Effects of Reflection-Oriented Inquiry Instruction on Grade 9 Students' Understanding on the Nature of Science

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Abstract
This study aimed to investigate the effects of reflection-oriented inquiry instruction on Grade 9 students' understanding on the Nature of Science (NOS) specifically on the aspects of observation and inference, and imagination and creativity. The study employed quasi-experimental research design with pretest-posttest control group design. The participants of the study involved two intact sections of Grade 9 junior high school students of Balindong National High School. An adopted instrument-Students' Understanding on Science and Scientific Inquiry Questionnaire (SUSSI-Q) was used. The findings of the study revealed that the control group of students demonstrated transitionary and informed levels and none in the naive level with more than half of the students demonstrated informed level while all the students in the experimental group demonstrated informed level in the two Nature of Science (NOS) aspects. Another is that, there is a significant difference between the control and experimental group at .05 level of significance in favor of the experimental group in the two Nature of Science (NOS) aspects. Apparently, on the average, the Reflection-Oriented Inquiry Approach was found to be beneficial in promoting students' understanding on the Nature of Science (NOS).

Keywords: Reflection-Oriented Instruction Approach, Inquiry Approach, Nature of Science (NOS), Observation and Inference, Imagination and Creativity

Introduction

In the context of scientific literacy, it has been a long standing goal in science education to promote a deeper understanding on the Nature of Science. The Trends International Mathematics and Science Study (TIMSS report, 2019), Philippines ranked last lowest among the 58 participating countries and ranked second lowest in the Programme for International Student Assessment (PISA report, 2018).

Most of the Filipino students had a very poor performance in the national and international science and mathematics assessment studies because their factual knowledge, NOS understanding, conceptual understanding and their skills in reasoning and analysis are very poor. According to the National Educational Testing and Research Center (NETRC) Reports 2015-2017, there is a poor quality of education in the Autonomous Region in Muslim Mindanao (ARMM) which was ranked 3rd from the bottom. There was also a poor performance in the National Achievement Test (NAT) in science in the schools division of Lanao del Sur I with a mean percentage score of below 75%.

The poor performance of the Philippines in national and international examinations may have been brought about by a host of factors such as: large class size, inadequate laboratory facilities, mismatch between intended or desired curriculum and implemented is actual curriculum carried out by schools (Ivowi, 2001). In addition, adherence of many science teachers to ask questions that require low order thinking skills rather than questioning that require high order thinking skills in classroom interactions and assessments may contribute to this dismal performance. Moreover, the teachers' resistance to adapt to more innovative and constructivist teaching approaches may also add to such result.

Scientific literacy has become one of the critical issues in our country. To increase the condition of lifelong literacy, reading and writing skills are no longer enough. Helping students to develop into scientifically literate citizens who are constructivist and reflective thinkers and have analytical and problem solving skills is a long-term objective and great challenges in science education. Hence, teaching the nature of science, through inquiry in tandem with scientific knowledge promotes students to develop scientific habits of mind that will enable them to be effective decision-makers beyond the classroom.

Thus, the teachers need to learn ways of guiding and supporting children in considering alternative views, innovative teaching methods, and constructing meanings of Nature of Science. They need to practice reflective teaching strategy in their classrooms. Reflective teaching can evaluate the level of intellectual processing and interaction in the classroom, and can make learning more relevant and meaningful to students' lives. This promotes inductive, critical thinking and problem solving. Because of this reason, the purpose of this study was to help students to develop understanding in the Nature of Science through the reflection-oriented inquiry instruction, in the hope that the solutions may be suggested to the school administrators and science teachers of Balindong National High School to improve students' understanding on Nature of Science.

Generally, this study investigated the effects of reflection-oriented inquiry instruction on the students' understanding of the nature of science among the grade 9 junior high school students of Balindong National High School on the school year 2017-2018. Specifically, this study sought answers to the following questions:

1. What are the control and experimental groups of Grade 9 students' understanding levels on the nature of science before and after intervention?
2. Is there a significant difference in the nature of science understanding test mean score between the control and experimental group of students before and after the intervention?

Conceptual Framework

This study was conceptualized that the reflection-oriented inquiry instruction has an effect on students' understanding on the nature of science. To guide in the implementation of the study, the research paradigm is shown in the Figure 1. The left box represented the independent variable–the method of instruction in the form of reflection–oriented inquiry instruction compared with the conventional lecture–discussion instruction. The dependent variable in the right box was the Nature of Science (NOS) understanding. The arrow coming from independent variable box represented the idea that the independent variable was hypothesized to affect or influence the dependent variable. This means that the grade 9 junior high school students' understanding on NOS was affected by instructional approaches used by the researcher.

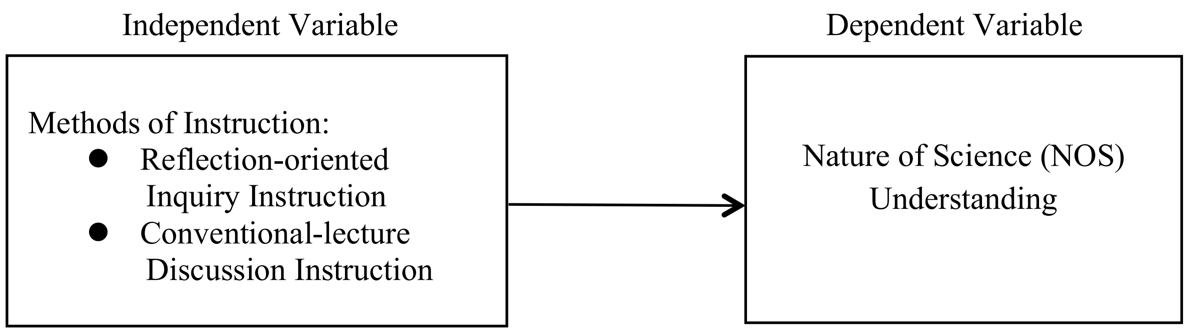

Figure 1. Research Paradigm

Scope and Delimitation of the Study

This study was limited to the investigation of the effects of reflection-oriented inquiry instruction on grade 9 junior high school students' understanding on the nature of science at Balindong National High School for the school year 2017-2018. The investigations of the students' NOS understanding were limited only on observation and inference aspect, and imagination and creativity aspect. Other variables which may affected the experimental group and control group which were beyond the control of the researcher were acknowledged as limitations of the study.

Research Design

This study used both quantitative and qualitative methods to investigate the effects of reflection-oriented inquiry instruction on the students' understanding on the nature of science. The quantitative aspect utilized quasi-experimental design using two intact groups. Specifically, the matching-only pretest-posttest control group design was used.

Experimental Group	**M**	**O_1**	**X**	**O_2**
Control Group	**M**	**O_1**	**C**	**O_2**

The symbol M refers to the match samples in terms of their average grades in Grade 8 in the experimental and control groups. The symbol O_1 represents the first administration of the research instruments including pretest to the experimental and control groups before the intervention. X stands for the instructional intervention (treatment) which was the reflection-oriented inquiry instruction given to the experimental group. C refers to the control group being exposed to the conventional lecture-discussion instruction. O_2 represents the second administration of the research instruments including posttest to the control group and experimental group after the intervention.

The quantitative aspect focused on the determining the number of students falling in each NOS understanding category and their scores in the NOS understanding test in both the control and experimental groups. In addition, statistical analysis was used in the numerical data to compare the NOS understanding levels. The qualitative aspect focused on the categorization of students' NOS understandings. Students' written responses in the questionnaire was categorized as naïve, transitionary, and informed using the adopted rubric guide of Liang et al (2008). Students' written responses were probed through semi–structured interviews.

To assess further the students' NOS understanding under the experimental group, the student participants were required to write a journal about what they have learned, the insights and reflection they have gained as they performed activities on the NOS aspects. Reflective questions were given after the activities underlining the NOS aspects. Moreover, observations (field notes) and uninformed interviews were done during the intervention.

Locale of the Study

This study was conducted in Balindong National High School, Balindong, Lanao del Sur, Philippines during the school year 2017–2018. The school is located specifically in Barangay Salipongan at the Municipality of Balindong, Lanao del Sur, Philippines. It is a public school under the Schools Division of Lanao del Sur-I and one of the top performing public schools in the province.

Subject Participants of the Study

The study involved two sections of intact classes namely, Section Masayahin with 64 students and Section Makadiyos with 69 students of grade 9 junior high school students in Balindong National High School. The 20 paired match students in the two sections of intact classes were assigned to the control and experimental groups by tossing a coin. Matching was unannounced to the subject participants. The experimental group was exposed to reflection-oriented inquiry instruction and the control group was taught under the conventional lecture-discussion method of teaching. Those students who were not matched were still part of the class discussions and activities but they were excluded in the data analysis.

Results and Discussions

The order of the data presentation, the data analyses and interpretations follows the sequence order of the presentation of the statement of the problem.

Control and Experimental Groups of Students' Levels of Understanding on the Nature of Science before and after Intervention

Table 1. Numbers and percentage distributions of control and experimental groups of students in the three levels of NOS understanding before and after intervention

NOS Aspects	Levels of Understanding	Before		After	
		Control Group (n=20)	Experimental Group (n=20)	Control Group (n=20)	Experimental Group (n=20)
1. Observation and Inference	Informed	3 (15.0%)	4 (20.0%)	12(60.0%)	20(100.0%)
	Transitionary	14(70.0%)	16 (80.0%)	8 (40.0%)	0(0.0%)
	Naïve	3 (15.0%)	0 (0.0%)	0 (0.0%)	0(0.0%)
2. Imagination and Creativity	Informed	0 (0.0%)	1 (5.0%)	17(85.0%)	20 (100%)
	Transitionary	10(50.0%)	10 (50.0%)	3 (15.0%)	0 (0.0%)
	Naïve	10(50.0%)	9 (45.0%)	0 (0.0%)	0 (0.0%)

Note: Legend: Raw score: 4–5–Informed; 3–Transitionary; 1–2–Naïve

To categorize the control and experimental groups of students' responses in the Likert–prompt items in the questionnaire (SUSSI–Q), the following rubric for level of understandings was used: raw score of 4–5 is informed, 3 is transitionary and 1–2 is naïve, and the students' written responses in the open–ended questions of the instrument (SUSSI–Q), a rubric developed by Liang, et al. (2008) was adopted.

Observation and inference. As shown in Table 1, before the intervention, more than half of the students in the experimental (80.0 %) and control (70.0 %) demonstrated transitionary level of NOS understanding. Very few (control group = 15.0%, experimental group = 20.0%) demonstrated informed level of understanding. For naïve level, there were few (15.0%) students on the control group demonstrated such level while none (0.0 %) in the experimental group.

The findings were supported by the study of Küçük and Cepný (2015) where the results gathered indicated that most students' nature of science understanding were weak or varying (78%) and only 22% of the students had adequate understanding.

This variation of numbers of students in each understanding level can be explained by the study of Abd–El–Khalick (2002) which that naïve or inadequate understandings of NOS are evident in participants who reflect an "absolutist view of scientific knowledge" meaning that scientific knowledge is certain and true, and does not change. Those ideas stem from the understanding that you have to see it to be true. Students with naïve understandings also believe that theories can be proven and eventually become scientific laws, and that scientific knowledge can only be obtained through precise experiments (Lederman et al., 2002).

On the other hand, students with informed or adequate understandings of NOS believe that scientific knowledge can change with new evidence and that scientists use inferences to determine things, such as atomic structure and knowledge about dinosaurs because neither can be directly observed by students in a classroom (Khishfe & Abd-El-Khalick, 2002).

After the intervention, below half of the control group (40.0%) demonstrated transitionary level of understanding while none (0.0%) in the experimental group. All the students in the experimental group (100.0%) demonstrated informed level of understanding while more than half in the control group (60.0%). None among the two groups demonstrated naïve level of understanding.

The results were supported by the contention of Küçük and Cepný (2015) that the direct-reflective methods should be used instead of indirect ones for students to understand the real nature of science. Furthermore, Abd-El-Khalick (2004) and Lederman, et. al (2012) declared that student gathered informed view on NOS aspect when exposed to reflective teaching method.

Imagination and creativity. As shown in Table 1, before the intervention, half of the students in both experimental (50.0%) and control (50.0%) group have transitionary level of NOS understanding. Very few demonstrated an informed level in the experimental group (5.0%) and none (0.0%) in the control group. For the naïve level, below half of the students (45.0%) in the experimental group demonstrated such level while half (50.0%) of the students in the control group.

This result was consistent with what Sangsa-ard, et. al.(2013) found out in their study investigating the role of creativity and imagination in the conduct of experiments which showed that majority of students held transitionary views to informed views in which they explain scientists used imaginative in some of step when they developed scientific knowledge and did experiments. Accordingly, these results indicated that grade 9 students' understanding of imagination and creativity NOS aspect is adequate in some ways and inadequate in the other ways.

After the intervention, all the students (100.0%) in the experimental group demonstrated informed level while more than half (85.0%) in the control group had a such level of understanding. None (0.0%) demonstrated a transitionary level in the experimental group while very few (15.0%) in the control group have such level. For the naïve level, none (0.0%) in both groups have such level.

Clearly, the results suggested that the activities and the lectures had a big impact on the students' levels of understanding on their imagination and creativity NOS aspect especially with the use of the reflection–oriented inquiry instruction. This was related to the study of Abd–El–Khalick, et. al. (2002) which had shown evidence that implicit NOS instruction was ineffective. From this study, the authors recommended that the teacher use explicit and reflective NOS instruction to improve students' understanding of NOS. Furthermore, teachers have to know their students' ideas about NOS because they can plan instruction to improve their students' understanding of NOS.

Comparison of Control and Experimental Groups of Students' NOS Understanding Test Mean Score before and after Intervention

To determine if there is a significant difference in the nature of science understanding test mean score between the control and experimental groups of students before and after the intervention, the t-test for independent samples was used. However, ANCOVA was used in explaining the posttest mean score on Observation and Inference aspect NOS understanding posttest mean score by using the pretest as covariate.

Observation and Inference. As shown in Table 3, before the intervention, the experimental group posted a higher mean score (3.12 vs 2.85) than the control group with a t–test value of

2.03 and p–value of .50 which is significant at .05 level. This implied that the two groups differed significantly in their NOS understanding test mean score at .05 level in favor of the experimental group. This further suggested that on the average, the students in the experimental group have better understandings than the control group as revealed in their test mean score.

To justify the initial incomparability of the two groups in their observation and inference NOS aspect mean score, Analysis of Covariance (ANCOVA) was additionally used using pretest as covariate in the posttest mean score comparison. It is utilized to see if the lead of the experimental group over the control group pretest mean score has an effect or influence on the posttest mean score result with the pretest mean score as a covariate. Table 2 showed the ANCOVA test results of observation and inference NOS aspect posttest mean score using the pretest mean score as covariate.

Table 2. ANCOVA test results of NOS understanding posttest on the Observation and Inference aspect for both experimental and control groups

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**p-value**	**Partial eta Squared**
Corrected	5.420[a]	2	2.710	12.409	0.000	0.401
Model	8.971	1	8.971	41.079	0.000	0.526
Intercept	0.163	1	0.163	0.749	0.393	0.020
OI_pre	**4.209**	**1**	**4.209**	**19.271**	**0.000**	**0.342**
Group	8.080	37	0.281			
Error	614.125	40				
Total	13.500	39				
Corrected Total						

Note: R Squared = 0.401 (Adjusted R squared = 0.369)

As shown in Table 2, the F–test has a value of 19.271 and a p–value equivalent to 0.000 which is less than .05 level of significance ($p < .05$). This implied that the lead of experimental group over the control group pretest mean score has no effect or influence on the lead of the experimental group over the control group posttest mean score. This means that the posttest results were statistically significant after controlling the effect of pretest as covariate.

This further suggested that the lead of the experimental group over the control group mean score before the intervention can be due to chances which are caused by some influential factors such as that most of the students in the experimental group were influenced by their readings in science textbooks and information they got form social media, an influence of easy–access to the internet through their electronic gadgets such as laptops, smart phones and tablets, and also, most of their parents have a strong parental support system in their educational process.

Table 3. T-test values and p–values on the comparison of the control and experimental groups of students' NOS understanding mean score before and after intervention

NOS Aspect	Period	Group	Mean Score	Standard Deviation	t-test value	p-value
1.Observation and Inference	Before Intervention	Control (n=20)	2.85	0.476	2.03	.050(s)
		Experimental (n=20)	3.12	0.376		
	After Intervention	Control (n=20)	3.51	0.489	4.90	.000 (s)
		Experimental (n=20)	4.24	0.440		
2.Imagination and Creativity	Before Intervention	Control (n=20)	3.43	0.398	-0.83	.411(ns)
		Experimental (n=20)	3.30	0.541		
	After Intervention	Control (n=20)	3.97	0.512	2.80	.008(s)
		Experimental (n=20)	4.36	0.348		

Note: s = significant at .05 level; ns = not significant at .05 level

However, after the intervention as shown in the Table 3, the observation and inference NOS understanding mean score of the two groups had a p–value of 0.000. This implied that the two groups were significantly different at .05 level of significance ($p < .05$). This further suggested that the exposure of the students in the experimental group to the reflection–oriented inquiry approach was found to be favorable in helping the improvement of their NOS understanding in observation and inference aspect. The students understood the concepts much deeper and the similarities and differences in the observation and inference aspect of NOS in which they may apply them not only in science classrooms but also in their daily lives.

Moreover, the reflection–oriented inquiry instruction given to the experimental group was found to be helpful in increasing the level of students' NOS understanding in observation and inference aspect. The students understood the concepts and the similarities and differences in the observation and inference aspect of NOS in which they may apply them not only in science classrooms but also in their daily lives. The students comprehended the meanings of their observations and distinguished on how they would give implications as they inferred.

Imagination and Creativity. As shown in Table 3, before intervention, the experimental group posted a lower mean score (3.30 vs. 3.43) than the control group with a t–test value of –0.83 and p–value of 0.411 which is not significant at .50 level ($p >.05$). This implied that the two groups of students were initially comparable in their NOS understanding in imagination and creativity aspect prior to the intervention. This suggested that the students from the two groups had the same level of understanding on the imagination and creativity NOS aspect. Generally, it is natural to expect this result because these two groups of students were handled by the same teacher, and were exposed to the same learning environment.

After intervention, the experimental group posted a higher mean score (4.36 vs. 3.97) than the control group with a t–test value of 2.80 and p–value of 0.008 which is significant at .05 level ($p< .05$). This implies that the two groups were significantly different in their NOS understanding test mean score at .05 level in favor of the experimental group. This suggested that the experimental group of students' exposure to the reflection–oriented inquiry instruction was found to be beneficial in facilitating the improvement of their NOS understanding in imagination and creativity aspect. As supported by experimental group of students' reflection written in their journal writing, their confusions and difficulties regarding the terminology usage on the said aspect were corrected, reconciled, clarified and well understood.

Conclusion

Based from the findings of the study, the following conclusions were drawn such as (1) students who were not exposed to reflection-oriented inquiry instruction of the Nature of Science (NOS) were capable of understanding the aspects of NOS at their own expense. Their understanding existed in naïve–transitionary–informed levels. However, most of the students were in the transitionary level of their NOS understanding. After exposure to reflection-oriented inquiry instruction, students' NOS understanding level was raised to informed level higher in the number of students exposed to reflection-oriented inquiry instruction than those exposed to conventional–lecture instruction. (2) In the Observation and Inference NOS aspect, there was a significant difference ($t=4.90$, $p=0.00<.05$) in favor of the experimental group. While, in the Imagination and Creativity NOS aspect, there was also a significant difference ($t=2.80$, $p=0.008<.05$) in favor of the experimental group. Therefore, the reflection–oriented inquiry instruction was found to be beneficial in promoting students' understanding on the nature of science (NOS).

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