Effectiveness of guided inquiry-based module to improve science process skills

J Arantika¹*, S Saputro² and S Mulyani²

¹ Postgraduate Program of Science Education, Faculty of Teacher Training and Education, Sebelas Maret University, Indonesia
² Magister of Science Education, Faculty of Teacher Training and Education, Sebelas Maret University, Indonesia

*janeantarika92@gmail.com

Abstract. Science process skills (SPS) are important in science learning. SPS is a skill process that encourages lifelong learning. In guided inquiry-based science learning, students engage in many of the activities and thought processes that scientists use to generate new knowledge. This inquiry approach can be implemented effectively with the use of chemistry modules for investigation in which students learn to understand the content of the subject. This study examines the effectiveness of guided inquiry-based modules for SPS. The study participants were 63 students in 11th graders. Data were collected through the test. Quantitative analysis is done to know the SPS of student. The test result shows that the n-gain of SPS students in the treatment class has a better percentage of categories than the control class. The effect size (ES) also shows a value of 0.51 which is moderate category. The achievement of indicator SPS in the treatment class is also better than the control class.

1. Introduction

Science education focuses on an understanding of the nature of science and its relation to everyday life, rather than simply focusing on knowledge [1]. Application of science process skills in teaching and learning processes tends to enable learners to learn phenomena and understandings [2]. This is relevant to the meaning of science is essentially the process of discovery [3]. Students can develop students' skills in developing the mastery of science process concepts and skills through discovery [4].

SPS are learning activities to recognize, define to some extent, solve problems [5]. Process skills are an important aspect of science learning [6]. It’s can enable students, develop students' sense of responsibility in their own learning, increase learning tenacity, and teach [7]. It’s also use to obtain information, think about problems and formulate results [8]. Chiappetta and Koballa classify process skills as basic science process skills (observing, measuring, summarizing, classifying, predicting, communicating) and integrated science process skills (controlling variables, hypothesizing, designing experiments, and interpreting data [9].

Science process skills can be learned if taught in a formally in the classroom with the use of proven teaching methods [1]. The availability of teaching media and teachers as facilitators in learning is required by appropriate learning models to develop process skills. Not all teachers are familiar with strategies to apply these techniques in classroom learning [10, 11, 12]. The suggested model for learning is constructivism, which is in line with process skills [13]. Yasar et al reveals that constructivism is a
way of developing high cognitive skills [5]. Knowledge cannot be transferred from teacher to student [14]. The learning process should give students the opportunity to build knowledge. An approach that can be used to develop students' process and thinking skills is the approach to learning models such as Inquiry [15]. According to Budak and Koseoglu in Aydin (2013), teachers can use the inquiry-based approach to enhance conceptual understanding and to empower the skills of the science process [5].

Modules can enable students in learning by thinking and finding out knowledge [4]. The inquiry-based module has learning steps that define the problem, verify by formulating hypotheses, conduct experiments and collect data, formulate explanations and analysis of inquiry processes [16]. Such activities also encourage students to use their science process skills in each of the five essential features of a investigation, so that students' science-process skills can be improved [17]. Inquiry-based learning can stimulate student motivation, application of student research skills, construct meaning, and acquire scientific knowledge [18].

The use of inquiry-based chemistry modules is expected to help develop students' science process skills. Some research believe that the SPS will be formed through inquiry activities. Ratnasari et.al's research reveals, the influence of science process skills on mastering the concept of heat giving significant results [19]. Some researchers and educators of science Minstrell and van Zee 2000, Windschitl and Thompson (2006) also support the view that teaching science as an inquiry with process skills enables students to gain authentic experience, thus enabling students to learn more meaningfully and increasing students' scientific understanding [20]. Wachanga and Mwangi study gives support to the fact that achievement of students in chemistry could be greatly improved if they are exposed to science process skills teaching approach [21].

These earlier studies discussed the application of inquiry models to improve process skills. Research related to the effectiveness of the use of inquiry modules as teaching materials is still limited to certain materials.

2. Method

The research method used is the quantitative method. The purpose of this research is to know the effectiveness of using guided inquiry-based module to improve students' science process skill.

2.1 Participants

Participants in those conducted at the high school in Sambas, West Borneo, consisting of high, moderate, and low categories. Participants in this study were high school category as many as 63 students class XI is divided into 31 student in the experimental class and 32 in the control class. Students in the experimental class were given a treatment of thermochemistry with guided inquiry-based module, while in the control class were students who used a textbook as usual.

2.2 Chemistry module based on guided inquiry

Module based on SSCS to improve SPS have conducted the activities used Inquiry by Joyce and Weil [16]. The module is validated by 7 validator experts and declared valid for use.

2.3 Science process skills test

This research instrument uses essay test to assess students' skills. The test instrument was developed independently by research validated by six validators consisting of 3 chemistry lecturers and 3 experienced chemistry teachers who had been tested. The reliability of the instrument is measured by Cronbach's alpha with a coefficient of 0.86. This assessment instrument to measure science process skills developed by Liliasari [22] there are formulating hypotheses, interpreting, applying concepts, communicating, formulating questions, and designing experiments. The experimental class and control class were given SPS test before (pre-test) and after learning (post-test).

2.4 Data analysis

Pre and post-test data were analyzed using n-gain test from Hake formula [23]:
The criterion of obtaining an n-gain score can be expressed as high if $n\text{-}gain > 0.7$; medium if $0.3 < n\text{-}gain \leq 0.7$; and low if $n\text{-}gain \leq 0.3$. Effect size (ES) analysis to find out how much the effectiveness of the use of modules. Effect Size was obtained by calculating the difference between mean experiment class and mean control group and the standard deviation of the control class [24].

$$ES = \frac{\text{mean}_{\text{experiment}} - \text{mean}_{\text{control}}}{\text{stdv}_{\text{control}}}$$

The criterion of obtaining effect size can be expressed as (ES) <0.5 = small; ES 0.5 - 0.8 to moderate, and ES> 0.8 high.

3. Result and discussion

The effectiveness of using guided inquiry-based chemistry can be seen from improvement or change of learning result. The results of the increase before and after receiving treatment based on the two research classes are presented in figure 1. The figure shows the comparisons of student achievement, experiment and control classes.

Figure 1 shows the comparison of n-gain values of the SPS test results between the experimental class and the control class. The experimental class is a class that uses guided inquiry-based chemical modules, while the control class is a class that uses textbooks used by teachers. Based on the table note that in the low category, in each class is zero. On the medium category improvement, the control class has a percentage of 84.38 while the experimental class is 61.29%. Medium grade improvement in control classes is better than experimental class. The percentage of improvement with the high category in the experiment class was 38.71% and the control class 15.62%. This means that the percentage of students with a high category improvement in the experimental class is better than the control class. Based on this data, it means that the class that gets treatment using the module has improved the better result compared with the improvement in the control class. The effectiveness of the use of modules is also seen from the effect size. Result of effect size shows value 0.51. If this value is converted with the ES table of Cohen indicated the moderate category. In addition to seeing effectiveness based on gain and effect size, the percentage of SPS achievement between the experimental class and the control class is also considered.
Table 1. The achievement indicator of students’ science process skill.

| Indicator of science process skill | Achievement of science process skill (%) |
|-----------------------------------|-----------------------------------------|
|                                   | Experiment | Control |
| Formulate Hypothesis             | 41.3        | 40.0    |
| Interpreting                     | 62.5        | 60.3    |
| Applying concept                 | 74.9        | 61.1    |
| Communicate                      | 51.6        | 40.1    |
| Formulate questions              | 61.3        | 48.4    |
| Designing an experiment          | 65.8        | 50.6    |

Based on table 1, it can be seen that the achievement of each indicator both the experimental class and the control class. The lowest achievement in the experimental class and control class is to formulate hypotheses (41.3% and 40%) and communicate (40.1% and 51.6%). Activities to formulate hypotheses are activities considered difficult by students. Indicators communicating on a given test is a student's skill to communicate a result or data into a diagram or table. Communicating activities done in learning, more often in activities such as classroom discussions. The highest percentage achievement in the control and experimental class is on the applying the concept of 61.1% for the control class and 74.5% in the experimental class. Applying the concept in this research is how students apply the concepts of equations to solve the calculation problems. The high achievement of this indicator because the students are more accustomed to solve the problem in the learning count. In addition to applying the concept, the highest indicator in the experimental class is to formulate questions. The experimental class is facilitated through the skill of formulating questions through a given teaching module. The percentage of skills achievement in formulating the problem in the experimental class is better than the control class, because in its application the chemical module used in the experimental class can facilitate students to formulate hypotheses that are part of the inquiry syntax. In the experimental class and control class have the same relatively high and low achievement. The difference between the two is the percentage of the two. The experimental class has a greater percentage of achievement than the control class. Other process skills such as interpreting, formulating questions and designing experiments on control and experiment classes indicate that the experimental class has better results than the control class, as seen from the achievement in the experimental class is better than the control class.

Interviewing of teachers after the test. This interview was conducted to determine the low tendency of interpretation and hypothesis. Each evaluation is to measure students' mathematical abilities. Often in the learning and evaluation questions given, the dominant students master mathematically in the appeal to interpret the concepts, so that the activities of interpreting students in less learning. Similarly, the activities of formulating hypotheses. Although learning is done by inquiry model, students still have difficulty in formulating hypothesis. When involved in formulating hypotheses, students can make temporary predictions about the given problem. Students can gather a little information related to the predictions they make and be mentored by the teacher or see the module’s instructions on what they need to find in relation to the problem, to form a descriptive hypothesis [25]. This hypothesis will be the foundation at the stage of collecting data. Lack of activity in formulating hypotheses in learning during this is one reason for the low achievement in this indicator. The skill of formulating hypotheses is an integrated process skill [9]. Akinbobola and afolabi revealed that integrated science process skills are more difficult to improve because they are not used to being taught [26].

SPS cannot necessarily increase with one treatment. It needs to be applied continuously in good learning. Embedding SPS during the science class is important to ensure skill acquisition and processes are continuous [14]. Science learning that uses guided inquiry-based modules in science lessons has additional advantages in terms of providing opportunities for the inculcation of SPS. The guided inquiry-based module has a step that is able to trace SPS. In the inquiry module, there is a stage of defining the problem given to the students. Then the students set predictions and formulate hypotheses for the formulation of the problem followed by conducting experiments and data collection to test the
hypothesis. The findings during the data collection and experiment were analyzed, and the inquiry analysis was done by making conclusions on what findings were obtained and whether the hypotheses made by the students were correct. It is confirmed that the science inquiry approach provides students with SPS through inquiry process [17]. Students have the opportunity to sharpen, clarify or ask scientifically-oriented questions, plan and conduct experiments to collect data on questions, formulate explanations of evidence to answer questions, link explanations with scientific knowledge, and communicate and justify explanations [27]. It also succeeds in giving students the opportunity to study independently and throughout the activities in the classroom. In a guided inquiry approach, learners seek and find the help of teachers as facilitators [28]. Students successfully acquire at least some skills. Several studies have demonstrated the application of inquiry to improve students' science process skills. According to Lati [17], investigation activities (inquiry) to improve the science process skills seen from the students postes score better than the value of pretest. Inquiry activities help students build students' understanding of science phenomena or their own science theories and also improve their experimental skills [29].

4. Conclusion
The application of guided inquiry based modules has a moderate ES value. The effectiveness of the application of the module in learning is also reviewed from the n-gain and the percentage of achievement of the experimental science process skill indicator is greater than the control class. This is why the application of guided inquiry-based modules effectively provides an influence in developing students' science process skills. In addition to applying the guided inquiry-based chemistry module, can also be developed similar modules with different bases to improve students' science process skills.

Acknowledgement
Thank you to student and teacher in senior high school at Sambas, West Borneo was used in this study who greatly assisted for complete this research.

References
[1] Paulo J and Cruz C 2015 Development of an Experimental Science Module to Improve Middle School Students’ Integrated Science Process Skills DLSU Res. Congr. 2015 3 1–6
[2] Rambuda A M and Fraser W J 2004 Perceptions of Teachers of The Application of Science Process Skills in The Teaching of Geography in Secondary Schools in The Free State Province South African J. Educ. 24 10–7
[3] Sari P, Sudargo F and Priyandoko D 2018 Correlation among science process skill, concept comprehension, and scientific attitude on regulation system materials Correlation among science process skill, concept comprehension, and scientific attitude on regulation system materials J. Phys. Conf. Ser. 948
[4] Febriana R, Haryono Y and Yusri R 2017 Effectiveness of Discovery Learning-Based Transformation Geometry Module 11–6
[5] Aydin A 2013 Representation of Science Process Skills in the Chemistry Curricula for Grades 10, 11 and 12 Int. J. Educ. Pract. 1 51–63
[6] Veal W R, Taylor D and Rogers A L 2009 Using Self-Reflection to Increase Science Process Skills in The General Chemistry Laboratory J. Chem. Educ. 86 393–8
[7] Carey S, Evans R, Honda M, Jay E and Unger C 1989 “An experiment is when you try it and see if it works”: A study of grade 7 students’ understanding of the construction of scientific knowledge Int. J. Sci. Educ. 11 514–29
[8] Karamustafoğlu S 2011 Improving the Science Process Skills Ability of Science Student Teachers Using I Diagrams Eurasian J. Phys. Chem. Educ. 3 26–38
[9] Zeidan A H and Jayosi M R 2015 Science Process Skills and Attitudes toward Science among Palestinian Secondary School Students World J. Educ. 5 13–24
[10] Anderson T R 2007 Bridging the Gap Bridging the Educational Research-Teaching Practice Gap:
The Importance of Bridging The Gap Between Science Education Research and Its Application in Biochemistry Teaching and Learning

[11] Henderson C 2007 Promoting instructional change in new faculty: An evaluation of the Physics and Astronomy New Faculty Workshop AIP Conf. Proc. 951 120–3

[12] Silverthorn D U, Thorn P M and Svinicki M D 2006 It’s difficult to change the way we teach: lessons from the Integrative Themes in Physiology curriculum module project. Adv Physiol Educ 30 204–14

[13] Aydin G C and Cakiroglu J 2017 Learner Characteristics and Understanding Nature of Science Sci. Educ. 26 919–51

[14] Rauf R A A, Rasul M S, Mansor A N, Othman Z and Lyndon N 2013 Inculcation of science process skills in a science classroom Asian Soc. Sci. 9 47–57

[15] Strom R K 2012 Using Guided Inquiry To Improve Process Skills and Content Knowledge in Primary Science (Bozeman, Montana)

[16] Joyce B, Weil M and Calhoun E 2016 Models of Teaching (Yogyakarta: Pustaka Pelajar)

[17] Lati W, Supasorn S and Promarak V 2012 Enhancement of Learning Achievement and Integrated Science Process Skills Using Science Inquiry Learning Activities of Chemical Reaction Rates Procedia - Soc. Behav. Sci. 46 4471–5

[18] Suduc A-M, Bizoí M and Gorgiu G 2015 Inquiry Based Science Learning in Primary Education Procedia - Soc. Behav. Sci. 205 474–9

[19] Ratnasari D, Sukarnin S, Suparmi S and Aminah N S 2017 Students’ Conception on Heat and Temperature toward Science Process Skill Journal of Physics: Conference Series vol 895

[20] Hatzikraniotis E, Kallery M, Molohidis A and Psillos D 2010 Students’ Design of Experiments: An Inquiry Module on The Conduction of Heat Phys. Educ. 45 335–44

[21] Wachanga S W and Mwangi J G 2004 Effects of the cooperative class experiment teaching method on secondary school students’ chemistry achievement in Kenya's Nakuru district Int. Educ. J. 5 26–36

[22] Liliasari and Tawil M 2014 Keterampilan-Keterampilan Sains dan Implementasinya dalam Pembelajaran IPA (Badan Penerbit UNM)

[23] Meltzer D E 2002 The relationship between mathematics preparation and conceptual learning gains in physics: A possible “hidden variable” in diagnostic pretest scores Am. J. Phys. 70 1259–68

[24] Glass G V, Smith M L and McGaw B 1981 Meta-analysis in social research (Sage Publications, Incorporated)

[25] Gurses A, Gunes K, Barin T B, Eroglu Z and Cozel F S 2015 Relation Between Pre-Service Chemistry Teachers’ Science Literacy Levels and Their Some Scientific Process Skills Procedia - Soc. Behav. Sci. 197 2395–402

[26] Akinbobola A O and Afolabi F 2010 Analysis of Science Process Skills in West African Senior Secondary School Certificate Physics Am. J. Sci. Res. 4 234–40

[27] National Research Council 2000 Inquiry and the National Science Education Standards: A Guide for Teaching and Learning (Washington DC: National Academy Press)

[28] Widiana R, Susanti S and Susanti D 2017 Student Needs to Practicum Guidance in Physiology of Animals Based on Guided Inquiry International Conference on Mathematics and Science Education

[29] Park J, Jang K A and Kim I 2009 An analysis of the actual processes of physicists’ research and the implications for teaching scientific inquiry in school Res. Sci. Educ. 39 111–29