RESEARCH ARTICLE

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 Toulmins' 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 interpretates 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 H0 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	273.195	1	273.195	7.511	.008	.120
Learning Material	114.036	1	114.036	3.135	.082	.054
Error	2000.598	55	36.375			
Total	433560.000	58				
Corrected Total	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	4135.860a	2	2067.930	36.465	.000	.570
Intercept	2096.648	1	2096.648	36.971	.000	.402
Pre-Problem-solving	659.981	1	659.981	11.638	.001	.175
Learning Material	1088.086	1	1088.086	19.187	.000	.259
Error	3119.054	55	56.710			
Total	424437.000	58				
Corrected Total	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 fast 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 helps 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.

References

AACU. (2010). *Scientific reasoning rubric*. https://www.aacu.org/initiatives/value-initiative/value-rubrics

Aksela, M., & Haatainen, O. (2019). Project-based learning (PBL) in practise: Active Teachers' views of its' advantages and challenges. *Integrated Education for the Real World : 5th International STEM in Education Conference Post-Conference Proceedings*, *Queensland University of Technology*, 9–16. https://researchportal.helsinki.fi/en/publications/project-based-learning-pbl-in-practise-active-teachers-views-of-i

Belecina, R. R., & Ocampo, J. M. (2018). Effecting change on students' critical thinking in problem solving. *EDUCARE: International Journal for Educational Studies International Journal for Educational Studies Article Timeline: Accepted*, *10*(102), 109–118. https://doi.org/10.2121/edu-ijes.v10i2.949

Bhattacharjee, B., & Deb, K. (2016). Role of ICT in 21st Century's teachers education. *International Journal of Educational and Information Studies*, *6*(1), 1–6. https://www.ripublication.com/ijeis16/ijeisv6n1_01.pdf

Brown, S. W., Lawless, K. A., Rhoads, C., Newton, S. D., & Lynn, L. (2016). Increasing students' science writing skills through a PBL simulation. *Proceedings of the 13th International Conference on Cognition and Exploratory Learning in the Digital Age, CELDA 2016*, 86–94. https://eric.ed.gov/?id=ED571428

Carlina, E., & Djukri. (2018). Science project-based learning integrated with local potential to promote student's environmental literacy skills. *Advanced Journal of Social Science*, *4*(1), 1–7. https://doi.org/10.21467/ajss.4.1.1-7

Cetin, P. S., Dogan, N., & Kutluca, A. Y. (2014). The quality of pre-service science teachers' argumentation: Influence of content knowledge. *Journal of Science Teacher Education*, *25*(3), 309–331. https://doi.org/10.1007/s10972-014-9378-z

Chiang, C. ., & Huaei, L. (2016). The effect of project-based learning on learning motivation and

problem-solving ability of vocational high school students. *International Journal of Information and Education Technology*, *6*(9), 709–712. https://doi.org/10.7763/ijiet.2016.v6.779

Cindikia, M., Achmadi, H. R., Prahani, B. K., & Mahtari, S. (2020). Profile of students' problem solving skills and the implementation of assisted guided inquiry model in senior high school. *Studies in Learning and Teaching*, *1*(1), 52–62. https://doi.org/10.46627/silet.v1i1.22

Creswell, J. W. (2014). Research design. In *Qualitative, quantitative, and mixed methods approaches* (Third). Sage Publisher. http://books.google.com/books?id=bttwENORfhgC&pgis=1

Daryanti, E. P., Rinanto, Y., & Dwiastuti, S. (2015). Peningkatan kemampuan penalaran ilmiah melalui model pembelajaran inkuiri terbimbing pada materi sistem pernapasan manusia. *Jurnal Pendidikan Matematika dan Sains*, *3*(2), 163–168. https://doi.org/10.21831/jpms.v6i2.10948

Davidsen, J., Ryberg, T., & Bernhard, J. (2020). "Everything comes together": Students' collaborative development of a professional dialogic practice in architecture and design education. *Thinking Skills and Creativity*, *37*(June), 100678. https://doi.org/10.1016/j.tsc.2020.100678

Engelmann, K., Neuhaus, B. J., & Fischer, F. (2016). Fostering scientific reasoning in education–meta-analytic evidence from intervention studies. *Educational Research and Evaluation*, *22*(5–6), 333–349. https://doi.org/10.1080/13803611.2016.1240089

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's Argument Pattern for studying science discourse. *Science Education*, *88*(6), 915–933. https://doi.org/10.1002/sce.20012

Facione, P. a. (2011). Critical thinking : What it is and why it counts. In *Insight assessment* (Issue ISBN 13: 978-1-891557-07-1.). https://www.insightassessment.com/CT-Resources/Teaching-For-and-About-Critical-Thinking/Critical-Thinking-What-It-Is-and-Why-It-Counts/Critical-Thinking-What-It-Is-and-Why-It-Counts-PDF

Fadli, A., & Irwanto. (2020). The effect of local wisdom-based ELSII learning model on the problem solving and communication skills of pre-service islamic teachers. *International Journal of Instruction*, *13*(1), 731–746. https://doi.org/10.29333/iji.2020.13147a

Fang, S. C., Hsu, Y. S., & Lin, S. S. (2019). Conceptualizing socioscientific decision making from a review of research in science education. *International Journal of Science and Mathematics Education*, *17*(3), 427–448. https://doi.org/10.1007/s10763-018-9890-2

Fischer, A., Greiff, S., & Funke, J. (2012). The process of solving complex problems. *The Journal of Problem Solving*, *4*(1). https://doi.org/10.7771/1932-6246.1118

Frey, B. B., Ellis, J. D., Bulgren, J. A., Craig Hare, J., & Ault, M. (2015). Development of a test of scientific argumentation. *Electronic Journal of Science Education*, *19*(4), 1–18. https://eric.ed.gov/?id=EJ1188271

Fujii, T. (2016). Designing and adapting tasks in lesson planning: a critical process of Lesson Study. *ZDM - Mathematics Education*, *48*(4), 411–423. https://doi.org/10.1007/s11858-016-0770-3

Gunawan, G., Harjono, A., Nisyah, M., Kusdiastuti, M., & Herayanti, L. (2020). Improving students' problem-solving skills using inquiry learning model combined with advance organizer. *International Journal of Instruction*, *13*(4), 427–442. https://doi.org/10.29333/iji.2020.13427a

Han, S., Yalvac, B., Capraro, M. M., & Capraro, R. M. (2015). In-service teachers' implementation and understanding of STEM project based learning. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(1), 63–76. https://doi.org/10.12973/eurasia.2015.1306a

Heng, L. L., Surif, J., & Seng, C. H. (2014). Individual versus group argumentation: Student's performance in a Malaysian context. *International Education Studies*, *7*(7), 109–124. https://doi.org/10.5539/ies.v7n7p109

Hussin, A. A. (2018). Education 4.0 made simple: Ideas for teaching. *International Journal of Education and Literacy Studies*, *6*(3), 92–98. https://doi.org/10.7575/aiac.ijels.v.6n.3p.92

Ika Noviyanti, N., Rosyadah Mukti, W., Dahlia Yuliskurniawati, I., Mahanal, S., & Zubaidah, S. (2019). Students' scientific argumentation skills based on differences in academic ability. *Journal of Physics: Conference Series*, *1241*(1). https://doi.org/10.1088/1742-6596/1241/1/012034

Jalinus, N., Nabawi, R. A., & Mardin, A. (2017). *The seven steps of project based learning model to enhance productive competences of vocational students*. *102*(Ictvt), 251–256. https://doi.org/10.2991/ictvt-17.2017.43

Kambeyo, L. (2017). Scientific reasoning skills: A theoretical background on science education. *NERA Journal*, *14*, 40–64. https://www.researchgate.net/publication/329196813_scientific_reasoning_skills_a_theoretical_background_on_science_education

Khoirina, M., Cari, C., & Sukarmin, S. (2018). Identify students' scientific reasoning ability at senior high school. *Journal of Physics: Conference Series*, *1097*(1). https://doi.org/10.1088/1742-6596/1097/1/012024

Kuhn, D. (2011). What is scientific thinking and how does it develop? In *The Wiley-Blackwell handbook of childhood cognitive development, 2nd ed.* (pp. 497–523). Wiley-Blackwell. https://onlinelibrary.wiley.com/doi/abs/10.1002/9781444325485.ch19

Kundariati, M, Munthea, R. N. S., & ... (2021). Analisis kesulitan membelajarkan plant cellular respiration melalui PBL untuk memberdayakan keterampilan argumentasi ilmiah. *Prosiding …*,

84–89. http://research-report.umm.ac.id/index.php/psnpb/article/view/4735%0Ahttp://research-report.umm.ac.id/index.php/psnpb/article/download/4735/4274

Kundariati, Maisuna, Maghfiroh, L., Indriwati, S. E., Rohman, F., Priyambodo, B., Setyawan, D., & Azean, N. (2020). Analysis of invertebrate and vertebrate animals in Malang Regency as an animal diversity learning resource for biology student at the Universitas Negeri Malang. *AIP Conference Proceedings*, *2215*. https://doi.org/10.1063/5.0003781

Kundariati, Maisuna, Maghfiroh, L., Indriwati, S. E., Rohman, F., & Priambodo, B. (2021). Scientific reasoning and argumentation: The correlation in animal classification study. *AIP Conference Proceedings*, *2330*(March). https://doi.org/10.1063/5.0043475

Kundariati, Maisuna, & Rohman, F. (2020). Developing local-based invertebrates e-encyclopedia to improve scientific reasoning skills. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *6*(2), 189–198. https://doi.org/10.22219/jpbi.v6i2.11953

Lewin, C., & McNicol, S. (2015). Supporting the development of 21st century skills through ICT. *KEYCIT 2014: Key Competencies in Informatics and ICT*, 181–198. https://publishup.uni-potsdam.de/ files/8267/cid07_S181-198.pdf

Lisesi, Ç. K. M. T. A. (2017). Examining the problem solving skills and the strategies used by high school students in solving non-routine problems. *E-Uluslararası Eğitim Araştırmaları Dergisi*, *8*(2), 91–114. https://doi.org/10.19160/ijer.321075

Liu, F., & Stapleton, P. (2020). Counterargumentation at the primary level: An intervention study investigating the argumentative writing of second language learners. *System*, *89*, 102198. https://doi.org/10.1016/j.system.2019.102198

Markham, T. (2012). *Project based learning: Design coaching guide*. Wilsted & Publishing Service. https://pdfcoffee.com/project-based-learning-design-and-coaching-guide-pdf-free

Mettas, A. C., & Constantinou, C. C. (2008). The technology fair: A project-based learning approach for enhancing problem solving skills and interest in design and technology education. *International Journal of Technology and Design Education*, *18*(1), 79–100. https://doi.org/10.1007/s10798-006-9011-3

Mikre, F. (2011). The roles of information communication technologies in education review article with emphasis to the computer and internet. *African Journals Online*, *6*(2), 109–126. http://www.ajol.info/index.php/ejesc/article/view/73521

Moorthi, S. (2018). Problem solving skills among college students. *International Journal of Innovative Research Explorer*, *April*. https://www.researchgate.net/publication/324569702_problem_solving_skills_among_college_students

Nawawi, S. (2017). Developing of module challenge based learning in environmental material to empower the critical thinking ability. *Jurnal Inovasi Pendidikan IPA*, *3*(2), 212. https://doi.org/10.21831/jipi.v3i2.15988

Novitasari, C., Ramli, M., & Karyanto, P. (2018). Facts and proofs diagnostic test and structural communication grid test on the topic of bacteria: A quantitative analysis. *Jurnal Pendidikan Biologi Indonesia*, *4*(3), 195–202. https://doi.org/10.22219/jpbi.v4i3.6166

Pallant, A., & Lee, H. S. (2015). Constructing scientific arguments using evidence from dynamic computational climate models. *Journal of Science Education and Technology*, *24*(2–3), 378–395. https://doi.org/10.1007/s10956-014-9499-3

Pratiwi, S. N., Cari, C., Aminah, N., & Affandy, H. (2019). Problem-based learning with argumentation skills to improve students' concept understanding. *Journal of Physics: Conference Series*, *1155*(1). https://doi.org/10.1088/1742-6596/1155/1/012065

Pritasari, A. C., Dwiastuti, S., Probosari, R. M., & Sajidan. (2015). Problem based learning implementation in class X MIA 1 SMA Batik 2 Surakarta. *Jurnal Pendidikan IPA Indonesia*, *4*(2), 158–163. https://doi.org/10.15294/jpii.v4i2.4185

Probosari, R., Ramli, M., Indrowati, M., Harlita, & Sajidan. (2016). Profil keterampilan argumentasi ilmiah mahasiswa pendidikan biologi FKIP UNS pada mata kuliah anatomi tumbuhan. *BIOEDUKASI*, *9*(2007), 29–33. https://doi.org/10.20961/bioedukasi-uns.v9i1.3880

Purwati, R., Suranto, S., Sajidan, S., & Prasetyanti, N. M. (2019). Analysis of argumentation skills in biology learning at Surakarta Senior High School. *International Conference on Advances in Education, Humanities, and Language*. https://doi.org/10.4108/eai.23-3-2019.2284903

Putri, M. D., & Rusdiana, D. (2017). Identifying students' scientific argumentation skill at Junior High School 1 Argamakmur, North Bengkulu. *IJAEDU- International E-Journal of Advances in Education*, *III*(9), 556–572. https://doi.org/10.18768/ijaedu.370424

Rahman, M. M. (2019). 21st Century skill "problem solving": Defining the concept. *Asian Journal of Interdisciplinary Research*, *2*(1), 71–81. https://doi.org/10.34256/ajir1917

Rokhanah, S., Suptiyanto, & Priyono, B. (2015). Pengaruh Penerapan Metode MASTER dengan Pendekatan Saintifik Terhadap Hasil Belajar Peserta Didik pada Materi Invertebrata di SMA. *Journal of Biology Education*, *4*(3), 231–236. https://doi.org/10.15294/jbe.v4i3.9546

Ryu, S., & Sandoval, W. A. (2012). Improvements to elementary children's epistemic understanding from sustained argumentation. *Science Education*, *96*(3), 488–526.

https://doi.org/10.1002/sce.21006
Suciati, S., Imaningtyas, C. D., Octovi, C., & Yuliawanti, E. (2020). The effect of problem-based learning model to students' cognitive achievement on high and low students' problem-solving abilities. *Journal of Physics: Conference Series*, *1567*(4). https://doi.org/10.1088/1742-6596/1567/4/042040
Susilowati, S. M. E., & Anam, K. (2017). Improving students' scientific reasoning and problem-solving skills by the 5E learning model. *Biosaintifika: Journal of Biology & Biology Education*, *9*(3), 506–512. https://doi.org/10.15294/biosaintifika.v9i3.12022
Syafii, W., & Yasin, R. M. (2013). Problem solving skills and learning achievements through problem-based module in teaching and learning biology in high school. *Asian Social Science*, *9*(12 SPL ISSUE), 220–228. https://doi.org/10.5539/ass.v9n12p220
Tawfik, A. A. (2017). Do cases teach themselves? A comparison of case library prompts in supporting problemsolving during argumentation. *Journal of Computing in Higher Education*, *29*(2), 267–285. https://doi.org/10.1007/s12528-017-9136-2.
Toulmin, S., Rieke, R., & Janik, A. (1984). *An introduction to reasoning*. Macmillan Publishing Co. Inc. https://www.academia.edu/37757999/Toulmin_and_Janik_An_Introduction_to_Reasoning_pdf
Turiman, P., Omar, J., Daud, A. M., & Osman, K. (2012). Fostering the 21st Century skills through scientific literacy and science process skills. *Procedia - Social and Behavioral Sciences*, *59*, 110–116. https://doi.org/10.1016/j.sbspro.2012.09.253
Ul-Amin, S. N. (2013). An effective use of ICT for education and learning by drawing on worldwide knowledge, research, and experience: ICT as a change agent for education. *Scholarly Journal of Education*, *2*(2), 38–45. https://www.scholarly-journals.com/sje/archive/2013/April/pdf/Noor-Ul-Amin.pdf
Widya, Rifandi, R., & Laila Rahmi, Y. (2019). STEM education to fulfil the 21st century demand: A literature review. *Journal of Physics: Conference Series*, *1317*(1). https://doi.org/10.1088/1742-6596/1317/1/012208
Yanto, B. E., Subali, B., & Suyanto, S. (2019). Improving students' scientific reasoning skills through the three levels of inquiry. *International Journal of Instruction*, *12*(4), 689–704. https://doi.org/10.29333/iji.2019.12444a
Yu, K. C., Fan, S. C., & Lin, K. Y. (2015). Enhancing students' problem-solving skills through context-based learning. *International Journal of Science and Mathematics Education*, *13*(6), 1377–1401. https://doi.org/10.1007/s10763-014-9567-4
Yulindar, A., Setiawan, A., & Liliawati, W. (2018). Enhancement of problem solving ability of high school students through learning with real engagement in active problem solving (REAPS) model on the concept of heat transfer. *Journal of Physics: Conference Series*, *1013*(1). https://doi.org/10.1088/ 1742-6596/1013/1/012052