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The Effects of Explicit Scientific Argumentation Instruction through Practical Work on Science Process Skills

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Abstract

The aim of this study was to investigate the effects of incorporating explicit instruction of scientific argumentation through practical work on 10th grade students' skills in science process. This research used a quasi-experimental method which involved one control group and two experimental groups from two national secondary schools in the category of rural school were involved in this study. A total of 112 10th grade students from the three classrooms were assigned randomly as the conventional (CON) group, experimental group with Inquiry without Argument approach (IWA) group and the Modified Argument-Driven Inquiry approach (MADI) group. In order to evaluate the effects of intervention on the tenth-grade students, Science Process Skills Test (SPS Test) was administered as pre-test and post-test on the control and experimental groups. Data collected from the experimental study were described by means of descriptive analysis and inferential analysis involving ANOVA analyses. The results of ANOVA showed there exist significant differences in science process skills among the three groups where students in the MADI group showed better performance compared to the other groups. The results of this research have implication on researchers and practitioners keen on promoting biology science process skills through instructions of scientific argumentations given explicitly in learning environments of science practical work.
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Keywords: Scientific Argumentation, Science Process Skills, Practical Work, Biology, Secondary School.

INTRODUCTION

Literacy in science has become the core aim of science education initiatives and science process skills are one of the common dimensions of scientific literacy in developed western societies. To be scientifically literate, a person should have science process skills (SPS) such as to classify, infer, observe, control variables, formulate hypothesis, and experiment which fit all scientific ventures (Durmaz & Mutlu 2017; Lilia Halim 2013; Herlanti et al. 2019; Yuliskurniawati et al. 2019). In Malaysia, science process skills are one of the seven new elements introduced into the existing science curriculum/ subject syllabus in view of the requirements of the 21st century since 2001 (Ministry of Education 2001) and it is continue to be stated as an integral component of the Malaysia's science education goals that is to be achieved in Malaysia (Ministry of Education 2013).

One of important part of scientific inquiry is science process skills. This is because science inquiry according to Lederman (2006) includes process skills, and science inquiry also refers to the combination of skills in process with knowledge in science, reasoning and thinking critically to knowledge of science. Furthermore, Durmaz and Mutlu (2017) and Yuliskurniawati et al. (2019) also mentioned that science process skills are playing as key role to develop the understanding in procedure and concept and also the scientific knowledge. Therefore, science process skills are also called as science inquiry skills (Segumpan 2001; Kuhn & Pease 2008; Gobert et al. 2013; Fang et al. 2016) or competence in scientific inquiry or science practices (Arnold et al. 2018).

Mastery in science process skills is said to have a relationship with student achievement as demonstrated in previous studies (Saçkes 2013; Mohd Atan & Noordin 2008; Okebukofa 1986) and it is also able to make improvement of students' achievement in science subject (Saçkes 2013; Fang et al. 2016; Suryanti et al. 2018). International comparative studies such as Programme for International Student Assessment (PISA) have offered rationale and support for the advancement of the dimension of science process skills in scientific literacy such as the ability to interpret data and evidence scientifically. Sunyono (2018) remarked that the low PISA rating obtained by countries such as Indonesia is indicative of their students' lack of science process skills. In the case of Malaysia, despite outperforming their Indonesian peers regionally, Malaysian students' science achievement continues to lag behind other developed countries and even lower income countries in the region like Vietnam quite considerably as well as the OECD averages according to the results of the 2012 PISA testing. Furthermore, the results of the 2016 PISA testing had indicated that the rural Malaysian students continues to lag behind 0.9 years from the urban Malaysian students (The World Bank Group 2017).

In addition to the Malaysian students' poor performance in PISA, the empirical research in science process skill assessments involving school students indicates that the urban-rural difference continues to be pronounced in primary schools (Sulaiman et al. 2009; Ong et al. 2015; Ong & Bibi Hazliana Mohd Hassan 2013) as well as in secondary schools. The findings in Sulaiman et al. (2009) and Ong et al.'s (2012) study shown that the secondary students in rural schools did not even obtain the standard of achievement for basic and integrated science process skills. The researchers attributed this finding to the science teachers' general teaching ways in school, i.e. didactic and expository manner (Ong et al. 2015). The findings of Ong et al.'s (2007) study also found that most of the school science investigation activities in practical work only involve the manipulation of apparatus and following teachers' instructions strictly. Thus, there will be obstacle for the development of the science process skills necessary for scientific inquiry in teacher-centred instruction because the learning seen only focuses on the mastery of content (Taraban et al. 2007).

Research in implementation of inquiry in science subjects involving lower science secondary school teachers (Edinin 2005), upper biology teachers during experimental lessons (Taridi 2007) and chemistry teachers during lessons (Sim & Arshad 2015). The previous researches have shown that most inquiry activities are more teacher-centred and that there seems to be a gap between the teaching approach implemented by the teachers and the approach required in the science curriculum. For instance, Taridi (2007) in his qualitative research examined the implementation of inquiry approach among four biology teachers. The finding of his study showed that the teachers practised teacher-centred instruction and used their own perspectives in applying the inquiry approach in their teaching during the experimental lessons. It was found that the problem faced by the teachers in implementing this approach was mainly due to the teachers' lack of knowledge as well as inadequate preparation by the students. This finding is further supported by the investigation on the progression of inquiry implementation in science teaching conducted by the Inspectorate of Schools in 2014 involving 20 primary schools and 14 secondary schools. The outcome of the investigation showed that 34.88% of the elementary science teachers and 61.29% of the secondary science teachers still taught science didactically (Curriculum Development Division 2015a). Hence, inquiry approach does not occur in the real context as intended in the Malaysian science curriculum (Curriculum Development Division 2015b).

The instructional approach of inquiry is complex that composed of many interconnected activities, i.e. requires students involving in questioning, collecting and analysing data, forming and justifying explanations, and connecting the explanation to concepts of science. However, due to the fact that its complexity, it often abandon of its capability in daily practice. Furthermore, school teachers (UNESCO 2016) or lecturers (Coil et al. 2010; Molefe & Stears 2014) typically do not spend enough time teaching science skills to students because of the pressure to cover the syllabus. This has regrettably compelled teachers to adapt their strategies of instruction to focus on content and thus disregard the practical work in science practices. The process skills are taught separately and students are often drilled with answering techniques in order to perform well in the high-stakes assessments (Lay 2017). Indeed, a growing body of evidence suggests that adequate mastery of science process skills is difficult to achieve up until now if approached through teacher-centred instruction.

Based on the constructivist influence, Millar and Driver (1987) argued that the separation of content and process is a wrong separation because the separation does little to make improvement of the science education quality. This is further supported by Roth and Roychoudhury (1993) who suggested that skills in science process need not be taught separately. Based on philosophical grounds, formation of hypothesis is intuitive process and the process is cannot be learned and transferred (Miller & Driver 1987). According to Mohd Saat (2004), this is because the learners’ understanding in a new situation appears to depend on the context in learning rather than through the acquisition of general rules or strategies.

When science education entered a new era of change after the mid-1990s which was partly caused by globalisation and rapid technological development, it called for achievement of competence in scientific inquiry through practices in science such as practical work which is an core component of literacy in science. Hofstein and Kind (2012) stated that practical work in this era should help the everyone to understand about science and to promote useful skills to judge scientific assert in daily life rather than training specialists in science field. Further development in constructivist perspectives towards the view of sociocultural in science education which promience that knowledge of science is constructed socially has been another field of development in recent times. Hofstein and Kind (2012) explained that scientific inquiry is seen to comprise explanation process to relate of data. The practical work should concentrate on how students know what they know and why students accept certain claims rather than promoting the scientific method. Therefore, students must critically comprehend, manage, and evaluate investigations in science through practical work for the preparation for 21st century's life and future work.

According to (Özgelen 2012 cited in Yildirim et al. 2016), science process skills act as a driving factor for scientific inquiry and help develop students' thinking, inquiry, reasoning, evaluation, and problem-solving skills. Osborne (2015) strongly advocates that there is no substitute for students in terms of having to experience science phenomena themselves through practical work as when appropriately carried out, it presents the students the opportunity to participate and engage in the scientific inquiry process. Hong et al. (2013) believe that concrete experiences through practical work enable students to build a better understanding of science. Therefore, practical work in the school science laboratory is the perfect place to make engagement for the practise of science process skills of students.

Scientific argumentation is closed relate with scientific inquiry. Kim and Song (2006) developed a mode of argumentative scientific inquiry in which they propose that practical work should be closely related to argumentation. They argued that 'Argumentation gives feedback to the experiment activity. The experiment is the basis for argumentation' (Kim & Song 2006, p. 230). Argumentation is an essential practice that should be put into action in all high school science classrooms (Weis 2015). Over the past twenty years, numerous empirical studies have investigated ways to encourage scientific argumentation in classrooms and ways to scaffold students' learning how to be involved and be engaged in argumentation. Indeed, studies have been carried out on arguments construction in science teaching; however, only a few have researched into argumentation in practical work (Katchevich et al. 2013). Osborne (2015) views practical work as being so central to the teaching of science and recommends that further research work is carried out to ensure improvement of pedagogic practice in practical work so that practical work can be used to scaffold the teaching in knowledge of science.

Inconsistent results have been found in various studies that researched into how science process skills are developed among students when engaged in scientific inquiries. For instance, Kim and Song (2006) who analysed the argumentation made by students during and after open-ended inquiries while they were involved in scientific inquiry activities discovered that the students demonstrated improvements in the interpretation and methods of experiment. Research findings (Sampson & Walker 2012; Enderle, Grooms & Sampson 2012; Enderle, Grooms & Williams 2012) have revealed the positive impact of argument-driven inquiry based instruction in developing students' proficiency in writing their investigation reports. However, these findings are different from the ones discovered by Sampson et al. (2012). In their study, Sampson and his colleagues found that students made the greatest gains in the investigation design aspect of the performance task but made smaller gains in the data collection and argument generation aspects of the assessment. In addition, the quasi-experimental study by Becker (2014) where scientific explanation and argument were explicitly instructed over a 14-period laboratory course showed that the change in students' integrated scientific process skills did not improve their laboratory report writing ability. Similarly, Gultepe and Kilic (2015) in their study on argumentation-based classroom activities over a 29-week period found that although the approach in teaching had significant effects on the students' integrated scientific process skills, the effect was not significant for designing experiment skills. Thus, it appears that how students can be effectively helped and sustained in the environment of laboratory remain difficult to achieve and is a challenging task for teacher of science.

In the Malaysian context, research on promoting argumentation skills is quite new. One particular study is the research by Foong and Daniel (2013). In their study, they introduced argumentation skills through socio-scientific issues to Form To students who were studying in the Confucian learning environment. Their findings revealed that the Confucian students were weak in their construction of rebuttal when presenting arguments. This is not surprising since the argumentation construction method through socio-scientific issues discussion is a contemporary approach in Malaysian science teaching. However, another method in developing a more advisable to scientific inquiry approach in the context of science teaching for Malaysian schools students as argued in the beginning is through the conduct of practical work. Hence, the aim of this study is on the formation of science process skills through argumentation driven inquiry activities. In this study, the objective is to provide the contribution to the field in relation to the effects of explicit instruction of scientific argumentation through practical work on students' science learning. Particularly, the study sought to determine the effectiveness of the model of modified argument-driven inquiry (MADI) in improving students' science process skills. Thus, the study attempted to answer the research question "is there a difference in the achievement of science process skills between the MADI group which used the LAB-MADI Module compared to the IWA group and the CON group?".

METHOD

The study used a quasi-experimental research design as the participants were not randomly assigned to the experimental groups and the control group. However, selection of the classrooms in the schools for the control and experimental groups was made randomly. A non-equivalent control group design was used to compare the pre-test and post-test scores of the students who were taught using three different learning approaches based on their grouping. The learning approaches used during the experimentation were the Modified Argument-Driven Inquiry (MADI) approach, Inquiry Without Argument (IWA) approach, and the conventional approach (CON). The first experimental group was taught using the Modified Argument-Driven Inquiry approach (MADI) while the second experimental group was taught using Inquiry Without Argument approach (IWA). Both of these treatment groups carried out practical work using the LAB-MADI Module but only the MADI group was given the opportunity to participate in the argumentation session. The third group, i.e. the control group was taught using conventional approaches (CON) to carry out practical work required by the Ministry of Education Malaysia. This study therefore sought to investigate the effect of explicit instruction of scientific argumentation through practical work using the MADI module on science process skills of 10th grade students who were studying in government rural secondary schools in district A in Sarawak.

In this study, the target population comprised public secondary school students in the 10th grade in Sarawak, a states in Malaysia. The accessible population were composed of students in Grade 10 who were attending public secondary schools in one of the divisions in Sarawak. Accordingly, from the twelve secondary schools in division S, two public schools were randomly selected. Thus, in total, 112 students made up the sample of the study. One of the schools was designated as the experimental school where students from two classrooms and two teachers teaching biology participated in the study. They were divided into two experimental groups – one was taught using the IWA approach and the other using the MADI approach. The other school constituted the control group where students in two classrooms and one biology teacher participated in the study. The control group was taught using the CON approach. The three teachers who participated in the study and assigned to the experimental and control groups were the original teachers responsible for teaching biology in their schools. The Modified Argument-Driven Inquiry (MADI) approach was developed to deliver a more advisable approach to scientific inquiry in the context of science teaching to students in Malaysian secondary school through practical work. The instructional approach of the LAB-MADI module was based on MADI model. The model of MADI was transformed from the original Argument-Driven Inquiry (ADI) model (Sampson & Gleim 2009; Sampson et al. 2011; Sampson et al. 2014) which was supported with the theory of cognitive load and learning theory of the social and cognitive constructivist. The validity and the feasibility of the activities in the LAB-MADI module had been presented in another papers (Ping & Osman 2019; Ping et al. 2019).

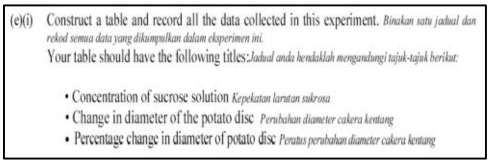
In developing the Science Process Skills Test (SPS TEST), the researcher adapted the test paper by referring to various sources, namely Form Four Biology Curriculum Specification (MOE 2012), *Sijil Pelajaran Malaysia* (SPM), or the Malaysian Certificate of Education past year examination questions, textbooks and reference books. Additionally, the researcher also referred to the design of SPM Biology examination question for Paper 3 in developing the test paper for the Science Process Skills Test. The researcher modified the base rubric for scientific argumentation developed by Mcneill, Lizotte, Krajcik and Marx (2006) so that the ability to construct and evaluate science process skills among the students in this study could be assessed. The modification was necessary because the rubric needs to be appropriate for use with the standard Biology Curriculum that is offered in the Malaysian Secondary School System. As shown in Table 1 (Table of Specification for Question 1) and Table 2 (Table of Specification for Question 2) below, the instruction consists of 11 (eleven) structural items tested with 11 SPS constructs for question 1 and 6 (six) open-ended response items tested with 6 SPS constructs for question 2. Figure 1 shows a sample item from question 1 that assesses the students' science process skills under the construct of communication (see Table 1) whereas Figure 2 shows a sample item from question 2 that assesses the students' science process skills for the constructs in experimental planning (see Table 2).

Table 1. Table of Specification for SPS Test Question 1 – Practical Assessment (PA)

Learning area	Item	Construct
3.2: Understanding the movement of substances across the plasma membrane in everyday life. Act. 3.4: Concentration of external solution which is isotonic to cell sap	(a)	Recording
	(b)(i)	Observation
	(b)(ii)	Inferring
	(c)	Controlling variables
	(d)	Hypothesising
	(e)(i)	Communication – table
	(e)(ii)	Communication – graph
	(f)	Relating
	(g)	Defining operationally
	(h)	Prediction
	(i)	Classifying

Table 2 Table of Specification for SPS Test Question 2 – Experimental Planning (EP)

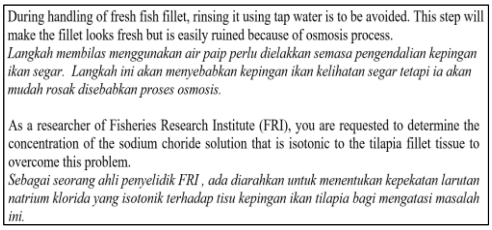
Learning area	Item	Construct
3.2: Understanding the movement of substances across the plasma membrane in everyday life. Act. 3.4: Concentration of external solution which is isotonic to cell sap	(a)	Statement of identified problem
	(b)	Making hypothesis
	(c)	Listing variables
	(d)	Listing of materials and apparatus
	(e)	Listing procedure
	(f)	Presentation of data



(e)(i) Construct a table and record all the data collected in this experiment. *Binakan satu jadual dan rekod semua data yang dikumpulkan dalam eksperimen ini.*
Your table should have the following titles:*Jadual anda hendaklah mengandungi tajuk-tajuk berikut:*

- Concentration of sucrose solution *Kepekatan larutan sukrosa*
- Change in diameter of the potato disc *Perubahan diameter cakera kentang*
- Percentage change in diameter of potato disc *Peratus perubahan diameter cakera kentang*

Figure 1. Sample Item in Question 1 that Assesses the SPS Construct of Communication



During handling of fresh fish fillet, rinsing it using tap water is to be avoided. This step will make the fillet looks fresh but is easily ruined because of osmosis process.
Langkah membilas menggunakan air paip perlu dielakkan semasa pengendalian kepingan ikan segar. Langkah ini akan menyebabkan kepingan ikan kelihatan segar tetapi ia akan mudah rosak disebabkan proses osmosis.

As a researcher of Fisheries Research Institute (FRI), you are requested to determine the concentration of the sodium choride solution that is isotonic to the tilapia fillet tissue to overcome this problem.
Sebagai seorang ahli penyelidik FRI , ada diarahkan untuk menentukan kepekatan larutan natrium klorida yang isotonik terhadap tisu kepingan ikan tilapia bagi mengatasi masalah ini.

Figure 2. Sample Item in Question 2 that Assesses SPS Construct of Experimental Planning

In order to verify the content validity of the instruments, three content experts were engaged to carry out content validity. Additionally, the instruments' face and language validity were also determined. A refinement was performed based on the feedback of the experts. The-retest reliability was used to determine the consistency of the instrument for SPS TEST. The reliability test revealed the subjective item utilized in the instrument obtained high reliability indices, which were r=+0.746 and p<0.05 for Science Process Skills Test of Question 1 and r=+0.924 and p<0.05 for Science Process Skills Test (SPS Test) of Question 2. The data used in this study were obtained from the pre-test and post-test results after all the test items' validity and reliability had been verified.

This study employed descriptive and inferential statistical analysis. The descriptive statistical analysis was used to summarise students' science process skills and score in the pre-test and post-test. The inferential statistical analysis was used to determine whether there exist differences in the effectiveness of instruction of scientific argumentation explicitly in practical work on the student's science process skills. The inferential analysis performed was Analysis of Variance (ANOVA).

RESULTS AND DISCUSSION

Descriptive statistical analysis of mean scores of Science Process Skills (SPS), Practical Assessment (PA) and Experimental Planning (EP) for the pre-test is summarised in Table 3.

Table 3. Descriptive Statistical Analysis of Mean Scores of SPS, PA and EP for the Pre-test

Test	Groups	N	Mean Score	Standard Deviation
SPS	CON	40	27.05	8.98
	IWA	42	29.52	10.08
	MADI	30	25.13	8.27
PA	CON	40	35.53	12.01
	IWA	42	38.64	9.81
	MADI	30	34.67	10.65
EP	CON	40	36.46	10.90
	IWA	42	10.28	15.07
	MADI	30	12.05	18.65

Table 3 present the mean scores for the SPS Test before intervention was carried out, and it can be observed that the mean scores are almost similar. This indicates that the three groups showed no significant difference in their ability. Analysis based on the ANOVA test as illustrated in Table 4 shows that before any intervention was carried out, the students' science process skills were of almost the same level. The mean scores in the SPS Test for the three groups of students as well as the non-significant differences [F (2, 109) = 2.04, p > 0.05] among the students in the three groups obtained from the ANOVA test suggest that all the students were homogenous prior to any intervention in the study.

The descriptive analysis of mean scores of Science Process Skills (SPS), Practical Assessment (PA) and Experimental Planning (EP) for the post-test is summarised in Table 5.

Table 5. Descriptive Statistical Analysis of Mean Scores of SPS, PA and EP for the Post-test

Test	Groups	N	Mean Score	Standard Deviation
SPS	CON	40	57.10	13.48
	IWA	42	63.88	10.16
	MADI	30	70.93	11.71
PA	CON	40	63.35	12.94
	IWA	42	57.10	13.48
	MADI	30	63.88	10.16
EP	CON	40	70.93	11.71
	IWA	42	63.35	12.94
	MADI	30	57.10	13.48

Inferential statistical analysis was carried out to identify if significant differences exist between the groups and the results are summarised in Table 6.

Table 4. Results of ANOVA for SPS, PA and EP Pre-test

	Group	Total square	Df	Mean square	F	p	Eta Squared
SPS	Between groups	348.01	2	174.01	2.04	0.14	0.04
	Within groups	9291.84	109	85.25			
	Total	9639.85	111				
PA	Between groups	331.57	2	165.79	1.41	0.25	0.03
	Within groups	12860.29	109	0.12			
	Total	13191.86	111				
EP	Between groups	624.43	2	312.22	1.32	0.27	0.02
	Within groups	25845.35	109	237.11			
	Total	26469.78	111				

Table 6. Results of ANOVA for SPS, PA and EP Post-test

	Group	Total square	Df	Mean square	F	p	Eta Squared
SPS	Between groups	3299.55	2	1649.77	11.76	0.000	0.18
	Within groups	15293.87	109	140.31			
	Total	18593.42	111				
PA	Between groups	6111.17	2	3055.59	24.49	0.000	0.31
	Within groups	13599.32	109	124.77			
	Total	19710.49	111				
EP	Between groups	323.93	2	161.96	0.34	0.716	0.01
	Within groups	52587.75	109	482.46			
	Total	52911.68	111				

Table 6 shows there exist significant differences ($p<0.05$) in the mean score of the SPS post-test for all three groups where $F(2,109) = 11.76$, $p < 0.05$ for SPS and $F(2,109) = 24.49$, $p < 0.05$ for PA. On the other hand, statistically significant difference was not found [$F (2, 109) = 0.34$, $p > 0.05$] among the three learning approaches for the achievement of SPS in EP. A post-hoc Bonferroni test as shown in Table 7 was used to further determine the differences in the students' SPS and PA.

Table 7. The Post-hoc Bonferroni Test for SPS and PA Post-test

Test	Group (I)	Group (J)	Mean Difference (I-J)	Standard deviation	P
SPS	KON	IWA	-6.78	2.617	0.033
		MADI	-13.83	2.861	0.000
	IWA	CON	6.78	2.617	0.033
		MADI	-7.05	2.832	0.043
	MADI	CON	13.83	2.861	0.000
		IWA	7.05	2.832	0.043
PA	KON	IWA	-9.53	2.468	0.001

	MADI	-18.79	2.698	0.000
IWA	CON	9.54	2.468	0.001
	MADI	-9.26	2.670	0.002
MADI	CON	18.79	2.698	0.000
	IWA	9.26	2.670	0.002

The result of the post-hoc Bonferroni test for SPS post-test shown in Table 7 indicates there exist significant differences (p<0.05) between the MADI group and the CON group with mean difference of 13.83%. There is also exist significant differences in mean score between the IWA group and the CON group with mean difference of 6.78%. There is also a significant difference in mean score between the MADI group and the IWA group with mean difference of 7.05%.

The result of the post-hoc Bonferroni test for PA post-test shown in Table 7 indicates exist significant differences (p<0.05) between the MADI group and the CON group with mean difference of 18.79%. There is also a significant difference in mean score between the IWA group and the CON group with mean difference of 9.54%. There is also exist significant differences in mean score between the MADI group and the IWA group with mean difference of 9.26%.

In this research, the practical assessment includes eleven SPS constructs which are recording (S1), observation (S2), inferring (S3), controlling variables (S4), hypothesising (S5), communication-table (S6), communication-graph (S7), relating (S8), defining operationally (S9), prediction (S10) and classifying (S11). The descriptive statistical analysis was carried out to determine the mean score and the standard deviation of the eleven SPS constructs for each group. The Table 8 shown the results of the descriptive analysis.

Table 8. Descriptive Statistical Analysis of Mean Score for SPS Constructs (Post-test) of Each Group

	Group	N	Mean score	Standard deviation
Recording (S1)	CON	40	2.98	0.158
	IWA	42	2.88	0.504
	MADI	30	2.93	0.254
Observation (S2)	CON	40	2.18	1.083
	IWA	42	2.83	0.621
	MADI	30	2.80	0.610
Inferring (S3)	CON	40	1.00	1.219
	IWA	42	1.36	0.958
	MADI	30	1.47	1.008
Controlling variables (S4)	CON	40	1.70	0.516
	IWA	42	2.69	0.563

	Group	N	Mean score	Standard deviation
Hypothesizing (S5)	MADI	30	2.23	0.858
	CON	40	2.38	1.213
	IWA	42	2.50	0.834
Communication-table (S6)	MADI	30	2.67	0.711
	CON	40	2.40	0.871
	IWA	42	2.33	0.928
Communication-graph (S7)	MADI	30	2.53	0.819
	CON	40	1.73	1.086
	IWA	42	1.83	1.208
Relating (S8)	MADI	30	2.40	0.770
	CON	40	0.53	0.905
	IWA	42	1.38	1.035
Defining operationally (S9)	MADI	30	1.87	0.973
	CON	40	0.30	0.687
	IWA	42	0.88	0.772
Prediction (S10)	MADI	30	1.20	0.664
	CON	40	1.18	1.318
	IWA	42	1.45	1.273
Classifying (S11)	MADI	30	1.77	1.251
	CON	40	1.98	1.368
	IWA	42	1.21	1.279
	MADI	30	2.70	0.915

Table 8 shows that the MADI group is more proficient at SPS constructs of inferring, hypothesising, communication-table, communication-graph, relating, defining operationally, prediction and classifying compared to the IWA group and the conventional (CON) group. The IWA experimental group, however, is better at observation and controlling variables compared to the MADI group and the CON group. For the SPS construct of recording, it was found that the CON group performed better than the MADI group and the IWA group. Therefore, it could be surmised that the treatment groups exceed the control group in almost all the SPS constructs analysed.

The findings of the study unveil that the implementation of argumentation through the modified argument-driven inquiry (MADI) approach in the practical work of Grade 10 biology is more effective in improving students’ science process skills compared to the inquiry without argumentation (IWA) approach and the conventional (CON) approach. It is believed that the expand phase is the initiation point in the development of argumentation. In the extend phase, the students have their reinforcement to apply the science process skills. Thus, scientific argumentation promotes and supports scientific inquiry in the subject of biology.

In this study, all three approaches, namely the MADI approach, the IWA approach and the CON approach had contributed to the development of the students' science process skills in practical assessment (PA). However, the activities of argumentation based on causal hypothesis, students able to defend their claims with reasoning, able to support their claims with strong evidence to relate concepts, able to listen to different claims and able to defend critically, and able to rebutte opposite views made greater contributions to science process skills of the students in the MADI group compared to those in the IWA and the CON group. This is supported by the literature in that scientific argumentation based teaching approach develop in better learning by students, therefore improving their skills in scientific thinking (Driver et al. 2000; Simon et al. 2006; Sampson & Gleim 2009; Gultepe & Kilic 2015).

Providing argumentation session allows the students in the MADI group to justify their hypothesis with evidence and evaluate the explanations provided by their peers through an active process which helps to ensure that the science process skills are acquired directly. As mentioned by Gultepe and Kilic (2015), creating argumentation sessions in science practical work provide opportunities for students' involvement in questioning, revision of their knowledge about evidence, evaluating the explanations of their peers, interpreting and analysing data, and considering alternative explanations. In this study, for practical work involving the MADI approach, the students took on a more functioning role in assessing their observations, in interpreting data, and deciding the ways in which their evidence were to be presented. Accordingly, the findings reveal that through the MADI approach and with the help of student activities, science process skills can be enhanced in time as students can use the science process skills in various ways. Students can use SPS (operational defining) to construct answers to questions, use SPS (making inferences, constructing hypotheses) to justify their views, use SPS (designing the investigation) to explain procedures, and use SPS (interpreting the graphs) to interpret and explain the data.

However, the result did not show any statistically significant difference among the three learning approaches for the achievement of SPS in experimental planning (EP). This finding is similar to findings in Becker (2014) and Gultepe and Kilic (2015). Becker (2014) expected that the results of both the experimental and the control groups in her study showed no significant difference because the students in both groups were given handouts with detailed instructions on how to write a formal laboratory report. Meanwhile, Gultepe and Kilic (2015) believed that the skills in experiment-designing process take more time and energy to improve or develop.

Therefore, based on the findings, it can be maintained that scientific inquiry is the foundation of science learning in which students develop and construct arguments to explain a scientific phenomenon or concept through their own investigations. This is supported by Kim and Song (2002) support this as they believe the whole process in this inquiry model is circular because argumentation activities provide feedback to the experimental activities, i.e. reformation of hypothesis, change in method, and reprocessing of data while claims and evidence used to support and corroborate the assertions or arguments are obtained from the experiments. Through the linkage between experiment and argumentation, students are provided opportunities for reflective thinking and making up their minds about the experiment through the argumentation carried out between groups and in their own group.

Additionally, constructing argumentation is a complex process that requires practice and entails the incorporation of many different types of activities. The collaboration among student should be an essential focus for teachers when employing scientific argumentation in their classrooms (Weis 2015). This is because constructing and discussing argumentation is hard for students as they are required to use their evidence to evaluate and revise their claims, relate their evidence to the relevant scientific principles and effectively communicate these understandings. This process is dependent on supportive and educative interactions with other people. Students need to make sense of their experiences of practical work and integrate the new views with prior knowledge through their engagement in argumentation.

CONCLUSION

The findings provide new intuitiveness for science teachers and instructional designers interested in promoting and supporting argumentation in practical work so that it is more useful and educative. In this study, it has been demonstrated that involvement and engagement in in argumentation as well as production of spoken and written arguments could improve students' science process skills. This study contributes to science teachers and biology educators in that it provides a way of implementing a learning approach which involves argumentation in practical work to develop students' science process skills.

The results of this research have implications for researchers and practitioners interested in fostering science process skills in biology among rural secondary school students in practical work learning environments. The development of the LAB-MADI module in the form of structured inquiry and supervised inquiry is one of the approaches that can be implemented by science teachers in teaching biology. The findings suggest that biology teachers should be aware that conventional approaches are less effective when it comes to applying science process skills. The modified argument-driven inquiry approach is more relevant to the needs of students in mastering science process skills. Furthermore, the activities used are more student-centred and require students to be actively involved in the process of practicing the practical work.

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