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Scientific reasoning skills (SRS): Predictor to the student's problem-solving in the biology classroom?

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ABSTRACT

Scientific reasoning and problem-solving have become primary interests in 21st-century education. These skills have an essential role in preparing students to face global competition. This study aims to determine the correlation between scientific reasoning and problem-solving skills of biology students in animal classification and whether scientific reasoning can be used to predict problem-solving skills. The participants were 56 undergraduate students of Biology Education. The scientific reasoning and problem-solving skills of students were assessed with the pre and post-test. A simple linear regression test using the SPSS 16.0 was applied in data analysis. The results showed a p-value of 0.00 < 0.05, so there is a correlation between scientific reasoning and argumentation skills. R-value indicates 0.523, which means a strong correlation. The contribution of scientific reasoning to argumentation skills was 27.3%, while other variables explained the rest.

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INTRODUCTION

Currently, education is facing a 21st-century challenge. Education systems attempt to meet the world's demand by managing its curriculum (Alismail & McGuire, 2015; Harjanti, 2018) and teaching-learning practice (Jansen & Merwe, 2015), including science classrooms. Students' understanding of the essence of science and ideas about the epistemological dimensions of formal science has long been an aim of science education in many countries (Sandoval, 2005). Furthermore, students need to be mastering specific skills such as problem-solving and scientific reasoning to makes it clear they can compete in the globalization and industrialization era.

Problem-solving is currently needed in the face of globalization (Nursyahidah, Saputro, & Rubowo, 2018; Turiman, Omar, Daud, & Osman, 2012; Yokhebed, 2018). Problem-solving is defined as the process of designing, evaluating, and implementing a strategy to answer questions (AACU, 2010a) and has a prominent place in scientific reasoning due to its impact on change and increasing emotional, cognitive, and psychomotor development (Alshamali & Daher, 2016). Furthermore, people should optimally solve problems in an evidence-based way to meet high-level problem-solving standards: by using scientific knowledge while engaging in scientific reasoning processes (Csanadi, Kollar, & Fischer, 2016).

Scientific reasoning, in general, is a type of reasoning that engages students in hypothesis development, particularly about how things work and then testing those hypotheses (Zulkipli, Mohd Yusof, Ibrahim, & Dalim, 2020). A particular aspect of scientific reasoning as organized thought used in our everyday lives, whether at work or in other contexts, is the "deliberate quest for knowledge and coordination of theory and evidence" (Mayer, Sodian, Koerber, & Schwippert, 2014). Thinking skills include reasoning skills. This mental process involves applying knowledge to make decisions, solve problems, and reach goals (Remigio, Yangco, & Espinosa, 2014). Thus, the ability to reason scientifically represents the ability of a person to think about research methods, including planning experiments, evaluating empirical data, inferencing, interpreting research findings, and understanding the principles and complex theories of science (Zimmerman, 2005). Scientific reasoning is necessary to prepare individuals for everyday life and citizenship to address and solve socioscientific problems facing their society or critique proposed solutions (Evagorou & Osborne, 2013).

As part of thinking skills, skills in reasoning are essential for making meaningful understandings in the scientific domain and supporting scientific paradigms and methodologies (Ramli, Khasanah, & Dwiastuti, 2021). Scientific reasoning conceptualizations can be differentiated into research spanning three scientific reasoning strands: (a) as a process in scientific discovery (e.g., Fischer et al., 2014); (b) with a focus on scientific argumentation (e.g., Kuhn, 2010; Osborne, 2010), and (c) on understanding the nature of science (e.g., Kuhn & Pearsall, 2000). According to AACU (2010), scientific reasoning skills adhere to self-correction on inquiry and depend on empirical evidence to describe, understand, and predict a phenomenon. Scientific reasoning skills have five indicators, which are: 1) selecting a topic or argument, 2) existing knowledge, 3) methodology, 4) analysis, and 5) conclusions, limitations, and implications whether scientific reasoning and problem-solving skills can be developed through Science Project-based Learning (SPjBL).

Both scientific reasoning and problem-solving have already been discussed in recent years. Some researches were conducted to investigate the role of scientific reasoning and to problem-solve in the biology classroom. Kundariati & Rohman (2020), developing encyclopedia to improve student's scientific reasoning; fostering scientific reasoning in education (Engelmann, Neuhaus, & Fischer, 2016). promoting Student's problem-solving skills through a hands-on activity (Shieh & Chang, 2014), enabling the acquisition of scientific reasoning with video modeling examples and inquiry tasks (Kant, 2016), and improving student's scientific reasoning skills by the 5E learning model (N Shofiyah, Supardi, & Jatmiko, 2013; Noly Shofiyah, Supardi, & Jatmiko, 2017; Susilowati & Anam, 2017). Scientific reasoning and problem-solving skills can be empowered by an innovative and collaborative learning model, i.e., Science Project-based Learning (SPjBL).

SPjBL has been shown to extraordinarily affect students' content understanding and developing skills (Han, Yalvac, Capraro, & Capraro, 2015; Maija & Haatainen, 2019), and also plays many roles in students' and teachers' learning experiences (Han et al., 2015). SPjBL can enhance students' scientific reasoning (Jamali, Zain, Samsudin, & Ebrahim, 2018) and problem-solving skills (Chiang & Huaei, 2016; Dewi, Khoiri, & Kaltsum, 2017; Husamah & Rahardjanto, 2018). SPjBL model can train students in collaboration, analyze real-world problems around them, collect and analyze data, construct solutions to problems and reflect on the learning process experienced (Carlina & Djukri, 2018). This learning model has six stages; (1) start with the essential question, (2) design a plan for the project, (3) create a schedule, (4) monitor the students and the progress of the project, (5) assess the outcome, and 6) evaluate the experience (Husamah & Rahardjanto, 2018). In PBL settings, students mainly learn through knowledge building and sense-making through iterative questioning, constructive learning, sharing, and reflection processes. It focuses on learning opportunities that are interdisciplinary, student-focused, collaborative, and interconnected with real-world problems and practices (English & Kitsantas, 2013). It has been used in various classroom settings (Mergendoller & Thomas, 2000), including biology (Jayanti, Sejati, Isnaeni, Saptono, & Semarang, 2021; Milla, Jufri, & Soepriyanto, 2019; Movahedzadeh, Patwell, Rieker, & Gonzalez, 2012).

Research investigating the relationship between scientific reasoning skills and other 21st century skills. However, there are no studies that reveal the relationship between problem-solving and other 21st century skills. Kundariati, Maghfiroh, Indriwati, Rohman, & Priambodo (2021), examining the relationship between scientific reasoning and argumentation, the results of his research show the contribution of scientific rationale to student arguments is 10.9%. Another study was conducted by Nurhayati, Yuliati, & Mufti (2016) based on scientific reasoning and problem-solving in physics. The results showed that scientific reasoning patterns and problem-solving abilities in Physics synthesis had a positive relationship. However, no one has investigated the relationship between scientific reasoning and problem-solving in biology using correlational design research. So we need research that aims to examine the relationship between scientific reasoning and problem-solving in biology class. This study result can hopefully help students to learn more effectively instead.

METHODS

Research Design

The research applied a correlational study. This research hypothesizes that scientific reasoning is positively related to problem-solving in the biology classroom. Correlation analysis is an approach that uses a correlational statistic to deal with the correlation of the two or more variables studied (Cresswell, 2011). Two variables measured in this study are Scientific Reasoning Skills (SRS) and problem-solving skills.

Population and Samples

The research was conducted at Biology Department, Universitas Negeri Malang. The population of this **research** is students of six classes of biology students at the Universitas Negeri Malang. The sample was selected purposively. The sample is based on a class test using GPA. The sample was two classes students of the Department of Biology Education at Universitas Negeri Malang (N=56) who attended the Animal Diversity Course in the third semester in the academic year 2019/2020. The demography of the participants is consists of males (10), females (46), average age (18-20). This research was conducted from August to December 2019.

Instrument

Data were collected from pre and post-test essays that have been previously tested for their validity in integrated scientific reasoning and problem-solving metrics. Instrument validity was carried out with external and internal validators, all of which stated valid. Scientific reasoning follows the AACU (2010) Scientific Reasoning Rubrics, which listed five scientific reasoning skills indicators as follows: (1) argument or topic selection: generating an empirically evidenced and logical argument, (2) existing knowledge, research, and views: distinguishing a scientific argument from a non-scientific argument, (3) methodology; recognizing methods of inquiry that lead to scientific knowledge, (4) analysis: reasoning by deduction, induction, and analogy, and (5) conclusions, limitations, and implications: distinguishing between causal and correlational relationships. Problem-solving follows the AACU (2010) Scientific Reasoning Rubrics, which listed six scientific reasoning skills indicators as follows: (1) define the problem, (2) propose solutions/hypotheses, (3) evaluate potential solutions, (4) implement the solution, and (5) evaluate outcomes. The examples of scientific reasoning and problem-solving skills can be shown in Table 1.

Table 1
Scientific reasoning and problem-solving skills test essay

Question 1
Look at the picture below!

Figure A
Source: seafriends.org.nz

Figure B
Source: www.iucngisd.org

Based on the picture above, answer some of the questions below;

a. *Please give your opinion regarding the two animal phenomena based on the characteristics of their bodies! (argument or topic selection)*
b. *Give a scientific argument for the difference between animal A and B based on body morphology! (existing knowledge, research, or views)*
c. *If allowed to observe the two animal pictures above, how would you follow their anatomical structure? (methodology)*
d. *Based on the results of your analysis, write down the basis for grouping the two animals? (analysis)*
e. *Conclude the morphological concept of the two animals! (conclusions, limitations, and implications)*

Question 2
Read and analyze the news text below!

It is collecting shells on the beach while on vacation is very fun. However, behind its beauty, the sting of some types of snails is very dangerous. One of them is the beautiful Conus conch. The unique shell shape with beautiful colors and patterns makes Conus the target of collectors. Its size is no more than 4.35 centimeters. It is found living in the Indo-Pacific region and along the southern coast of Australia.

In Indonesia, there are *Conus omaria, Conus pulicarius, Conus textile,* and the most deadly, *Conus geographus*. Not many people know that this beauty is one of the most dangerous killers in the world. Conus' cruelty lies in the poison he possesses.

Conus geographus sting is very deadly. The victim will feel stiff 10 minutes after being stabbed. In the next half hour, the victim will experience paralysis. Within an hour, the victim lost consciousness and was in a coma, the pulse was getting weaker, and breathing was heavy and slow. Without medical help, the victim can die five hours later.
Source: http://lipi.go.id/berita/conus-si-indah-yang-mematikan/1253

Based on the news text above, answer the questions below.

a. In your opinion, what strategies/approaches can be taken to identify the types of Conus snails on the beach, to avoid these types of snails? *(define the problem)*
b. Analyze the hypotheses/solutions that show your understanding of the problem! (*propose solutions/hypotheses*)
c. Analyze the results of the evaluation of the solutions you offer by considering the origin of the problem! (*evaluate potential solutions*)
d. Based on the solution chosen, come up with workaround steps to prevent the problem! (*implement the solution*)
e. Analyze the possible success rate of your given solution! (*evaluate outcome*)

Procedure

This research begins with a needs analysis which aims to collect information about the strategies used by the lecturers, the teaching materials and media used, and to be able to see the thinking skills of students. After that, the researchers compiled research instruments in lesson plans, worksheets, and pretest and post-test instruments. The instrument used has been validated before. Scientific reasoning and problem-solving skills were empowered in the learning process, which discusses the classification of phylum Vermes (Platyhelminthes, Nemathelminthes, and Annelids), Mollusca, Arthropoda, Echinodermata, five classes of vertebrates, namely Pisces, Amphibians, Reptiles, Aves, and Mammals. The pretest was carried out at the beginning of the meeting, namely on the Vermes material, the first post-test after completing the last topic of invertebrates, namely the phylum Echinoderms. The second pretest was carried out before entering the Pisces material, and the second post-test was carried out at the end, i.e., completing the mammal material. The learning process refers to the syntax of the Science Project-based Learning (SPjBL) model. All students agree to be participants in this research.

Data Analysis Techniques

Data were analyzed using a simple linear regression test with SPSS 16.0. it was processed by evaluating scientific reasoning and problem-solving correlation. The pre and post-test data of scientific reasoning and problem-solving skills were sought for the corrected mean obtained by subtracting the pretest and post-test scores and multiplying by the regression coefficient.

The results of the corrected standard are used as material to test the regression. Before the data was tested with parametric testing, the data were measure for normality testing. This testing showed a p-value (0.685) > 0.05, which means the data was distributed normally.

RESULTS AND DISCUSSION

The correlation of scientific reasoning and argumentation was determined by simple linear regression analysis using SPSS 16.00. Simple linear regression is shown in Table 3 and Table 4.

Table 3

A correlation value of scientific reasoning and problem-solving

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.523[a]	.273	.260	4.63390

Table 4

Significance number of scientific reasoning and problem-solving analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	33.997	8.508		3.996	.000
	Scientific Reasoning	.511	.113	.523	4.503	.000

Based on Table 4, p-value 0.00 < 0,05, there is a correlation between scientific reasoning and problem-solving. R *(correlation value)* is 0.523 means they were in a strong relationship. The linear regression analysis revealed the regression equation as follows Y = 33.997+0.511X. Scientific reasoning and problem-solving skills have a positive relationship. The influence of the dependent variable on the independent variable is equal to 27.7%%, and the rest, 72.3%, were affected by other variables. This contribution percentage can be seen in Figure 1.

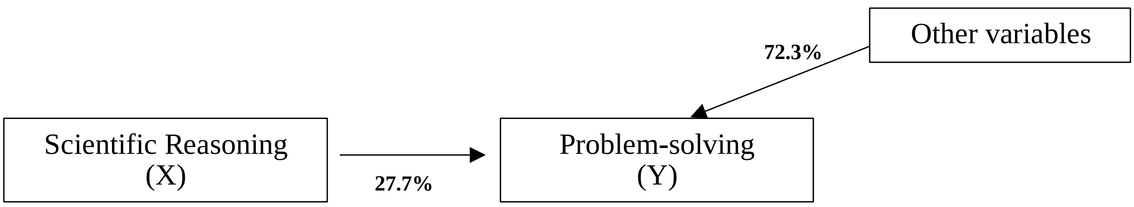

Figure 1. Simplified correlation model between scientific reasoning and problem-solving skills.

From the analysis above, scientific reasoning has a positive correlation to problem-solving skills. Research by Alshamali & Daher, (2016); Croker, & Zimmerm (2012), also report that problem-solving is part of scientific reasoning and vice versa. Moreover, scientific reasoning can support problem-solving skills (Charysma, Widoretno, & Dwiastuti, 2018) and obtaining problem solutions (Charysma et al., 2018). When problem-solving involves science learning, there are many similarities with the applications of scientific reasoning. Scientific reasoning as an integral part of training students in a highly dynamic and knowledge-based society can solve problems (Brew, 2006; Fischer, Chinn, Engelmann, & Osborne, 2018; Halpern et al., 2012) and also giving positive effects on students' learning in science (Collete & Chiapetta, 1994). Zimmerman (2005) argues there are two approaches to develop Students' scientific reasoning: focusing on developing conceptual knowledge in particular scientific domains and "focused on the reasoning and problem-solving strategies involved in diverse activities such as hypothesis generation, experimental design, evidence evaluation, and drawing inferences.

A strong correlation of scientific reasoning and problem-solving can be formed because the learning process for animal diversity is taught with SPjBL to accommodate every indicator of critical thinking and problem-solving skills. Each indicator accommodated in the SPjBL learning steps is related to each other so that there is an increase in both skills in students. In this study, the correlation between scientific reasoning and problem-solving can be explained in Figure 2.

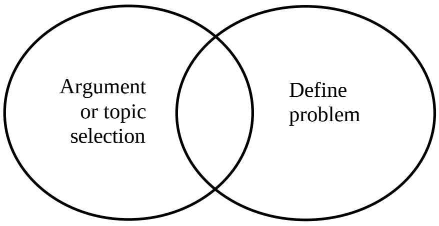

Figure 2. Argument or topic selection and define problem thinking framework

The two indicators above have parts that are related to one another to form a wedge. Learning steps in PjBL, namely formulate questions, can support the development of argumentation and the Student's ability the select and define the topic or thinking framework. When students state or write down questions, they also argue on the selected topic and determine what problems arise based on the phenomena seen or displayed. Students identify a creative, focused, and manageable argument or topic that addresses potentially significant yet previously less-explored aspects to define the ethical problem. Based on AACU (2010a), students have defined the problem clearly if they can demonstrate the ability to construct a clear and insightful problem statement with evidence of all relevant contextual factors. The best practice to defining problems is finding the newest one or unexplored before. Thus, students should have a sense of sensitivity to the environment. The problems triggering students to be more creative (Vizioli & Kaminski, 2017). If students can state arguments or choose the right topic, then students can define the problem thinking framework.

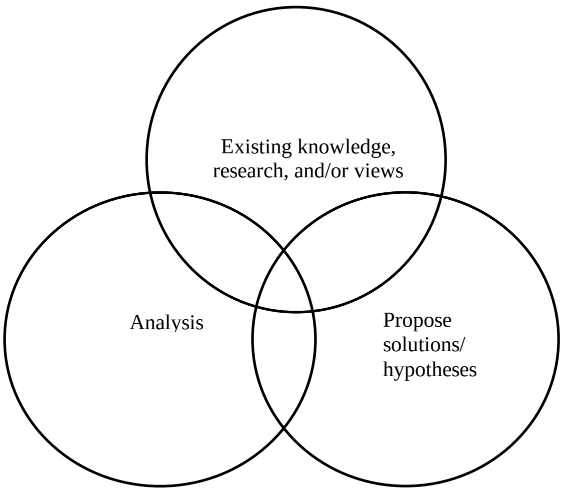

Figure 3. Existing knowledge, research, or view; analysis, and propose solutions/hypotheses thinking framework

These indicators above have parts related to one another to form a wedge Knowledge, research, and existing views are manifested by students looking for references related to the stated problem formulation. This activity can be used to answer the Student's questions that were formulated before. Exploration and organizational of knowledge used to build ideas or solutions that can be facilitated by reading references (Chang, 2009), doing practice (Irmawanty, 2018; Mendenhall, 2007; Nisa, 2017; Wrenn & Wrenn, 2009), and observation (Oguz-Unver & Yurumezoglu, 2009). References in the problem-solving process are required to source credibility to support scientific processes (Argote & Miron-Spektor, 2011). References serve to relate scientific facts with multiple interrelated knowledge so that it can deliver solutions. From the information that students have, they propose solutions or hypotheses and analyze matters they questioned before.

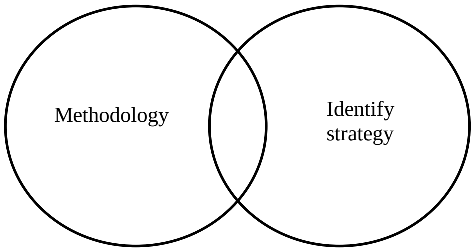

Figure 4. Methodology and identify strategy thinking framework

The methodology and identify strategy have a part that is related to one another. Students can build these skills indicators by designed a plan for the project. While designing a plan for the project, student's identifying strategy supports the methodology to solving the problems. Scientific reasoning positively affects students' science learning (Coletta & Phillips, 2005), including problem-solving. Solving problems let students associate science concepts by working actively and not passively with solutions (Chen & She, 2015). To find the right solution, students need to determine what method or approach. This step is carried out before retrieving data through practical activities, observation, and literature study. Students identify multiple approaches or methods to solving the problem that applies within a specific context. Recognize the methods of inquiry that lead to scientific knowledge. When students develop a methodology for conducting an investigation, they identify what strategies are appropriate. These two things are essential points in biology class.

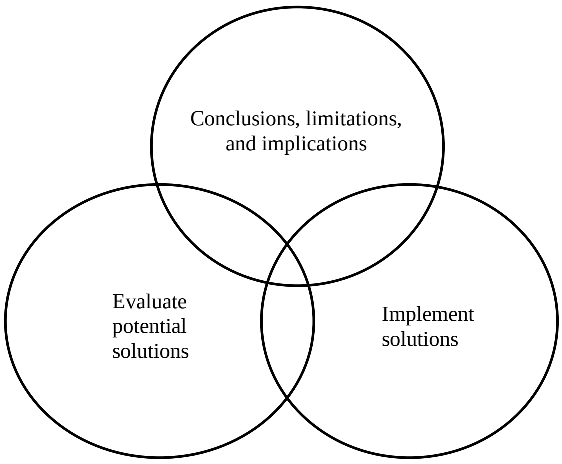

Figure 5. Conclusions, limitations, and implications; evaluate potential solutions, and implement solutions thinking framework

The three indicators, namely conclusions, limitations, and implications, evaluate potential solutions and implement solutions thinking framework are related to one another. After students analyze the information they get, then they conclude and find the best solution. The idea's solution to the problems found must be effective and efficient, both time and resources. Solutions that are good but irrelevant or unenforceable are not precisely the right solutions. Students must arrange solutions as detailed as possible and describe the possibilities about the positive and negative impacts of these solutions. Individuals should be aware of how to evaluate "what is currently known or believed, develop testable questions, test hypotheses, and draw appropriate conclusions by coordinating empirical evidence and theory" (Morris et al., 2012). Such reasoning also requires the ability to attend to information systems and draw reasonable inferences from observed patterns. Furthermore, it requires the ability to assess one's reasoning at each stage in the process (Alshamali & Daher, 2016). Thus, this learning experience helps students to determine appropriate solutions in real life.

CONCLUSION

Based on the data analysis, we can conclude that students' scientific reasoning skills positively correlate to problem-solving skills. It means that scientific reasoning can be a predictor of problem-solving. This study does not reveal other contributions that affect the problem-solving skills of students. Therefore, a study is needed to reveal the involvement of other aspects of student problem-solving skills.

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