IMPROVING STUDENTS' SCIENCE PROCESS SKILLS USING ARGUMENT-DRIVEN-INQUIRY (ADI) LABORATORY METHOD

Abstract:

This study aimed to determine the effects of the Argument-Driven-Inquiry (ADI) laboratory method on high school students' science process skills. The study further investigated the method's effect on students with different reasoning ability levels, namely the hypothetico-deductive, transitional, and empirical-inductive. A mixed method employing both quantitative and qualitative procedures for gathering data was employed. A quasi-experimental study using a 2 x 3 factorial design was implemented where Reasoning Ability Level was the moderating variable. The study was conducted on two intact classes of fourth-year students at Iloilo National High School-Science, Technology and Engineering enrolled in the subject "College Physics". Lawson's Classroom Test of Scientific Reasoning was utilized to categorize students according to their reasoning ability levels. To measure students' science process skills before and after the study, the Test for Integrated Process Skills II (TIPS II) was employed. Mean, standard deviations, t-test for independent samples, and one-way analysis of variance were determined as part of the statistical analyses. Results revealed that students in the two groups were comparable in terms of science process skills before the intervention was employed. However, exposure to the ADI laboratory method improved students' science process skills better than exposure to the traditional laboratory method. Further, the improvement of students' science process skills is deemed independent of the student's reasoning ability level but relies mainly on the type of laboratory instruction.

Keywords: *ADI, science process skills, reasoning ability level, TIPS II, laboratory method, concept cartoons, scientific argumentation*

Introduction:

A wide range of research had pointed out that for a student to be able to successfully process and evaluate information in solving a problem, he should be competent in the different science process skills. Other researchers had reported that competence in the science process skills also indicates high critical thinking abilities. In addition, conceptual understanding of science also involves the use of these skills. Thus, the development of the different science process skills should be vital in the learning of science. This idea has long been accepted and reflected in the science curriculum, particularly in the basic education curriculum, worldwide. This is also apparent in the newly implemented K to12 curriculum of the Philippine Basic Education.

One best venue where students would be able to acquire and improve their science process skills is through the conduct of laboratory activities. In recent years, science education research, both in local and international communities, stress the importance of inquiry-based instruction, particularly in the laboratory where students are given opportunities where they would be able to design their investigations rather than simply follow a certain set of procedures and verify what they have learned in their lecture course. Further, reports had shown that many benefits can be derived from inquiry laboratories such as better conceptual understanding, development of different skills, and even a more positive attitude towards science.

In answer to these reports, many countries re-designed their science curricula and national policies were created which incorporate inquiry as the primary mode of both classroom and laboratory instruction (Watson, Swain & McRobbir, 2004; NRC, 2006). This new curricular emphasis is also projected in the present K to 12 curriculum of the Philippine Basic Education. As stated in this curriculum's conceptual framework, the acquisition of the three identified learning science domains can best be facilitated with the use of student-centered approaches such as inquiry-based learning (DepEd, 2016).

Another big emphasis on science education reforms is the importance of evidence in supporting conclusions or claims – a process known as argumentation. In fact, argumentation is considered "the language of science" (Duschl, Ellenbogan, & Erduran, 1999 in Tippett, 2009) and therefore, plays an important role in the learning of science, especially in the laboratory. As Luneta, Hofstein & Clough (2007) had suggested, inquiry-based laboratories can be very good venues for student argumentation. Since students are required to come up with decisions in different stages of an investigation or inquiry, argumentations can also be done not only at one stage but at several stages of the investigation. Thus, the teacher can fully utilize the potential of inquiry-based laboratories with the use of argumentation to promote a better understanding of core concepts, improve critical thinking abilities and enhance students' science process skills.

However, despite what research says and these curricular reforms, reports had shown that actual laboratory activities and practices in science classes still follow the traditional method of mechanically following routine procedures using activity sheets. Furthermore, laboratory reports are usually in the form of filling-up activity sheets rather than writing an actual report. This observation also holds true, especially in high school and introductory physics classes in the Philippines. In fact, argumentation opportunities are rarely observed in these laboratories, and in some cases, even post-lab discussions are not done, assuming that students' laboratory reports/outputs already indicate student learning. It can therefore be said that the development and assessment of science process skills in the laboratory are not given due emphasis.

Based on these premises, the researcher believes that there is a great need in reforming the conduct of laboratory activities, particularly in high school sciences. Laboratory practices must be shifted from the traditional cookbook format to a more inquiry-oriented format. Further, the integration of argumentation-oriented opportunities should also be considered in the restructuring of these science laboratory practices. Thus, this study proposes the use of a modified argument-driven-inquiry (ADI) instructional model described by Sampson, Grooms & Walker (2009) in high school physics and even in introductory physics laboratory courses. Most of the related studies done involved argumentation in the classroom and very few were done involving its use especially in Physics laboratories. Further, published studies involving the use of argumentation and inquiry in Philippine laboratories are scarcely seen. Thus, this study would not only help in bridging the gap between research and actual practice of the use of argumentation and inquiry in the laboratory but also add to the limited existing literature involving its use in the physics laboratory, particularly in the Philippine setting.

Statement of the Problem:

The purpose of this study was to determine the effect of Argument-Driven-Inquiry (ADI) Laboratory Method on high school students' conceptual understanding of Electric Circuits and science process skills. The study further investigated its effect on students with different reasoning ability levels, namely the hypothetical deductive (HD), translational (T) and empirical inductive (EI). In particular, this study attempted to answer the following questions:

1. What are the levels of students' science process skills before and after the implementation of the study?
2. Is there a significant difference in the developed science process skills among students exposed to ADI and those exposed to Traditional Laboratory Method (TLM) when they are classified based on their reasoning ability levels as to hypothetical deductive (HD), translational (T), and empirical inductive (EI)?

Methodology:

The design of the study was a quasi-experimental-pretest-post-test control group design employing a 2x3 factorial design with reasoning ability level as the moderating variable. The basis for the choice of the factorial design was to determine the effects of the two laboratory conditions (ADI lab and TLM) not only on students in these laboratories but also on students of different reasoning levels (HD, Transitional & EI). A quasi-experimental design was favored instead of a pure experimental design since students belonging to a particular laboratory class were already pre-determined. The pretest-posttest design was also favored instead of the posttest only to have a common ground for comparison and to establish that students in both laboratory conditions were comparable before the interventions were introduced.

The environment that best suited the design of the study is the Iloilo National High School – Science, Technology & Engineering (INHS-STE) program in La Paz, Iloilo City, Philippines. There are three (3) sections in every year level in the STE program with approximately 25-30 students in each section. The assignment of students in these sections was done following a certain criteria. The top 30 students were determined from their grades and were assigned to the star section. The remaining students were assigned to the other two sections through a pairing scheme based on different criteria such as grades, gender, and attitude. Thus, the last two sections were ideal for the chosen two groups.

Further, the Physics subject offered in the fourth year is parallel to the Introductory Physics subject offered in college. This will, therefore, widen the applicability of the proposed instructional method. In addition, since the offered Physics subject for fourth-year students is a continuation of their third-year Physics, there is a longer period allotted for certain topics rather than in the regular class. This set-up gave sufficient time for conducting laboratory activities. This is imperative since inquiry-based methods take a longer time for topics to be covered.

In this study, the original ADI model proposed by Sampson, et al (2009) was adopted but revisions on some steps were done. Concept cartoons (Naylor & Keogh, 1999) were used in the first step as a stimulus for students to formulate their problem and plan their investigation to answer the problem. In addition, a possible replication of the investigation by another group as part of the peer-review was integrated in the model, although the actual replication was done only once in the whole semester due to time constraints. The distribution of the different steps was followed as those suggested by Walker, et al (2010).

Moreover, Integrated Process Skills Test II (TIPS II) to test students' science process skills was also integrated. The process skills measured were the five (5) identified integrated process skills – identifying & controlling variables (ICV), generating hypothesis (GH), defining operationally (DO), interpreting data (ID), and experimenting (E). These process skills were described as Beginning (B), Developing (D), Accomplished (A), and Exemplary (E). The data were subjected to appropriate statistical treatment for analysis. The mean was determined to describe the level of students' science process skills. T-test for independent samples was used to compare the science process skills of students having the same reasoning ability level belonging to the different laboratory conditions. One-Way ANOVA, on the other hand, was used to compare students of different reasoning ability levels in the same laboratory condition.

Results and Discussion

Results revealed that before the intervention, students' science process skills for both groups were already within the accomplished level and even at the exemplary level for HD students. These data are reflected in Table 1.

Table 1

Level of Students' Science Process Skills before the Intervention

Categories	n	Mean	SD	Description
Experimental Group				
HD	3	29.33	2.52	Exemplary
T	18	25.00	3.78	Accomplished
EI	5	21.60	0.89	Accomplished
Entire Group	26	24.85	3.85	Accomplished
Control Group				
HD	3	29.00	2.65	Exemplary
T	17	25.41	3.76	Accomplished
EI	6	22.17	6.08	Accomplished
Entire Group	26	25.08	4.58	Accomplished

When students' skills in the five integrated science processes are further scrutinized, it was observed that students in the experimental group have exemplary skills in both *interpreting data* and *experimenting* while the control group is only for *experimenting*. Both groups have accomplished skills in *identifying and controlling variables*, *generating hypothesis* and *defining operationally*. Tables 2 and 3 indicate these data.

Table 2

Level of Students' Skills in the Five Integrated Science Processes of the Experimental Group before the Intervention

Skill	**no of items**	**HD**			**T**			**EI**			**WHOLE GROUP**		
		M	**SD**	**Level**	**M**	**SD**	**Level**	**M**	**SD**	**Level**	**M**	**SD**	**Level**
ICV	12	8.67	1.53	A	8.67	1.71	A	6.60	1.14	A	8.27	1.76	A

GH	9	7.33	0.58	A	5.33	1.71	A	4.80	0.84	A	5.46	1.63	A
DO	6	5.33	0.58	E	4.00	0.97	A	3.80	1.10	A	4.12	1.03	A
ID	6	5.00	1.00	E	4.67	0.69	E	4.40	0.89	A	4.65	0.75	E
E	3	3.00	0.00	E	2.33	0.91	E	2.00	0.71	A	2.37	0.85	E
Total	36	29.33	2.52	E	25.00	3.78	A	21.60	0.89	A	24.85	3.85	A

Table 3

Control Group's Level of Skills in the Five Integrated Science Processes before the Intervention

Skill	**no of items**	**HD**			**T**			**EI**			**WHOLE GROUP**		
		M	**SD**	**Level**	**M**	**SD**	**Level**	**M**	**SD**	**Level**	**M**	**SD**	**Level**
ICV	**12**	**9.00**	**0.00**	**A**	**8.00**	**2.03**	**A**	**8.00**	**2.53**	**A**	**8.12**	**2.01**	**A**
GH	**9**	**7.33**	**0.58**	**E**	**5.59**	**1.62**	**A**	**5.17**	**0.98**	**A**	**5.69**	**1.52**	**A**
DO	**6**	**5.00**	**1.00**	**E**	**4.59**	**1.23**	**E**	**3.83**	**1.94**	**A**	**4.46**	**1.39**	**A**
ID	**6**	**4.67**	**1.15**	**E**	**4.65**	**0.86**	**E**	**3.83**	**1.94**	**A**	**4.46**	**1.21**	**A**
E	**3**	**3.00**	**0.00**	**E**	**2.59**	**0.51**	**E**	**1.33**	**0.82**	**D**	**2.35**	**0.80**	**E**
Total	**36**	**29.00**	**2.65**	**E**	**25.41**	**3.76**	**A**	**22.17**	**6.08**	**A**	**25.08**	**4.58**	**A**

When the students' science process skills were compared, results showed that at the start of the intervention, the experimental group's HD students had significantly better science process skills compared to its EI students, but no significant differences were seen between the experimental group's HD and T students as well as its T and EI students. On the other hand, no significant differences lie among students in the control group when they are classified according to their reasoning ability levels. When taken as a whole, no significant difference was seen between the control and experimental group. Further, no significant difference exists between HD students, T students, and EI students in the two laboratory conditions. These data suggest that the two groups were comparable in terms of students' science process skills before the implementation of the study.

Table 4 shows the level of students' science process skills in the experimental group and control group, after the intervention. As can be observed, students of different reasoning ability levels in the experimental group were already at the exemplary level while their counterparts in the control group were still at the accomplished level except for the HD students who were within the exemplary level. When taken as a whole, students in the experimental group had exemplary science process skills while the control group's science process skills was within the accomplished level.

Table 4

Level of Students' Science Process Skills after the Intervention

Categories	n	Mean	SD	Description
Experimental Group				
Entire Group	26	30.19	3.71	Exemplary
HD	3	32.00	1.00	Exemplary
T	18	30.56	3.58	Exemplary
EI	5	27.80	4.55	Exemplary
Control Group				
Entire Group	26	26.12	5.19	Accomplished
HD	3	31.00	2.00	Exemplary
T	17	26.88	4.72	Accomplished
EI	6	21.50	4.46	Accomplished

Tables 5 and 6 reveal students' skills in the five processes of the experimental group and control group, respectively. As can be observed, the experimental group students' skills in the five science processes were already at the exemplary level while students in the control group were still at the advanced level except for the HD students who were within the exemplary level. In fact, when the control group's skills level in these five processes after the intervention (Table 6) are compared with their skills level before the intervention (Table 3), there was no change in the described level.

Table 5

Experimental Group's Level of Skills in the Five Integrated Science Processes after the Intervention

SPS	**no of items**	**HD**			**T**			**EI**			**WHOLE GROUP**		
		M	**SD**	**level**	**M**	**SD**	**level**	**M**	**SD**	**level**	**M**	**SD**	**level**

ICV	12	9.67	0.58	E	10.61	1.75	E	9.00	2.45	A	10.19	1.88	E
GH	9	8.00	0.00	E	7.06	1.51	E	7.20	0.84	E	7.19	1.33	E
DO	6	5.67	0.58	E	5.11	0.76	E	4.60	1.52	E	5.08	0.93	E
ID	6	6.00	0.00	E	5.22	0.73	E	5.20	0.84	E	5.31	0.74	E
E	3	2.67	0.58	E	2.50	0.62	E	2.00	1.00	A	2.42	0.70	E
Total	36	32.00	1.00	E	30.56	3.58	E	27.80	4.55	E	30.19	3.71	E

Table 6

Control Group's Level of Skills in the Five Integrated Science Processes after the Intervention

SPS	**no of items**	**HD**			**T**			**EI**			**WHOLE GROUP**		
		M	**SD**	**level**	**M**	**SD**	**level**	**M**	**SD**	**level**	**M**	**SD**	**level**
ICV	12	10.67	1.15	E	8.76	2.19	A	7.33	1.97	A	8.65	2.21	A
GH	9	8.00	0.00	E	6.59	1.70	A	4.67	1.63	A	6.31	1.85	A
DO	6	4.67	1.15	E	4.76	0.75	E	3.67	1.03	A	4.50	0.95	A
ID	6	5.33	1.15	E	4.47	1.37	A	3.67	1.51	A	4.38	1.42	A
E	3	2.33	1.15	E	2.29	0.69	E	2.17	0.98	A	2.27	0.78	E
Total	36	31.00	2.00	E	26.88	4.72	A	21.50	4.46	A	26.12	5.19	A

When students' gains in their science process skills after the intervention were compared, statistical analysis revealed that T and EI students in the experimental group showed better gains in their science process skills compared to their counterparts in the control group while HD students had comparable gains. When taken as a whole, students in the experimental group had better gains in science process skills than those in the control group. In addition, no significant differences were seen in the gains among students of different reasoning ability levels belonging to the same group.

The results of this study support those reports by Basaga et al (1994), Brickman et al, (2009), Ergül et al (2011), Lati et al (2012), and Myers, et al (2003) that inquiry-based laboratories promote the development of different science process skills. This study is also in consonance with the findings of Walker et al (2010) that the ADI method facilitates the development of science process skills. Since the ADI method requires students to formulate a hypothesis to explain the concept cartoon, test this hypothesis by performing a well-planned experiment and evaluate their explanation based on their data, thus, science process skills are promoted. The absence of such opportunities in the traditional laboratory method may have hindered the improvement in students' skill development.

In this study, students employing the ADI laboratory method were able to determine their working problem, make a sound hypothesis, define variables operationally, identify and control the different variables in their investigation, plan out and execute their own experiments, and interpret their data correctly. As observed in the present study, students in the ADI Laboratory method executed these skills better compared to students exposed to the traditional cookbook format which further supports the reports of Demircioglu & Ucar (2015). Even Siahaan, et al (2019) reported that the ADI method is more effective in developing students' generic science skills compared to a guided inquiry method.

Conclusions

The findings of the study imply that the Argument-Driven-Inquiry Laboratory Method is effective in promoting the development of integrated science process skills. It also revealed that the ADI is more effective in promoting students' development of science process skills compared to the Traditional Laboratory Method. The study had also shown that regardless of students' reasoning ability level, all students benefit from the ADI method.

Recommendations

Department of Education and other Basic Education Institution

The present K+12 Basic Science curriculum encourages the use of inquiry-based activities as well as performing scientific investigations and this study had shown that the ADI Laboratory Method is a very good strategy that can be used to materialize these objectives. It is recommended that this method be used in the STE program in the junior high school and the STEM strand in the senior high school.

Higher Education Institutions

It is also recommended that the ADI Laboratory Method be utilized in all science classes especially where scientific investigation is given emphasis. For teacher education programs, it is recommended that pre-service science teachers be trained on the use of inquiry-based laboratory methods particularly the ADI laboratory method.

Educational Researchers and Curriculum Planners

Different research can also be done related to this study. It is suggested that the effectiveness of the ADI Laboratory Method be examined on students of different learning styles as well as its effect on students' argumentation skills, attitude towards science, and social skills. It is also recommended that different group compositions (such as heterogeneous, homogenous, and friend-based groups) and group sizes be tested to determine which group composition and size would best facilitate cooperative learning.

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