The Effect of Scientific Inquiry Learning Model Based on Conceptual Change on Physics Cognitive Competence and Science Process Skill (SPS) of Students at Senior High School

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Abstract
The purpose of this research was to analyze the physics cognitive competence and science process skill of students using scientific inquiry learning model based on conceptual change better than using conventional learning. The research type was quasi experiment and two group pretest-posttest designs were used in this study. The sample were Class XI(A) as experiment class and Class XI(B) as control class with the total number sixty two students. The instruments in this research were essay test for physics cognitive competence of students and observation sheet for science process skill of students. The essay instrument had been validated and fulfilled the requirements of validity and reliability of test. Based on the data tabulation obtained, the mean of physics cognitive competence of students in experimental class was 72.97 and 54.97 in control class, the mean of science process skill of students in experimental class was 79.66 and 63.97 in control class. Based on the hypothesis testing, it can be concluded that physics cognitive competence and science process skill of students using scientific inquiry learning model based on conceptual change was better than using conventional learning
Keywords: Scientific inquiry learning, conceptual change, cognitive competence, science, process skill

1. Introduction

Studying physics does not only focus to the facts, law, theory, principle, models, and mastery the formulas but also focus to understand the basic concepts. Concepts are abstract or psychological constructs represent ideas that a learner uses in reasoning and thinking. They constitute the general tools of inquiry used in making sense of the world and are the most significant influence in learning. In Physics, Learner's existing concepts are known to have a profound influence on how phenomena is interpreted, and learners draw on these concepts in making predictions and explaining what they see and experience in the world (Heywood &Parker, 2019).

Studying physics also requires more than just learning about the products of science like concept. The culture of science involves very special actions called science process skill. The science process skills describe the actions or active doing within the culture of science that students can develop through practice and provide benefits to the classroom that extends beyond science learning. Thus, Teachers, in terms of supporting their students' science learning are challenged to achieve a balance between science concepts and process skills.

Based on the observation and interview result from Physics teacher at SMA Muhammadiyah 1 Medan Nort Sumatera Indonesia obtained, students' learning outcomes in cognitive domain was still in low level because they are still less ability to solve the problems related to the physics concept and they are mostly concerned to the formula and calculation. Thus, students felt so difficult to apply what they have known in their daily life situation. This was indicated from physics means grades of students before remedial in academic year 2014/2015 with grade 69, this average value has not achieved the standard grades, that is 70. Moreover, students science process skill is also in low level which is indicated from the unusual of students to conduct experiments in learning physics, meant learning physics just theoretically. Besides, learning which familiarized conducts by teacher are direct instruction and cooperative learning where methods are lectured, discussion, investigation, and mapping concept. But, all these models have not conducted as the phases of each model. This condition make students have not familiarized to find knowledge by themselves through scientific inquiry, thus students cannot provide explanations based on evidence.

Most of student's difficulties in learning physics are not caused by lacking of their understanding because they often come to school with already formed ideas on many topics, including how they view and interpret the world around themselves. Students have ideas about the world that are very different from the ideas of scientists which delivered in the class. Thus, teacher needs listening to how learner explain their understanding because that's not possible that their ideas are certain logics, therefore it is inappropriate to dismiss their thinking as errors that simply need to be corrected. Furthermore, teacher needs to develop learning that would move learners away from their initial ideas so they became aligned with accepted scientific explanations. This label suggests that students are using evidence to support their explanation and that way is consistent with the actions within the culture of science. This kind of learning is called as conceptual change.

Conceptual Change reflects the desire to have students discard naive concepts about the world in favor of explanations that are more scientifically accurate and focus was on changing students' science conceptions with the goal of having students discard or reshape their non-scientific explanations of natural phenomena in favour of the explanations accepted within the scientific community(Settlage & Southerland, 2007). It is a science teaching that begins by helping the students to become clear about their own ideas on a scientific topic, followed by having students participate in an activity in which their current ideas are not adequate to explain so that students recognize the shortcomings of their current explanations, after which the teacher introduces the new more scientifically appropriate explanation and students explore the strengths of the new idea and finally, the students compare the new ideas with their original explanations.

A conceptual change guides student to build knowledge after the experiment is over. Conceptual change requires that students discover improved knowledge that moves them closer to the understanding of scientist. The purpose of conceptual change is helping students to change their non-scientific preconceptions. It has been found that by explicitly recognizing the discrepancy between their current beliefs and the scientific ones (experience), students can be motivated to change their current beliefs (Bao et al., 2013). Besides, conceptual change learning has significant effect in students' learning outcomes and tolerance attitude (Badlisyah, 2013). Then, conceptual change become as an alternative source material for students and science teacher (Şahin & Çepni, 2011). Thus, the conceptual change is a teaching that focus on changing students' science conceptions with the goal of having students discard or reshape their non-scientific explanations in favor of the scientific explanations which is accepted within the scientific community that consist of four steps namely elicit and confirm current ideas, exposure to conflicting evidence, construct new explanation, apply and evaluate new explanation, and review change in ideas and explanations.

To seek ways to challenge thinking about the awareness of students' ideas and the best viewed as a process of conceptual change through scientific inquiry learning model as learners actively construct their own understanding of the world as a result of their experiences and interactions (Kalman, 2008). Scientific inquiry is the varied learning scientists use to investigate the natural world and the evidence-based explanations they propose as a result of their investigations and propose explanations based on the evidence derived from their work (Settlage & Southerland, 2007). Scientific inquiry designed to teach the research system of a discipline, but also expected to have effects in other domains, sociological methods may be taught in order to increase social understanding and social problem solving which is consist of four phases, first area of investigation is posed to students, second students structure the problem, third students identify the problem in the investigation, and the fourth students speculate on ways to clear up the difficulty (Schwab in Joyce & Weil, 2003).

In scientific inquiry learning model, students are guided by teachers to understand physics and to help them become participants within the culture of science. Moreover, scientific inquiry learning model will help students to develop critical thinking abilities and enables students to think and construct knowledge like a scientist, (Ali & Sencer, 2012; Bao et al., 2013). Thus, understandings of Scientific Inquiry are believed to be critical and essential components of the modern day battle cry of "scientific literacy" (Lederman et al., 2013).Then, scientific inquiry has significant effect on the student's achievement to apply the concepts of physics in real situations (Dumbrajs et al., 2011; and Hussain et al., 2011). Furthermore, the Inquiry-based Science Teaching enhance students' science process skills and attitudes toward science (Ergül et al., 2011; Turpin, 2004).

Scientific inquiry learning model based on conceptual change is learning that focus on changing students' concepts by involving students in a genuine problem of inquiry to be investigated and proposed the explanation based on evidence derived from their investigation in order students' explanation become aligned with accepted scientific explanations This learning makes learners to really learn the science concepts. The inquiry investigations capture their interest and generate for them evidence about the natural world and conceptual change helps them master the scientific ideas that explain the evidence from their inquiries. So inquiry combined with conceptual change is better for science teaching because students actually restructure their knowledge (Settlage & Southerland, 2007).

The purpose of this study was to find out which was better physics cognitive competence and science process skill (SPS) of students using scientific inquiry learning model based on conceptual change or using conventional learning. The benefit of this study were, to provide good information and donations in order to improve the learning process and school quality through increased students' achievement and professionalism of teachers working; for consideration in selecting or integrating a variety of appropriate learning model class, especially in physics learning; students are more motivated and continue to be active during the learning process takes place, so it can improve learning outcomes and provide a fun learning experience; and as an input, and increase knowledge for the researcher as candidate for future in the implementation of scientific inquiry learning model based on conceptual change.

2. Method

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This research was conducted at SMA Muhammadiyah 1 Medan, Class XI of Senior High School in even semester academic year 2014/2015 on March. The sample were Class XI (A) and XI (B) with the totaling of sixty two students. Experimental class used scientific inquiry learning model based on conceptual change while in control class used conventional learning.

The variables in this research consisted of independent and dependent variable. The independent variable was the scientific inquiry learning model based on conceptual change and the conventional learning. The dependent variable was physics cognitive competence and science process skill.

The research type was quasi experiment and two group pretest-posttest designs were used in this study.

Table 1. The Design of Research

Sample	Pre-test	Treatment	Post-test
Experimental Class	Y_1	X_1	Y_2
Control Class	Y_1	X_2	Y_2

Y1 : Pre-test
Y2 :Post-test
X1 :Treatment by using Scientific Inquiry Learning Model Based on Conceptual Change
X2 :Treatment by using Conventional Learning

In order to address research formulations in this study, Physics Cognitive Competence (PCC) and Science Process Skill (SPS) test were used.

Physics Cognitive Competence (PCC): The PCC test was in essay form consist of 11 items. They were differed by the types of knowledge namely factual, conceptual, procedural, and meta cognitive knowledge and then categorized their cognitive process based on the revised of Bloom's Taxonomy developed by Anderson & Krathwohl (2001) namely understand (C2) in items problem number 3, 5, and 7; apply (C30)in items problem number 6 and 10); evaluate (C5)in items problem number 1, 2, 4, 8, and 11; and create (C6)category in items problem number 9. The PCC-pre was given whether it in experimental or control class before treatment. The experimental class used the scientific inquiry learning model based on conceptual change where the learning consist of four phases, first, area of investigation is posed to student (elicit and confirm current ideas), second, students structure the problem (exposure to conflicting evidence), third, students identify the problem in the investigation (construct new explanations), fourth, students speculate on ways to clear up the difficulty (apply and evaluate new explanations& review change in ideas and explanations). While in control class used conventional learning. At the end of the treatment, both the experimental and the control class were administered the PCC-post. Then, the PCC was also evaluated cognitive process based on their categories individually whether it in experimental or in control class.

Science Process Skill (SPS): The students' SPS were assessed with test instrument in observation sheet form. The used skills were science process skills developed by Sani (2012), they are observing, inferring, questioning, interpreting, classifying, predicting, communicating, making hypothesis, planning, applying concepts or principle, and generalizing. The assessment of students' SPS was conducted in each meeting and calculated the average of the three meetings. Then, the observation of SPS was also evaluated their skills individually in experimental and control class.

An independents t-test (right side) was conducted to find out which was better students' PCC and SPS using scientific inquiry learning model based on conceptual change or using conventional learning,. Before conducting the analysis of testing, the normality and homogeneity were checked. The entire statistical calculations were using SPSS 18.0.

3. Result

The description of the data presented in this study was learning outcomes of students consisting of PCC and SPS by using conventional learning in control class and scientific inquiry learning model based on conceptual change in experimental class. Descriptive statistics for pre and post-test scores for the control and experimental class on PCC were given in Table 2.

Table 2. Pre and Post-PCC

Class	N	Mean	Mean
Experimental	32	52.76	72.79
Control	30	57.29	54.97

Table 2 showed that the mean of pre-PCC in experimental and control class was almost same. But the mean of post-PCC in experimental class was higher than in control class.

After the data was obtained, the testing of data analysis requirements was conducted, they are normality and homogeneity test.

Table 3. Normality and Homogeneity of Pre-PCC

Class	N	Kolmogorov-Smirnov[a]			Levene	
		Statistic	df	Sig.	F	Sig.
Exp.	32	0.120	32	0.200	0.708	0.404
Cont.	30	0.134	30	0.178		

Based on the result of normality of pre-PCC in Table 3, the significant value to the Kolmogorov-Smirnov was greater than 0.05 in experimental and control class. This result indicated that the data in both class was normal. Then the result of homogeneity of pre-PCC showed the significant value was greater than 0.05, so the both of classes was homogeneous.

Table 4. Normality and Homogeneity of Post-PCC

Class	N	Kolmogorov-Smirnov[a]			Levene	
		statistic	df	Sig.	F	Sig.
Exp.	32	0.127	32	0.200	0.572	0.452
Cont.	30	0.122	30	0.200		

Based on the result of normality of post-PCC in Table 4, the significant value to the Kolmogorov-Smirnov was greater than 0.05 in experimental and control class. This result indicated that the data in both class was normal. Then the result of homogeneity of post-PCC showed the significant value was greater than 0.05, so the both of classes was homogeneous.

In order to investigate the effect of scientific inquiry learning model based on conceptual change on students' PPC, an independents t-test (right side) by SPSS 18.0 was conducted.

Table 5. The t-test of pre-PCC

Class	t-test (right side)		
	t	df	Sig.
Experimental	-0.806	60	0.423
Control			

Table 5 showed the significant value was greater than 0.05, thus indicated that students' PCC in experimental class was not better than in control class before the treatment

Table 6. The t-test of post-PCC

Class	t-test (right side)		
	t	df	Sig.
Experimental	3.453	60	0.001
Control			

Table 6 showed the significant value was greater than 0.05, thus indicated that students' PCC using scientific inquiry learning model based on conceptual change was better than using conventional learning.

The post-PCC was also evaluated cognitive process based on their categories individually whether it in experimental or in control class. The percentage of each category in PCC was shown in Table 7.

Table 7. The Percentage Data of Each Category in PCC

Category	Percentage (%)	
	Experimental	Control
Understand (C2)	69	54
Apply (C3)	67	41
Evaluate (C5)	53	44
Create (C6)	56	32

According to the results given in Table 7showed the percentage of each category in physics cognitive competence was higher in the experimental class than in the control class.

The second description of the data presented in this study was students' science process skill (SPS). The assessment of SPS through observation sheet was conducted in each meeting and then calculated the average of the three meetings. The descriptive statistics for test scores for the control and experimental class on SPS were given in Table 8.

Table 8. Average grades of SPS

Class	N	Mean
Experimental	32	79.66
Control	30	63.97

Table 8 showed that the mean of SPS in experimental class was higher than in control class.

After the data was obtained, the testing of data analysis requirements was conducted, they are normality and homogeneity test.

Table 9. The Normality and Homogeneity SPS

Class	N	Kolmogorov-Smirnov[a]			Levene	
		statistic	df	Sig.	F	Sig.
Exp.	32	0.093	32	0.200	0.426	0.516
Cont.	30	0.149	30	0.088		

Based on the result of normality of SPS in Table 9, the significant value to the Kolmogorov-Smirnov was greater than 0.05 in experimental and control class. This result indicated that the data in both class was normal. Then the result of homogeneity of SPS showed the significant value was greater than 0.05, so the both of classes was homogeneous.

In order to investigate the effect of scientific inquiry learning model based on conceptual change on students' SPS, an independents t-test (right side) by SPSS 18.0 was conducted.

Table 10. The t-test of SPS

Class	t-test (right side)		
	t	df	Sig.
Experimental	5.634	60	0.000
control			

According to the results given in Table 10, students' SPS using scientific inquiry learning model based on conceptual change was better than using conventional learning. Then, observation results ofSPS in the experimental and control class in each meeting showed in Table 11.

Table 11. The Observation Result Data of Students' SPS in each Meeting

n-th meeting	Percentage (%) / Category	
	experimental	control
Meeting I	40% competent	34%fail
Meeting II	63% good	48% competent
Meeting III	85% excellent	69% good
Average	63% good	50% /competent

Table 11 showed the average percentage of SPS assessment was higher in experimental class with good category than in control class with competent category. The observation of SPS was also evaluated by individual process skill in experimental and control class. Based the research result, the average percentage of each indicator in experimental class was higher than in control class showed in Table 12.

Table 12. Data of Each Indicator SPS in Experimental and Control Class

Indicator	Percentage (%)	
	Experimental (category)	Control (category)
Observing	63.80 (good)	54.17 (competent)
Inferring	59.38 (competent)	47.22 (competent)
Questioning	65.36 (good)	56.67 (competent)
Interpreting	61.20 (good)	41.67 (competent)
Classifying	66.93 (good)	51.67 (competent)
Predicting	62.50 (good)	52.22 (competent)
Communicating	62.24 (good)	51.94(competent)
Making hypothesis	55.73 (competent)	44.17 (competent)
Planning	66.15 (good)	42.50 (competent)
Applying concept or principle	64.32 (good)	58.33 (competent)
Generalizing	61.20 (good)	50.83 (competent)

Based on Table 12, obtained the sequence from the higher to the lower percentage average in the experimental class were classifying, planning, questioning, applying concept or principle, observing, predicting, communicating, interpreting, generalizing, inferring, and making hypothesis. While in control class the sequence were applying concept or principle, questioning, observing, predicting, communicating, classifying, generalizing, inferring, making hypothesis, planning, and interpreting.

4. Discussion

The main purpose of this research was to analyze the effect of scientific inquiry learning model based on conceptual change on students' physics cognitive competence and science process skill (SPS) at senior high school. In the experimental class students were taught by scientific inquiry learning model based on conceptual change, while in the control class students were taught by conventional learning.

According to the findings of the collected data for the first research formulation of the study, it'd been obtained that students' physics cognitive competence using scientific inquiry learning model based on conceptual change was better than using conventional learning. This was reinforced by the acquisition of the mean grades of PCC-post in the experimental class was 72.97 with standard deviation was 19.10 and in the control class the mean grades of PCC-post was 54.97 with standard deviation was 21.93 showed in Figure 1.

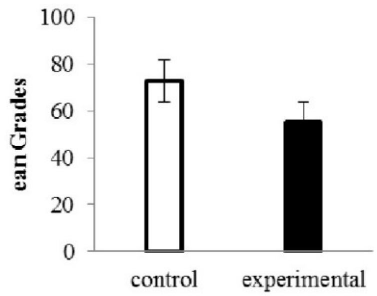

Figure 1. The result of Students' PCC

Furthermore, based on the evaluation of each category namely understand (C2), apply (C3), evaluate (C5), and create (C6) category obtained that the average percentage in experimental class was higher than in control class. Results of the study were consistent with the result of similar studies previously conducted. Many researchers have shown that the scientific inquiry learning model or conceptual learning improve students' achievement (Hussain et al., 2011). This learning model also enhanced the meaningful learning and students' answers reflected a deeper understanding of the phenomenon (Dumbrajs et al., 2011), engage students in an active process of constructing knowledge (Bao et al., 2013), , helps students develop critical thinking abilities (Ali & Sencer, 2012; Lederman et al., 2013), and refute students' possible misconceptions(Şahin & Çepni, 2011).

According to the findings of the collected data for the second research formulation of the study, it'd been obtained that students' science process skill using scientific inquiry learning model based on conceptual change was better than using conventional learning. This was reinforced by the acquisition of the mean grades of SPS-post in the experimental class was 79.66withstandard deviation was 10.83 and in the control class the mean grades of SPS-post was 63.97 with standard deviation was 11.09 showed in Figure 2.

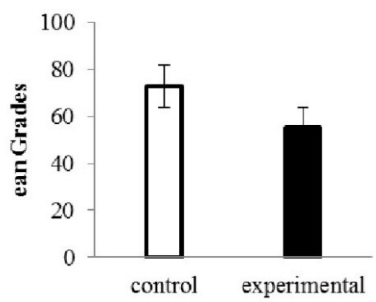

Figure 2. The result of Students' SPS

Furthermore, based on the evaluation of each indicator namely observing, inferring, questioning, interpreting, classifying, predicting, communicating, making hypothesis, planning, applying concepts or principle, and generalizing obtained that that the average percentage in experimental class was higher than in control class. Results of the study were consistent with the result of similar studies previously conducted. Many researchers have shown that the scientific inquiry learning model or conceptual learning improve students' SPS (Ergül et al., 2011). Furthermore, students' SPS can be improved through an integrated, activity-based science curriculum(Turpin, 2004), by Hands on Physics Experiments(Hırça, 2013), by I-diagram(Karamustafaoğlu, 2011).

5. Conclusion

Based on the study results and discussion, several conclusions were obtained, First, the mean of physics cognitive competence of students in experimental class was 72.97 and 54.97 in control class, based on the hypothesis testing obtained that students' physics cognitive competence using scientific inquiry learning model based on conceptual change was better than using conventional learning. Second, the mean of science process skill of students in experimental class was 79.66 and 63.97 in control class, based on the hypothesis testing obtained that students' science process skill (SPS) using scientific inquiry learning model based on conceptual change was better than using conventional learning.

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