UNIVERSITAS AHMAD DAHLAN
JURNAL BIOEDUKATIKA
http://journal.uad.ac.id/index.php/BIOEDUKATIKA
2338-6630 (Print) | 2541-5646 (Online)

Instructional Techniques Concept Map at the Planning Investigation Stage in Project Based Learning on Students' Argumentation Skills

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ARTICLE INFO

Article history

Submission	March 24, 2022
Revision	July 25, 2022
Accepted	September 06, 2022

Keyword:
Argumentation skills
Instructional techniques
Concept map
Project based learning
Planning stage

ABSTRACT

Argumentation skills are one of the characteristics of higher-order thinking skills that students need in learning. The research aims to identify differences in the argumentation skills of students in classes that apply the concept map instructional technique at the planning investigation stage in PjBL with students in classes that only apply PjBL. The study used a quasi-experimental research design with a posttest-only nonequivalent group design. The research subject is 72 students in 10th grade majoring in Mathematics and Natural Sciences of Senior High Schools (SHS). The learning topic in this research is Ecosystem. The research instrument was an argumentation question totaling 11 numbers in the form of reasoned true-false multiple-choice questions that matched the argumentation component. Instrument validation uses the Rasch model. Analysis of research data using independent sample t-test. The results showed that the significance value of the t-test to the score of argumentation skills was 0.000, meaning that the significance value was <0.05 it can be stated that there is a significant difference in the argumentation skills of students in the class who applied the concept map instructional technique at the planning investigation stage in the PjBL model with the argumentation skills of students in the class which only uses the PjBL.

Introduction

Argumentation is the skill of connecting facts and concepts to apply knowledge to examples of everyday life (Erduran, 2018). Argumentation skills are the process of compiling statements through critical thinking analysis supported by data and logical reasons (Pangestika et al., 2017). Argumentation is a scientific skill that is widely recognized as the main goal of science (Erduran et al., 2015). Argumentation skills are the core of knowledge construction because students are required to convey, support, criticize, evaluate and improve ideas about a concept as well as use theory and scientific evidence to confirm the claims made (Heng et al., 2015).

Arguments based on Toulmin's argumentation patterns have six components, namely evidence, claims, warrants, backing, qualifiers, rebuttal (Toulmin, 2003; Ho et al., 2019).

Argumentation skills indicate higher-order thinking skills (Tsai, 2018) because they encourage students to reflect on the results of their own thinking (Haruna & Nahadi, 2021) through the process of collecting evidence, making decisions, expressing and communicating ideas with evidence (Hefter et al., 2014). Argumentation skills are a negotiation process that involves students in discussions to clarify ideas with one another to build a statement (claim) that is supported by evidence (Chen et al., 2019).

Research in Indonesia shows that high school students' argumentation skills are still relatively low (Noviyanti et al., 2021). Research by Tama et al. (2016) showed that the average percentage of high school students' argumentation skills in ecosystem material at a school in Surakarta was 24.81% consisting of 20% evidence aspect, 28.89% reasoning aspect, and 25.56% rebuttal aspect. Students' low argumentation skills are caused by a poor understanding of scientific concepts and a lack of understanding of the purpose and process of building arguments (Heng et al., 2015). Another cause is the lack of active student involvement in learning (Noviyanti et al., 2021). Active learning can support students in building arguments through research data collection activities and using reasoning to serve as evidence as a basis for solving real-world problems (Noviyanti et al., 2021). One example of active learning is the Project Based Learning (PjBL) model (Hsu et al., 2015).

PjBL is a student-centered learning model for creating projects related to the concepts of the material being studied and problems found in the real world (Juuti et al., 2021). Project based learning according to Turgut (2008) has five stages, namely: 1) planning investigation, 2) searching theory, 3) presenting theory and discussion, 4) deciding, collecting, and analyzing data, 5) evaluating the project and arriving a conclusion. Planning investigation is the initial stage of PjBL (Turgut, 2008). The planning investigation stage in the PjBL is the investigative planning stage based on directive questions to develop the project (Surahman et al., 2019). The planning stage determines how to collect and analyze data (Du & Han, 2016).

In addition to active learning through the PjBL learning model, learning is also needed that can help students understand the concept of the lesson because students' conceptual understanding supports their argumentation skills (Trouche et al., 2014). This can be achieved through the application of concept map instructional technique (Novak & Gowin, 1984; Gündüz, 2016). Concept map instructional technique allows it to be applied to the planning investigation stage in PjBL (Sottilare et al., 2014). The planning investigation stage in PjBL contains student activities in determining problem topics to be investigated, designing activity procedures, detailing the tools and materials needed to help complete the project (Surahman et al., 2019).

Concept maps as instructional techniques are concepts that are interconnected and arranged hierarchically to form a scheme (Apodaca et al., 2019). The application of concept map instructional techniques is stimulated by questions from the teacher. Questions are useful for stimulating students' thinking (Buchanan, 2016), helping students to convey clear ideas, and encouraging students to act (Shanmugavelu et al., 2020). The concept map instructional technique explores students' thinking abilities to organize, analyze, and represent understanding concept (Su, 2020).

The concept map instructional technique facilitates students in identifying ideas that are interconnected in a logical pattern (Memiş, 2021). Ideas with logical patterns can be developed into arguments (Osborne et al., 2016). So far, PjBL learning has been carried out according to the syntax. In this study, modifications were made to the planning investigation syntax in PjBL with the application of concept map instructional technique which aims to identify differences in student argumentation skills in classes that apply the instructional concept map technique at the planning investigation stage of the PjBL model with argumentation skills students in classes that apply PjBL only.

Method

This research uses a quasi-research type with a post-test-only nonequivalent group design. The population used in the study were 10th-grade students majoring in mathematics and natural sciences at the senior high school level for the 2021/2022 academic year with a total of 179 students. The technique of determining the sample using cluster random sampling technique. Determination of the sample based on the results of the one-way ANOVA test on the results of the midterm assessment which showed a significance level of 0.096 > 0.05 meaning that there was no difference in the average of the student's midterm exam scores (equivalent class). The sample used for the research consisted of two classes with a total sample of 72 students. Learning in the experimental class used concept map instructional technique at the planning investigation stage in PjBL and learning in the control class only used the PJBL model. The learning syntax used in the experimental and control classes is presented in Table 1.

Table 1. Learning Syntax in Experiment Class and Control Class

No.	Experiment Class	Control Class
1.	Planning investigation + instructional technique concept map of ecosystem lesson	Planning investigation
2.	Searching theory,	Searching theory,
3.	presenting theory and discussion	presenting theory and discussion
4.	deciding, collecting, and analysis data	deciding, collecting, and analysis data
5.	evaluating project and arriving a conclusion	evaluating project and arriving a conclusion

Differences in the implementation of experimental class learning were only found in the planning stage because there were modifications treated with concept map instructional techniques. Students in the experimental class were asked to construct a concept map according to the sub-material that would be studied at each meeting at the planning investigation stage in the PjBL model. The research instrument was in the form of 11 reasoned true and false questions in accordance with the argumentation components, namely evidence, warrants, backing, qualifiers, rebuttals and claims (Table 2).

Table 2. Indicators of Argumentation Skills Questions

No. question	Argumentation component	Sub-material	Indicator
1.	*Evidence*	Ecosystem	Explain the meaning of ecosystem
2.	*Warrant*	Community	Explain the meaning of community
3.	*Warrant*	Biogeochemistry cycle	Identify the chemical elements that undergo biogeochemical cycles
4.	*Backing*	Interaction	Analyze the types of interactions in the community
5.	*Backing*	Food chain and energy flow	Analyze the composition of the food chain in the ecosystem
6.	*Qualifier*	Ecological pyramid	Explain the meaning of ecological pyramid
7.	*Qualifier*	Biogeochemistry cycle	Analyzing the process of changing the form of phosphorus in the phosphorus cycle
8.	*Qualifier*	Biogeochemistry cycle	Analyzing changes in the form of water in the hydrological cycle
9.	*Rebuttal*	Biogeochemistry cycle	Analyze examples of carbon compounds that experience the carbon cycle
10.	*Claim*	Biogeochemistry cycle	Describe the stages of the nitrogen cycle
11.	*Claim*	Biogeochemistry cycle	Analyzing the sulfur cycle in ecosystems

The argumentation skills question instrument was developed from the ecosystem chapter. Argumentation skill questions were tested on students at the end of the lesson. Validation of argumentation skills questions using the Rasch model. The validity of the content in each item is seen based on the value of the outfit means-square, outfit z-standard, and point measure correlation from the results of the validity test with the Rasch model (Sumintono & Widhiarso, 2015). The results of testing the validity of the item about argumentation skills can be seen in Table 3.

Table 3. Test Item Validity Test Results using the Rasch Model

Number of question	Outfit MNSQ	Explanation	Outfit ZSTD	Explanation	Pt Mean Corr	Explanation	Interpretation
1. Evidence	0,96	V	0,05	V	0,29	X	Valid
2. Warrant	1,01	V	0,18	V	0,29	X	Valid
3. Warrant	0,83	V	-0,82	V	0,47	V	Valid
4. Backing	0,78	V	-0,86	V	0,46	V	Valid
5. Backing	0,97	V	-0,07	V	0,35	X	Valid
6. Qualifier	0,91	V	-0,52	V	0,44	V	Valid
7. Qualifier	0,65	V	-0,89	V	0,49	V	Valid
8. Qualifier	0,80	V	-1,41	V	0,54	V	Valid
9. Rebuttal	1,19	V	0,94	V	0,23	X	Valid
10. Claim	0,98	V	-0,07	V	0,40	X	Valid
11. Claim	1,28	V	1,76	V	0,14	X	Valid

The item is said to be valid if it meets one validity criterion based on the value of the MNSQ outfit (0.5 < MNSQ < 1.5), ZSTD outfit (-2.0 < ZSTD < +2.0), Point measure correlation (0.4 < PT Measure Corr < 0.85) (Boone et al., 2014). The research data is in the form of post-test scores of argumentation skills. Each student's answer was given a score of 0.5 – 3 based on the assessment rubric of argumentation skills questions developed by Acar & Patton (2012) (Table 4). Analysis of research data used an independent sample t-test with a significance level of 0.05 using SPSS 24 software.

Table 4. Assessment Rubric on Argumentation Skills

Score	Answer	Description
3	True	Correct answers according to the answer key with clear, relevant reasons and refer to observations and are scientifically correct
2.5	True	Correct answers according to the answer key with clear, relevant reasons and referring to observations and some are scientifically correct
2	True	The correct answer according to the answer key with clear reasons refers to observations with 2 scientifically correct statements
1.5	True	The correct answer is according to the answer key with clear but irrelevant reasons
1	True	The answer is correct according to the answer key but the reasons are unclear and irrelevant
0.5	False	Wrong answer has no reason

Source : Acar & Patton (2012)

Results and Discussion

The research data consists of post-test scores for argumentation skills. The post-test was conducted in both the control class and the experimental class. Argumentation scores were obtained from student responses to true-false reasoning questions. The reasons provided by students for their answers on the questions were analyzed based on Acar & Patton (2012). The description of the post-test data for argumentation skills is presented in Table 5.

Table 5 Description of post-test data for argumentation skills

Description	Post-test	
	Experiment Class	**Control Class**
N	36	36
Average	89.69	82.57
Minimum	74.24	60.61
Maximum	98.48	92.42
Median	90.91	83.33

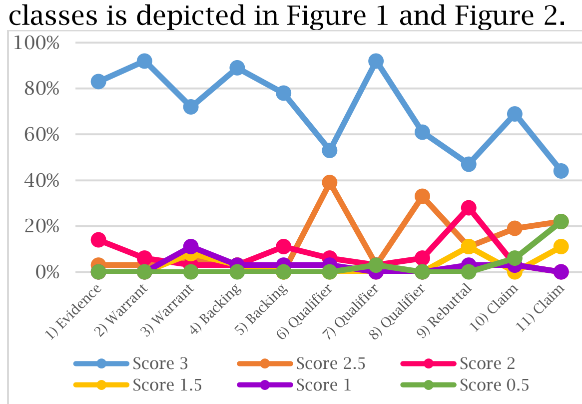
Based on Table 5, it is evident that the average score, minimum score, maximum score, and median score in the experimental class are higher compared to the control class. The distribution of Argumentation scores based on the Corrective Model (CM) for all items 1-11 is presented in Table 2.

Table 6 The proportion of argumentation skill scores for all question items

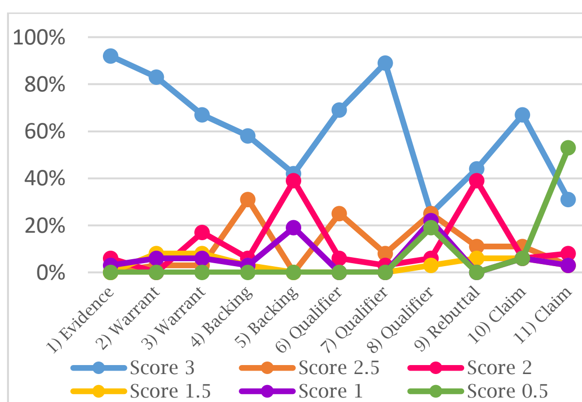
Class type	Score					
	3	**2.5**	**2**	**1.5**	**1**	**0.5**
Experiment	281	51	29	15	13	11
Control	240	43	48	13	24	28

The data on the proportion of student argumentation skill scores from all question items indicates that a higher number of students in the experimental class received a score of 3, while fewer students in the experimental class received scores of 1 or 0.5 compared to the control class. Based on the proportions, it can be inferred that the experimental class has a greater number of students scoring 3, implying that a majority of students in the experimental class are able to provide answers with the highest score.

The components of argumentation consist of claim, evidence, warrant, backing, qualifier, and rebuttal. Claim represents a conclusion or opinion about an event (Heng et al., 2015). It is the main statement under debate and needs to be supported with theoretical or empirical evidence (Mühlen et al., 2019). Evidence refers to empirical evidence or data, which are factual information used to support a statement or claim (Probosari et al., 2022). Warrant serves as the bridge between the claim and data, derived from scientific laws, principles, rules, or theories (Su, 2020). Qualifier is used to represent scientific accuracy and limit the strength of an argument. Rebuttal involves countering an argument or statement, indicating situations where the argument doesn't apply. Backing is a statement that supports the warrant (Gabriel et al., 2020). The percentage of student argumentation skill scores for each component in the experimental and control classes is depicted in Figure 1 and Figure 2.



Gambar 1. Percentage of Student Argumentation Skill Component Scores in the Experimental Class



Gambar 2. Percentage of Student Argumentation Skill Component Scores in the Control Class

Comparing the graphs of the percentage of argumentation skill component scores presented in Figure 1 and Figure 2 for each question item in the experimental and control classes, it can be observed that, overall, the percentage of argumentation skill scores in the experimental class is higher than in the control class. The highest percentage of argumentation skill scores in the experimental class, with a percentage of 92%, is found in question item 2, which includes the warrant component, and question item 7, which includes the qualifier component. Meanwhile, for the control class, the highest percentage is in item 1, which includes the evidence component, with a percentage of 83%. The lowest percentage achieved in the experimental class is in question item 11 (claim) at 44%, whereas the lowest percentage in the control class is in question item 8 (qualifier) at 25%.

The argumentation skill component score data were tested for prerequisites before conducting the t-test. The prerequisites testing involved normality and homogeneity tests with a significance level of 0.05. Based on the normality test results, the significance values for the experimental class and control class were 0.113 and 0.200, respectively, which are > 0.05, indicating that the data in both classes are normally distributed. The homogeneity test using Levene's statistic yielded a value of 0.926, which is > 0.05, indicating that the data is homogenous.

The argumentation skill component score data were analyzed using an independent-sample t-test with a significance level of 0.05 to identify the difference in argumentation skills between the control and experimental classes. The decision-making basis for the t-test is as follows: if the significance value ≤ 0.05, there is a significant difference in argumentation skills between the experimental class, which applies the instructional technique of concept map in the planning an investigation stage of PjBL, and the control class, which applies the PjBL model alone (rejecting the null hypothesis, H0). If the significance value ≥ 0.05, there is no significant difference in argumentation skills between the experimental class, which applies the instructional technique of concept map in the planning an investigation stage of PjBL, and the control class, which applies the PjBL model alone (accepting the null hypothesis, H0). The results of the t-test are presented in Table 7.

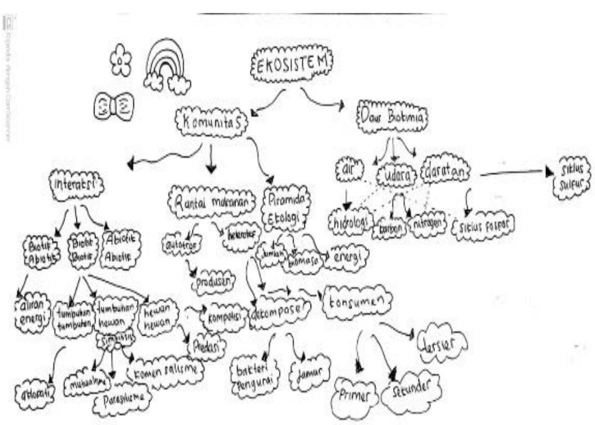
Table 7. t-Test Results of Students' Argumentation Skill Scores

Indicator	t	Significance	Description	Decision
Argumentation skill	4.472	0.000	Sig. < 0.05	Reject H_0 and accept H_1

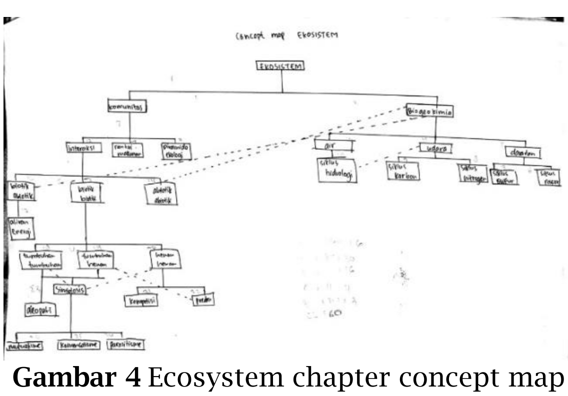
The results of the t-test in Table 2 show a significance value of 0.000, which is < 0.05. Therefore, it can be concluded that the null hypothesis (H0) is rejected, and the alternative hypothesis (H1) is accepted. Based on the t-test results, it can be inferred that there is a significant difference in students' argumentation skills between the experimental and control classes, attributed to the treatment applied in the study, namely the implementation of the instructional technique of concept map in the planning an investigation stage of PjBL, as present in the experimental class.

The instructional technique of concept map in the planning stage of PjBL has an influence on students' argumentation skills, as indicated by the higher percentage of argumentation skill scores in the experimental class compared to the control class, as shown in Figure 1 and Figure 2. This suggests that the implementation of the instructional technique of concept map in the planning stage enhances students' argumentation skills by emphasizing their focus on concepts during the planning phase to identify evidence, connect evidence, and associate concepts with the evidence found in order to support arguments (Ishaq et al., 2022). The lower percentage of argumentation skill component scores in the control class compared to the experimental class could be attributed to students struggling to provide accurate scientific concepts and reasoning to connect evidence with claims. This aligns with research conducted by Heng et al. (2015), which stated that students' constructed arguments were unsatisfactory due to a lack of understanding of scientific concepts, and the study by Antonio & Prudente (2021), which mentioned that students face difficulties in providing evidence to support reasons and establishing relationships between them.

Concept map as an instructional technique in the planning stage is beneficial for students in organizing learned content. Concept maps help students understand complex ideas and clarify relationships between ambiguous concepts (Woldeamanuel et al., 2020). Figure 3 and Figure 4 provide examples of concept maps created by students. These concept maps represent a unity of subtopics, including interactions, food chains, ecological pyramids, and biogeochemical cycles.



Gambar 3 Ecosystem chapter concept map made by student number 21



Gambar 4 Ecosystem chapter concept map made by student number 1

Based on Figure 3 and Figure 4, both students created concept maps for the ecosystem topic, but the concept map in Figure 3 is more complex than the one in Figure 4. The concept map in Figure 3 has more branches and is more specific compared to Figure 4. However, both students have created concept maps in a general manner that represent the relationships between general and specific concepts connected by linking lines (Machado & Carvalho, 2020). The implementation of the CM instructional technique in the planning stage of PjBL supports the process of constructing arguments, as arguments are built by connecting evidence (data) and learned concepts with the intended claim (Zahra et al., 2021). Concept map as an instructional technique in the planning stage helps students build knowledge and understand the relationships between concepts during the learning process (Chen et al., 2016).

The concept maps created by students are stimulated by questions, and the answers to the questions are visualized in the form of interconnected concepts (Woldeamanuel et al., 2020). Questions stimulate students' thinking and focus on concepts (Buchanan, 2016). Students who focus on concepts find it easier to make decisions in the planning stage (Widatama et al., 2019).

The concept map constructed by students depicts their understanding of a topic as an external representation of meaningful relationships, creating new integrated concepts alongside prior knowledge (Reiska et al., 2018). Understanding a concept helps students construct arguments because argumentation skills involve explaining relationships between concepts and encouraging reasoning about the concepts being learned (Eichler & Peepler, 2016). Students' argumentation skills seem to be related to their understanding of a concept (Antonio & Prudente, 2021). The level of students' understanding of a subject concept influences the quality and complexity of the arguments they construct (Dawson & Venville, 2013).

Limitations of the study include the fact that the learning was only conducted within the ecosystem topic. The implementation of the learning was carried out for three sessions, with each session lasting only 70 minutes due to the ongoing COVID-19 pandemic and the restrictions it imposed. Therefore, the time for implementing each PjBL syntax was reduced. Future researchers are encouraged to conduct studies with a longer time allocation, covering different topics within biology education, in order to optimize students' argumentation skills.

Conclusion

Application of the concept map instructional technique at the planning investigation stage in PjBL has an effect on students' argumentation skills as evidenced by the results of the t test. The percentage of score obtained for the argumentation skills component is generally higher in the experimental class compared to the control class because the application of CM instructional techniques at the planning stage places more emphasis on planning that focuses on lesson concepts so that students are better to understand concepts very well and find evidence to develop arguments.

References

Acar, O., & Patton, B. R. (2012). Argumentation and Formal Reasoning Skillsin an Argumentation-Based Guided Inquiry Course. *Procedia - Social and Behavioral Sciences*, *46*, 4756–4760. https://doi.org/10.1016/j.sbspro.2012.06.331

Antonio, R. P., & Prudente, M. S. (2021). Metacognitive Argument-Driven Inquiry in Teaching Antimicrobial Resistance: Effects on Students' Conceptual Understanding and Argumentation Skills. *Journal of Turkish Science Education*, *18*(2), 192–217. https://doi.org/10.36681/tused.2021.60

Arya Widatama, D., Widoretno, S., Dwiastuti, S., Sajidan, & Maridi. (2019). Instructional technique questions in the planning phase of project based learning to increase the score of concept map. *Journal of Physics: Conference Series*, *1241*(1). https://doi.org/10.1088/1742-6596/1241/1/012047

Buchanan Hill, J. (2016). Questioning Techniques: A Study of Instructional Practice. *Peabody Journal of Education*, *91*(5), 660–671. https://doi.org/10.1080/0161956X.2016.1227190

Chen, C. H., Chou, Y. Y., & Huang, C. Y. (2016). An Augmented-Reality-Based Concept Map to Support Mobile Learning for Science. *Asia-Pacific Education Researcher*, *25*(4), 567–578. https://doi.org/10.1007/s40299-016-0284-3

Chen, Y. C., Benus, M. J., & Hernandez, J. (2019). Managing uncertainty in scientific argumentation. *Science Education*, *103*(5), 1235–1276. https://doi.org/10.1002/sce.21527

Dawson, V., & Venville, G. (2013). Introducing High School Biology Students to Argumentation About Socioscientific Issues. *Canadian Journal of Science, Mathematics and Technology Education*, *13*(4), 356–372. https://doi.org/10.1080/14926156.2013.845322

Du, X., & Han, J. (2016). A Literature Review on the Definition and Process of Project-Based Learning and Other Relative Studies. *Creative Education*, *07*(07), 1079–1083. https://doi.org/10.4236/ce.2016.77112

Erduran, S. (2018). Toulmin's argument pattern as a "horizon of possibilities" in the study of argumentation in science education. *Cultural Studies of Science Education*, *13*(4), 1091–1099. https://doi.org/10.1007/s11422-017-9847-8

Erduran, S., Ozdem, Y., & Park, J. Y. (2015). Research trends on argumentation in science education: a journal content analysis from 1998–2014. *International Journal of STEM Education*, *2*(1), 1–12. https://doi.org/10.1186/s40594-015-0020-1

Gabriel, V. de O., Panisson, A. R., Bordini, R. H., Adamatti, D. F., & Billa, C. Z. (2020). Reasoning in BDI agents using Toulmin's argumentation model. *Theoretical Computer Science*, *805*, 76–91. https://doi.org/10.1016/j.tcs.2019.10.026

Halil TURGUT. (2008). Prospective Science Teachers ' Conceptualizations About Project Based. *International Journal of Instruction*, *1*(1), 62–79.

Haruna, A., & Nahadi. (2021). Menjelajahi Hubungan Level Argumentasi Dengan Kemampuan Berfikir Kritis Siswa Dalam Menyelesaikan Soal Ikatan Kimia. *Jurnal Inovasi Pendidikan Kimia*, *15*(1), 2686–2694.

Hefter, M. H., Berthold, K., Renkl, A., Riess, W., Schmid, S., & Fries, S. (2014). Effects of a training intervention to foster argumentation skills while processing conflicting scientific positions. *Instructional Science*, *42*(6), 929–947. https://doi.org/10.1007/s11251-014-9320-y

Heng, L. L., Surif, J., & Seng, C. H. (2015). Malaysian Students' Scientific Argumentation: Do groups perform better than individuals? *International Journal of Science Education*, *37*(3), 505–528. https://doi.org/10.1080/09500693.2014.995147

Ho, H. Y., Chang, T. L., Lee, T. N., Chou, C. C., Hsiao, S. H., Chen, Y. H., & Lu, Y. L. (2019). Above- and below-average students think differently: Their scientific argumentation patterns. *Thinking Skills and Creativity*, *34*, 100607. https://doi.org/10.1016/j.tsc.2019.100607

Hsu, P. S., Van Dyke, M., Chen, Y., & Smith, T. J. (2015). The effect of a graph-oriented computer-assisted project-based learning environment on argumentation skills. *Journal of Computer Assisted Learning*, *31*(1), 32–58. https://doi.org/10.1111/jcal.12080

Ishaq, I. M., Khaeruddin, K., & Usman, U. (2022). Analisis Kemampuan Berargumentasi Dalam Pembelajaran Fisika Peserta Didik Sma Negeri 8 Makassar. *Jurnal Sains Dan Pendidikan Fisika*, *17*(3), 211. https://doi.org/10.35580/jspf.v17i3.29781

Juuti, K., Lavonen, J., Salonen, V., Salmela-Aro, K., Schneider, B., & Krajcik, J. (2021). A Teacher–Researcher Partnership for Professional Learning: Co-Designing Project-Based Learning Units to Increase Student Engagement in Science Classes. *Journal of Science Teacher Education*, *32*(6), 625–641. https://doi.org/10.1080/1046560X.2021.1872207

Machado, C. T., & Carvalho, A. A. (2020). Concept Mapping: Benefits and Challenges in Higher Education. *Journal of Continuing Higher Education*, *68*(1), 38–53. https://doi.org/10.1080/07377363.2020.1712579

María, A., Apodaca, J., Mcinerney, J. D., Sala, O. E., Katinas, L., & Crisci, J. V. (2019). *A Concept Map of Evolutionary Biology to Promote Meaningful Learning in Biology FEATURE ARTICLE A Concept Map of Evolutionary Biology to Promote Meaningful Learning in Biology We propose a way to visualize main ideas about evolution in the context of the* . *81*(May), 79–87.

Memiş, E. K. (2021). An evaluation of academic achievements through the use of argument and concept maps embedded in argumentation based inquiry. *Asia Pacific Education Review*, *22*(3), 463–481. https://doi.org/10.1007/s12564-021-09679-9

Noviyanti, N. I., Mahanal, S., Mukti, W. R., Yuliskurniawati, I. D., Zubaidah, S., & Setiawan, D. (2021). Narrowing the gaps of scientific argumentation skills between the high and low academic achievers. *AIP Conference Proceedings*, *2330*(March). https://doi.org/10.1063/5.0043308

Osborne, J. F., Henderson, J. B., MacPherson, A., Szu, E., Wild, A., & Yao, S. Y. (2016). The development and validation of a learning progression for argumentation in science. *Journal of Research in Science Teaching*, *53*(6), 821–846. https://doi.org/10.1002/tea.21316

Pangestika, I. W., Ramli, M., & Nurmiyati, N. (2017). The changing of oral argumentation process of grade XI students through Socratic dialogue. *International Journal of Science and Applied Science: Conference Series*, *2*(1), 198. https://doi.org/10.20961/ijsascs.v2i1.

16710

Probosari, R. M., Sajidan, S., Suranto, S., & Prayitno, B. A. (2022). Integrating Reading As Evidence To Enhance Argumentation in Scientific Reading-Based Inquiry: a Design-Based Research in Biology Classroom. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 171–184. https://doi.org/10.15294/jpii.v11i1.29350

Reiska, P., Soika, K., & Cañas, A. J. (2018). Using concept mapping to measure changes in interdisciplinary learning during high school. *Knowledge Management and E-Learning*, *10*(1), 1–24. https://doi.org/10.34105/j.kmel.2018.10.001

Shanmugavelu, G., Ariffin, K., Vadivelu, M., Mahayudin, Z., & R K Sundaram, M. A. (2020). Questioning Techniques and Teachers' Role in the Classroom. *Shanlax International Journal of Education*, *8*(4), 45–49. https://doi.org/10.34293/education.v8i4.3260

Sottilare, R., Defalco, J., & Connor, J. (2014). *A Guide to Instructional Techniques, Strategies and Tactics to Manage Learner Affect, Engagement, and Grit Standards for Adaptive Tutoring Systems View project Using GIFT and MOOCs to support adaptive training experiences View project*. *July*, 7–33. https://www.researchgate.net/publication/267039871

Su, K. D. (2020). An argumentation-based study with concept mapping approach in identifying students' scientific performance skills. *Interdisciplinary Journal of Environmental and Science Education*, *16*(4).

Surahman, E., Kuswandi, D., & Wedi, A. (2019). Students' Perception of Project-Based Learning Model in Blended Learning Mode Using Sipejar. *… Conference on Education …*, *372*(ICoET), 183–188. https://www.atlantis-press.com/proceedings/icoet-19/125925078

TAMA, N. B., PROBOSARI, R. M., WIDORETNO, S., & INDRIYATI, I. (2016). Project Based Learning to Improve Written Argumentation Skill of Tenth Graders. *Bioedukasi: Jurnal Pendidikan Biologi*, *9*(2), 67. https://doi.org/10.20961/bioedukasi-uns.v9i2.4224

Trouche, E., Sander, E., & Mercier, H. (2014). Arguments, more than confidence, explain the good performance of reasoning groups. *Journal of Experimental Psychology: General*, *143*(5), 1958–1971. https://doi.org/10.1037/a0037099

Tsai, C. Y. (2018). The effect of online argumentation of socio-scientific issues on students' scientific competencies and sustainability attitudes. *Computers and Education*, *116*, 14–27. https://doi.org/10.1016/j.compedu.2017.08.009

von der Mühlen, S., Richter, T., Schmid, S., & Berthold, K. (2019). How to improve argumentation comprehension in university students: experimental test of a training approach. *Instructional Science*, *47*(2), 215–237. https://doi.org/10.1007/s11251-018-9471-3

Woldeamanuel, Y. W., Abate, N. T., & Berhane, D. E. (2020). Effectiveness of Concept Mapping Based Teaching Methodson Grade Eight Students' Conceptual Understanding of Photo synthesisat Ewket Fana Primary School, BahirDar, Ethiopia. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(12), 1–16. https://doi.org/10.29333/ejmste/9276

Zahra, F., Zubaidah, S., Mahanal, S., & Astriani, M. (2021). The improvement of students' argumentation skills through Remap-NHT learning model. *AIP Conference Proceedings*, *2330*(March). https://doi.org/10.1063/5.0043291