dan Beristirahat

No.	Nama Siswa	Jenis Aktifitas	Denyut Nadi/Menit
	Anderson	Lari	105

Figure 6. The Example of Student Work in Data Organizing

The data in Figure 6 informs that the students did not comprehend the command to compare the number of pulses between people who move and rest. As a result, the data were difficult to be analyzed.


B. Kesimpulan percobaan

Berdasarkan aktivitas percobaan maka dapat disimpulkan faktor-faktor yang mempengaruhi denyut nadi adalah .....

Figure 7. The Example of Student Work in Making Conclusions

The data in Figure 7 shows that students could not conclude well. This can be seen from an empty worksheet.

CONCLUSION

Based on the research findings, it concluded that the XI grade students' profiles of scientific thinking abilities on the implementation of scientific approach was at the low category. It suggested that the scientific approach-based learning be conducted to further develop students' scientific thinking abilities.

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