

Revealing the effect of local-based teaching materials toward scientific reasoning, argumentation, and problem-solving in biology classroom

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Abstract: Scientific reasoning, argumentation, and problem-solving are essential skills in 21st century. They help people solve problems in daily life. This study aimed to investigate the effect of local-based teaching materials on student's argumentation, scientific reasoning, and problem-solving skills using Science Project-based Learning (SPjBL). Argumentation skill is a social and dynamic process, involving individuals engaged in thinking, constructing, and critiquing knowledge in science. Scientific Reasoning skills require students to give reasons in the form of opinion or actions and conclusions by using appropriate language to explain what they think and making judgments or decisions based on the produced reasons or evidence. Problem-Solving skill is a process of designing, evaluating, and implementing a strategy to answer questions. In this study, the time series approach was used as a part of the quasi-experimental design with Science Project-based Learning (SPjBL) as the learning model. A total of 29 Biology students of Universitas Negeri Malang participated in this study in August-November 2019 at the Department of Biology of the university. The data was collected using pre-test and post-test instruments which measured scientific argumentation, scientific reasoning, and Problem-solving skill variables. The data analysis was done using ANCOVA test in SPSS 16.0. The results of this study show that there is positive effects of local-based invertebrate and vertebrate materials on scientific argumentation, scientific reasoning, and problem-solving skills. These findings can be used as reference for educator to gain students' scientific reasoning, argumentation, and problem-solving skills in science classroom through Science Project-based Learning (SPjBL) with the help of local-based teaching materials.

Keywords: argumentation, local-based teaching, problem-solving, scientific reasoning

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Introduction

The 21st century is known as the age of knowledge due to the existence of information technology (Bhattacharjee & Deb, 2016; Lewin & McNicol, 2015; Mikre, 2011; Ul-Amin, 2013), globalization (Turiman *et al.*, 2012), and the industrial revolution (Hussin, 2018). These factors challenge various aspects including education. Education system and its processes are expected to be able to prepare competent human resources who are ready to compete globally. Furthermore, education must integrate several skills which are relevant to the era of 21st century. Therefore, it is crucial to incorporate 21st century skills in science education. 21st century skills consist of four main domains, namely argumentation (Ika *et al.*, 2019; Kundariati *et al.*, 2021; Kundariati *et al.*, 2021), scientific reasoning (Kambeyo, 2017; Khoirina *et al.*, 2018; Kuhn, 2011; Kundariati & Rohman, 2020), and problem-solving (Rahman, 2019; Turiman *et al.*, 2012).

Scientific reasoning specifies activities or practices in scientific discovery. The process of reason begins with the observation of an unexplained phenomenon, the abduction of several alternative hypotheses,

and the hypothetical-deductive test of these hypotheses which supports but never proves whether the hypotheses are right or wrong (Engelmann *et al.*, 2016). Scientific reasoning is expected to increase when students can build their knowledge through understanding (Daryanti *et al.*, 2015). According to AACU (2010), scientific reasoning skill is adherent to self-correction on inquiry and dependent on empirical evidence to describe, understand, and predict a phenomenon. Scientific reasoning skill has five indicators, namely: 1) selection of a topic or argument, 2) existing knowledge, 3) methodology, 4) analysis, and 5) conclusions, limitations, and implications. The previous research showed that students' scientific reasoning skill was still low (Khoirina *et al.*, 2018). Scientific reasoning relates to the students' argument in science context, therefore this ability should be coherent to built a strong scientific concept and understanding of phenomena.

Scientific argumentation can be conceptualized as a claim that is supported by scientific evidence or is warranted in a scientific process. It also can be conceptualized as a thinking process or dialogue to come to a reasoned view about science, scientific constructs, or constructs within a scientific process (Engelmann *et al.*, 2016). Argumentation as a reasoning process has been defined by Toulmin *et al.* (1984) which is commonly known as Toulmin's Argument Pattern (TAP Toulmin). The Toulmin presents study consisting of six elements of argumentation. Argumentation centers on a claim, a position being taken and evidence or grounds that support the claim. Toulmin refers to the link between the evidence and the claim as a warrant. The type and quality of the reasoning involved in the chain of reasoning are called as backing. An argument consists of a rebuttal that identifies exceptions to the claim or presents counter-arguments (Frey *et al.*, 2015). There are 5 levels in the argumentation skill in which each level has its own category and tier. Level 5 is the highest level of argumentation and level 1 interpretes the lowest level of argumentation (Cetin *et al.*, 2014). Student's argumentation skill is still low and needs to be improved (Purwati *et al.*, 2019; Putri & Rusdiana, 2017).

The third important skill that needs to be improved in the 21st century learning is problem-solving as it is currently needed to face the globalization (Turiman *et al.*, 2012). Problem-solving is a process of designing, evaluating, and implementing a strategy to answer questions (AACU, 2010). Problem-solving skill needs to be improved to face a new problem and develop learning (Moorthi, 2018). According to (Fischer *et al.*, 2012), problem-solving activities are divided into two groups. The first is about the structure of the contents of the problems to be solved and the second is about the scientific process that students must master to solve a problem. Based on the facts in the previous researches, it was found that student's problem-solving skill is still low (Cindikia *et al.*, 2020; Yulindar *et al.*, 2018) and needs to be improved (Moorthi, 2018).

Argumentation, scientific reasoning, and problem-solving skills can be developed through Science Project-based Learning (SPjBL) model. SPjBL has been proven to have a tremendous effect on students' content understanding and developing skills (Aksela & Haatainen, 2019; Han *et al.*, 2015), and SPjBL plays many roles in students' and teachers' learning experiences (Han *et al.*, 2015). SPjBL model can train students in collaboration, analyze real-world problems that occur around them, collect and analyze data, construct solutions to problems, and reflect on the experienced learning process (Carlina & Djukri, 2018). Effective learning can be supported by some factors, such as learning material and learning resources. Universitas Negeri Malang is located in Malang Regency which has high potential of animal diversity including invertebrates or vertebrate species. This diversity can be utilized as learning resources as well as being a tool to make students feel closer to their environment (Kundariati *et al.*, 2020).

There has been several studies on students' scientific reasoning, argumentation, and problem-solving. (Brown *et al.*, 2016; Pratiwi *et al.*, 2019) showed in their study that problem-based learning could effectively facilitate students' argumentation skill. Argumentation skill can be empowered through the provision of problems that are used as triggers in the syntax of problem-based learning (Fang *et al.*, 2019; Pritasari *et al.*, 2015; Tawfik, 2017). The studies includes positive effect of learning model toward scientific reasoning, i.e three level inquiry based learning (Yanto *et al.*, 2019) and 5E learning model (Susilowati & Anam, 2017). Some researchers also reveal the effectiveness of context-based learning (Yu *et al.*, 2015); problem-based learning (Suciati *et al.*, 2020; Syafii & Yasin, 2013); and inquiry learning (Gunawan *et al.*, 2020) toward problem-solving skill. The research conducted only assessed the effect of various learning models on reasoning skills, scientific argumentation, and problem solving on other variables that could influence these skills. Another variable that may influence these skills is local-based potential materials. The utilization of local potential in learning supports contextual learning theory, therefore research that examines the effect of local-based teaching materials toward scientific reasoning, argumentation, and problem solving is needed. This study provides biology educators a better learning process which helps students reason scientifically, develop arguments scientifically well, and solve the current problems through local-based teaching.

Methods

Research Setting and Sample

This research was carried out to determine the effect of local-based invertebrate and vertebrate materials on argumentation, scientific reasoning, and problem-solving skills using Science Project-based Learning (SPjBL). In this present study used the quasi-experimental design. The researchers had performed this study in August-November 2019. The samples of this study consisted of a total of 29 Biology students (Erduran *et al.*, 2004) in Universitas Negeri Malang with random sampling technique. The study design of the research was a time-series (Creswell, 2014).

Instrument

The research instruments used were essay which integrated with the scientific reasoning and problem-solving indicators and essay test to assess students' scientific reasoning. The argumentation test refers to the level of argumentations by (Erduran *et al.*, 2004). Scientific reasoning and problem-solving tests are prepared based on the (AACU, 2010) indicators. All test instruments were validated by the expert assessment with the validity number of 0.85 (categorically valid) and validated by reliability testing using Pearson correlation, making reliable results for all test instruments.

Data Analysis Techniques

Data analysis was statistically tested using ANCOVA with the significance level of 5% in SPSS 16.0 software. The data obtained was first tested on the prerequisite normality and homogeneity test.

Results and Discussion

The influence of the learning model on students' critical thinking

The results of data analysis in determining the effects of invertebrates and vertebrates on argumentation skill are presented in Table 1.

Table 1. Summary of differences in students' argumentation skill on invertebrate and vertebrate material

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4061.825 ^a	2	2030.912	17.248	.000	.385
Intercept	1710.882	1	1710.882	14.530	.000	.209
pre	3789.997	1	3789.997	32.187	.000	.369
Learning Material	100.895	1	100.895	.857	.359	.015
Error	6476.193	55	117.749			
Total	210435.000	58				
Corrected Total	10538.017	57				

Based on Table 1, it can be seen that the significance p-value of 0.359 is higher than the α -value of 0.05. These values indicate that H_0 is not rejected, which means that invertebrate and vertebrate material has no effects on argumentation skill. Furthermore, to find out the level of increase in argumentation skills in each material, the formula below was used and the results are presented in Table 2.

Table 2. The percentage of level of increase in argumentation skill

Material	Pretest Score	Posttest Score	Percentage
Invertebrates	60	66	10%
Vertebrates	45	53	17,8%

Based on the results of data analysis, there was an increase in argumentation skill, calculated using pre-test and post-test scores on invertebrate (10%) and vertebrate (17%). The results of data analysis in determining the effects of invertebrates and vertebrates on scientific reasoning skill are presented in Table 3.

Based on Table 3, it can be seen that the significance p-value of 0.082 is higher than the α -value of 0.05. These values indicate that H_0 is not rejected, which means that invertebrate and vertebrate material has no effects on scientific argumentation skill. To find out the level of increase in argumentation skill in each

material, the test results are presented in [Table 4](#).

Table 3. Summary of differences in students' scientific reasoning skill on invertebrate and vertebrate material

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	869.678 ^a	2	434.839	11.954	.000	.303
Intercept	1971.537	1	1971.537	54.201	.000	.496
Pre-Reasoning Learning Material	273.195	1	273.195	7.511	.008	.120
Error	114.036	1	114.036	3.135	.082	.054
Total	2000.598	55	36.375			
Corrected Total	433560.000	58				
	2870.276	57				

Table 4. The percentage of level of increase in scientific reasoning skill

Material	Pretest Score	Posttest Score	Percentage
Invertebrates	76	89	17,1%
Vertebrates	67	83	23%

Based on the analysis, there was an increase in scientific reasoning skill, calculated using pre-test and post-test scores on invertebrate (17.1%) and vertebrate (23%). The results of data analysis in determining the effects of invertebrates and vertebrates on problem-solving skill are presented in [Table 5](#).

Table 5. Summary of differences in students' problem-solving skill on invertebrate and vertebrate material

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4135.860 ^a	2	2067.930	36.465	.000	.570
Intercept	2096.648	1	2096.648	36.971	.000	.402
Pre-Problem-solving Learning Material	659.981	1	659.981	11.638	.001	.175
Error	1088.086	1	1088.086	19.187	.000	.259
Total	3119.054	55	56.710			
Corrected Total	424437.000	58				
	7254.914	57				

Based on [Table 5](#), it can be seen that the significance p-value < 0.001 is lower than the α -value of 0.05. These values indicate that H_1 is accepted, which means that invertebrate and vertebrate material has an effect on scientific argumentation skill.

SPjBL is a constructivist pedagogy that intends to bring deep learning by allowing the learners to use an inquiry-based approach to engage with issues and questions that are rich, real, and relevant to the topic being studied ([Markham, 2012](#)). Out of these contemporary modern methods, SPjBL has been widely recognized as a collaborative, progressive, student-centered, interactive, active, and deep learning approach ([Jalinus et al., 2017](#)). It is in line with [Lewin and McNicol \(2015\)](#); [Widya et al \(2019\)](#) who argued that project-based learning promoted students' critical thinking in learning activities. Learning material such as students' worksheets has a great impact to promote students' argumentation, scientific reasoning, and problem-solving skills through the SPjBL model. The student's worksheet was prepared by compiling the syntax of SPjBL model which has several ways of teaching and learning activities. Students followed either instruction of learning activities in the worksheet or the syntax of the learning model ([Jalinus et al., 2017](#); [Nawawi, 2017](#)). The learning process is given with an appropriate student-centered approach, which makes the student more active and collaborative, as well as triggering them to observe evidences through environment cases.

Argumentation is the basis for showing and submitting proof of opinion on a matter ([Novitasari et al., 2018](#); [Pritasari et al., 2015](#)). [Heng et al \(2014\)](#) stated that in the development of scientific concepts, argumentation had an important role. It was further explained that argumentation and scientific reasoning have a connection to draw conclusions which involve critical thinking skill in making statements based on the existing facts ([Pallant & Lee, 2015](#)). The discussion indicates that students showed an increase in argumentation on vertebrate material because the material is more closely related to their daily life

and so they observe vertebrate animal members more often than the invertebrate animals. Vertebrate animals also have larger size than invertebrate animals, making it easier for students to make observations and provide opinions or arguments about the structure of morphology of the animals. [Probosari et al \(2016\)](#) also revealed that good argumentation started with real phenomena that occurred in nature which could trigger different responses. The increase in students' argumentation skills on vertebrate material occurs because students have been trained in arguing, in which before studying vertebrate material students have learned to argue well. This is in accordance with [Probosari et al \(2016\)](#) which stated that the right strategy was needed in teaching argumentation, and it took time for students to get used to arguing.

Improved argumentation skill can be accommodated in the first and fourth steps, namely problem orientation and project development and presentation. Problem orientation activity supports students to develop arguments comprehensively based on observed phenomena. [Carlina and Djukri \(2018\)](#) stated that project-based learning could support students to be active in the learning activities by observing the real phenomenon around them. Project development and presentation step help students present their findings and thoughts. This activity accommodates students to submit arguments in front of the class in writing and orally. Students' argumentation skill is generally shown in the second level. According to the [Cetin et al \(2014\)](#), argumentation-assessing tools refer to TAP Toulmin. It means that argumentation consists of a single claim versus a claim which is supported with data, warrants, or backings, and does not contain any rebuttals.

Construction of the rebuttal, however, is not simple, and several studies have found that individuals struggled with the creation of rebuttal even after repeated interventions ([Liu & Stapleton, 2020](#); [Ryu & Sandoval, 2012](#)). Students need to think deeply and find some opposite fact to countering the claim and make it a rebuttal. During this study, students show much data and claim in the argument as they are getting used to give much more evidence to the fact in one point of view in their secondary schools. In the term of rebuttal, students need to think out of the common. For example, to claim mammals, students might question, "How many appendixes are needed?" "What do they eat?" "How do they reproduce?". To make a good argument, adding rebuttals is required such as "mammals may not reproduce viviparous, mammals may not give baby breastfeeding". To enhance the quality of argument to level 5, students are required to have complete data, warrant, backing, and appropriate rebuttals in the argument to support their claim. Complicated sentences and scientific evidences make argumentations more trustworthy. It may need a long time to gain a student's argumentation skill, but it needs to be applied well in the science classroom.

Scientific reasoning is in compliance with investigation and reliance on empirical evidence to describe, understand, predict, and control phenomena ([AACU, 2010](#)). [Facione \(2011\)](#) mentioned that reasoning was a specific way of thinking to conclude the premise. Scientific reasoning is the ability to infer based on existing evidence. According to [AACU \(2010\)](#), scientific reasoning skill is trained using Student Worksheets which are integrated with scientific reasoning indicators namely the selection of topics or arguments, distinguishment of knowledge, methodology, analysis, and conclusions. Students experience increased scientific reasoning on vertebrate material because they are larger, more closely related to daily life, and easier to be observed than invertebrate animals, akin to biological objects are considered more difficult, abstract, and unpopular among students ([Rokhanah et al., 2015](#)). Stages of learning activities which observe the morphology and anatomy of visible vertebrate animals are easier to understand and thus more likely improve student's scientific reasoning skill.

The syntax of SPjBL gives a good impact on scientific reasoning skill. The first steps of the learning process started with problem orientation which can improve scientific reasoning indicator namely the selection of a topic or argument. Second, the students are divided into several groups to work on worksheets as well as practicing in the field or laboratory. These steps help students explore existing knowledge. Third, while students are doing the project, they manage to develop their analytical skills by thinking deeply, comprehensively, and collaboratively with their group. These steps promote analysis indicator. And the last, students are able to develop their analytical skills and make conclusions/generalizations by presenting project steps. Some evidence shows scientific reasoning ability to produce empirical evidence and logical arguments and the reasons for deduction, induction, and analogy to distinguish the relationship between cause and effect ([Daryanti et al., 2015](#)).

Problem-solving is a complicated process that requires a lot of skills in it ([Lisesi, 2017](#)). According to [Belecina and Ocampo \(2018\)](#); [Fadli and Irwanto \(2020\)](#), problem-solving skill is important for students to help them use to with the process of decision-making in any problems occur in society. Based on the results of the analysis above, it is shown that student's problem-solving skill is increased in the vertebrate material. Vertebrate material discusses the morphology and anatomy of vertebrate animals that are easily found in daily life and more observable. Meanwhile, invertebrate material discusses invertebrate animals that are difficult to see, for example, members of the Porifera and Coelenterate. This finding is in line with [Belecina and Ocampo \(2018\)](#) which stated that contextual learning which emphasized student's involvement in knowledge finding or learning could improve their problem-solving skill.

SPjBL gives a positive impact on problem-solving improvement. The syntax of SPjBL help students in

creating solutions to their problems. The steps of organizing learning and work on the project at the syntax of SPjBL support students to work collaboratively and solve the problems based on the project design that has been prepared. According to Chiang and Huaei (2016); Fujii (2016), project-based learning can improve students' problem-solving skill. Project-based learning challenges students to solve the problem and become good collaborators (Davidsen *et al.*, 2020). To complete the project, students need to overcome all the difficulties so that their problem-solving ability is gradually improving and getting better (Chiang & Huaei, 2016).

Conclusion

The results of this study show that there is an effect of local-based invertebrate and vertebrate materials on scientific argumentation, scientific reasoning, and problem-solving skills in the subject of animal diversity. Student's scientific argumentation, scientific reasoning, and problem-solving skills on vertebrate material are increased as vertebrate animals are easily found in our daily life and more observable than invertebrate animals which are difficult to find. In this research, we cannot identify arguments verbally, even though it is an important point in active learning. For further research, it is highly recommended to study other locally-based learning resources in order to reveal other local wisdoms throughout the country and region so that it will eventually encourage science learning and integrated transcript-based lesson analysis (TBLA) in identifying students' verbal arguments in class.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

M. K. and L. M.: collecting data and writing article; S. E. I.: research coordinating and review article; F. R. and B. P.: research directing, review, and editing article.

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