JPPIPA 9(8) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Concept Map Instructional Techniques in the Deciding Stage - Project Based Learning on Students' Argumentation Skills

Rakhmatdi[1], Sri Widoretno[1*], Joko Ariyanto[1], Bowo Sugiharto[1], Sri Dwiastuti[1], Chandra Adi Prabowo[1]

[1] Department of Biology Education, Sebelas Maret University, Indonesia

Received: February 11, 2023
Revised: July 8, 2023
Accepted: August 25, 2023
Published: August 31, 2023

Corresponding Author:
Sri Widoretno
sriwidoretno@staff.uns.ac.id

DOI: 10.29303/jppipa.v9i8.3157

Abstract: Argumentation is an assessment that identifies HOTs through collaborative learning activities. Learning that supports collaboration through project design is found in project-based learning at the deciding stage. Decisions in planning investigations tend to be less than optimal and the presentation of data at the deciding stage is incomplete so that it is optimized using the instructional concept map technique. The use of concept maps as an instructional technique guides students to find and relate concepts logically so as to stimulate argumentation skills because it explores critical thinking skills through activities of organizing, categorizing, analyzing, and reasoning. The research aims to analyze differences in students' argumentation skills from the use of concept map instructional techniques at the deciding stage – project-based learning. The research design was quasi-experimental. Determination of the sample using cluster random sampling of 70 students who are determined based on the paired F test. The research instrument consisted of an expert concept map and a matter of argumentation. Data on students' argumentation skills were obtained from an assessment that was arranged according to the argumentation component according to Toulmin (2003) is evidence, warrants, backing, qualifier, rebuttal, and claim a total of 11 questions. The data analysis technique used the t-test. The results of the hypothesis test show that the significance value is 0.001 (<0.05), so there are differences in students' argumentation skills from the use of the instructional concept map technique in the deciding – project-based learning stage. The argumentation skills of the students in the experimental class were better than the control class in argumentation components is evidence, rebuttal, and claim. The concept map instructional technique has aspects that can improve students' argumentation skill scores because it helps students focus on finding and connecting concepts based on evidence and data as a result of investigations.

Keywords: Argumentation skill; Concept map; Deciding stage, Instructional techniques; Project based learning.

Introduction

Argumentation according to Erduran et al. (2018), is a process of gathering the various components needed to build an opinion. The components of argumentation according to (Toulmin, 2003) are claims, evidence, warrants, backing, qualifiers, and rebuttals. A claim is a statement or conclusion about the existing situation. Evidence is evidence used to support a claim. Warrant means giving reasons related to describing the protocol in the form of rules and principles related to data and claims. Backing, means answering all questions based on theory or basic assumptions that support warrants. A qualifier is a statement made based on specific information that claims stated are accurate. Rebuttal, means being able to refute opinions that are considered incorrect (Handayani & Sardianto, 2015).

Erduran et al. (2018), state that the argument initiated by Toulmin is very important because it serves as a reference for honing knowledge skills including analyzing, evaluating, and creating which fall into the category of high-order thinking skills. The argument identifies higher-order thinking skills (HOTs) because it reflects the results of one's reasoning (Deane & Song, 2015). The reasoning is a hypothesis that connects several concepts, re-examines written evidence

How to Cite:
Rakhmatdi, R., Widoretno, S., Ariyanto, J., Sugiharto, B., Dwiastuti, S., & Prabowo, C. A. (2023). Concept Map Instructional Techniques in the Deciding Stage - Project Based Learning on Students' Argumentation Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 6359–6367. https://doi.org/10.29303/jppipa.v9i8.3157

(Permana et al., 2020), and draws valid conclusions through analysis of the data obtained (Amiroh & Admoko, 2020).

The data obtained to build arguments in the form of a statement or claim requires collaboration (Si et al., 2018). Collaboration is participation in every activity and group work that is useful for achieving the goals that have been set (Nouwens et al., 2007). Collaboration is needed to decide on data collection and analysis procedures (Saenab et al., 2017). Data collection and analysis are facilitated by investigative activities in learning (Handayani & Ayub, 2021).

Learning that supports investigation through project design to produce products is found in project-based learning at the deciding stage (Turgut, 2008). Deciding is a stage that facilitates the preparation of an investigation plan and decides on a working group to collect data through investigative activities (Turgut, 2008).

Investigative activities need to be directed because according to (Thomas, 2000), planning in the deciding stage - project based learning tends to be less than optimal. Hardiana et al. (2019) also stated that the presentation of data at the deciding stage – project-based learning was incomplete. Weaknesses in the deciding stage – project-based learning can be maximized by asking questions as an instructional technique (York & Ertmer, 2016). Dack et al. (2016) stated that asking questions at the deciding stage – project-based learning can build on students' knowledge gained during data collection and focus on topics that need to be investigated and analyzed. Questions as an instructional technique (Kalelioğlu & Gülbahar, 2013) function to improve communication in the learning process (Pandey, 2017) and assist students in compiling rational answers (Widoretno et al., 2023). The answers are constructed in a concept map so that the instructional technique used is the concept map instructional technique (Novak & Cañas, 2008).

Widoretno et al. (2023), states that the expanded teacher's questions in the deciding study group, the way of collecting data, and the data analysis significantly contributed to the improvement in the quality of students' thinking. Hardiana et al. (2019), explain that the instructional technique of the questions in the deciding the study group the way of collecting data and data analysis stage on project-based learning increased the students' concept map score of students. The concept map used by Hardiana et al. (2019) is an assessment and has not been used as an instructional technique, so further research is needed.

Another study conducted by Puspitasari et al. (2022) explained that student argument scores in a Senior High School in each argumentation component were still relatively low. Some of the factors that cause low student argumentation to include the learning process that occurs being less meaningful, students' understanding and reasoning of the material being less in-depth, and the process of generalizing evidence or theories that are not appropriate. The drawback of this research is the level of supervision that researchers lack because it is done online. So, it is necessary to do other research that does project-based learning with instructional map technique in the deciding stage.

The instructional concept map technique in the deciding stage – project based learning is needed to: 1) Direct students in collecting and analyzing data so that the conclusions made are in accordance with the results of observations that have been verified by evidence and theory (Hardiana et al., 2019); 2) Facilitate students' focus on the concepts learned in order to present complete and correct data (Yin et al., 2005); 3) Guiding students to find and connect concepts logically (Puspita et al., 2014).

The ability to connect logical concepts can stimulate argumentation skills because it explores critical thinking skills through activities of organizing, categorizing, analyzing, and reasoning (Su, 2020). Aydeniz & Kaya (2012), stated that the better the argumentation skills, the better the understanding of a concept. An understanding of a concept is the key to building a quality argument (Deane & Song, 2015).

Based on the benefits of the concept map instructional technique in the deciding stage which serves to simulate argumentation skills, the title of the research is "Concept Map Instructional Techniques in the Deciding Stage - Project Based Learning on Students' Argumentation Skills". The research aims to analyze differences in students' argumentation skills from the use of concept map instructional techniques in the deciding stage – project-based learning.

Method

The type of research used is a quasi-experimental design with a posttest-only non-equivalent control group design. Implementation in the control class uses project-based learning. Learning activities in the experimental class use concept map learning techniques at the stage of deciding on the study group to collect and analyze data in project-based learning.

The argumentation skill data was obtained from the assessment in the form of true-false questions equipped with 11 reasons. Data analysis used quantitative descriptive analysis and independent t-test, calculations using the help of Microsoft Excel version 2021 and SPSS version 26 with a significance level of 0.05.

The research population was 142 class X SHS students. The sample was determined using clustered

random sampling based on the paired F test for end-of-semester assessment (PAS) with the criteria for the significance value between classes > 0.05. The sample set as the control and experimental classes is the class that has a significance value of 0.95 (F_{count} 0.95 > F_{table} = 0.05) which means that both classes have the same cognitive ability. The number of samples used is 70 participants.

The research instruments are lesson plans, syntax implementation, expert concept maps, and assessment of argumentation skills based on the material of ecosystem components and the interactions between their components. The concept maps instructional technique applied at the deciding stage was followed by questions compiled based on the answers in the expert concept maps by Novak (2010). Assessment of argumentation skills in the form of causal questions accompanied by 11 reasons which are arranged based on the argumentation component by Toulmin (2003). Details of the indicators for argumentation are presented in Table 1.

Assessment to measure argumentation skills is calculated based on the rubric of argumentation assessment based on Acar & Patton (2012). Details of the argumentation assessment indicators are presented in Table 2.

Validation of argumentation questions using the Rasch model includes validity and reliability tests. The construct validity of the argumentation questions is classified as good with raw explained by measure 57.5% for empirical values (> 20%), so it is said that the construct validity of the instrument is classified as good (Sumintono & Widhiarso, 2015). The validity of the content per question item was analyzed based on the following assessments: The validity of the content per question item was analyzed based on the following assessments: 1) The value of the outfit Mean Square (MNSQ) received: 0.5 < MNSQ < 1.5; 2) Value of outfit Z-Standard (ZSTD) received: -2.0 < ZSTD < +2.0; 3) Point Measure Correlation (Pt Mean Corr): 0.40 < Pt Measure Corr < 0.85 (Boone et al., 2014). The test results show that the 11 questions used in the study are categorized as valid because all questions meet at least one criterion from MNSQ, ZSTD, and Pt Mean Corr, meaning that the questions can measure what should be measured (Ng et al., 2018).

The next test is the reliability test using the Rasch test to see the feasibility of the argumentation questions. Based on the results of the reliability test, the value of the person measure is 1.79 logit (>0), so the correct answers are more than the incorrect answers. The value of item reliability is 0.92 which has good criteria so that the questions are suitable for use in research (Ng et al., 2018).

Table 1. Argumentation Questions Indicator

Question Number	Argument Component	Theory	Indicator
1.	Evidence	Definition of ecosystem	Explain the meaning of ecosystem
2.	Warrants 1	Definition of community	Explain the meaning of community
3.	Warrants 2	Biogeochemical cycle	Name all the chemical elements that undergo the biogeochemical cycled
4.	Backing 1	Interaction	Analyzing the types of interactions in the community
5.	Backing 2	Food chain	Analyzing the composition of the food chain in the ecosystem
6.	Qualifier 1	Ecological pyramid	Analyzing the types of ecological pyramid
7.	Qualifier 2	Biogeochemical cycle	Analyzing the process of changing the shape of phosphorus in the phosphorus cycle
8.	Qualifier 3	Biogeochemical cycle	Analyzing the process of changing the shape of water in the hydrological cycle
9.	Rebuttal	Biogeochemical cycle	Analyze examples of carbon compounds that undergo the carbon cycle
10.	Claim 1	Biogeochemical cycle	Describe the stages of the nitrogen cycle
1 1.	Claim 2	Biogeochemical cycle	Analyzing the sulfur cycle in the ecosystem

Table 2. Argumentation Scoring Indicators

Score	Answer	Description
0.5	Wrong	Wrong answer based on the answer key and wrong reason
1	Correct	The correct answer is based on the answer key but the reason is not clear and does not fit
1.5	Correct	The correct answer is based on the answer key, the reason is clear, but it doesn't fit
2	Correct	The correct answer is based on the answer key, the reasons are clear and appropriate
2.5	Correct	The correct answer is based on the answer key, the reasons are clear, appropriate, and based on observations
3	Correct	The correct answer is based on the answer key, the reasons are clear, appropriate and based on proven observations

Result and Discussion

Result

Based on the conducted research, hereby the following result:

Argumentation Skill Score

Scores of students' argumentation skills were obtained from the posttest in the form of true or false questions with a total of 11 reasons. The results of student answers were confirmed using the theory of Acar & Patton (2012) which can be seen in Figure 1.

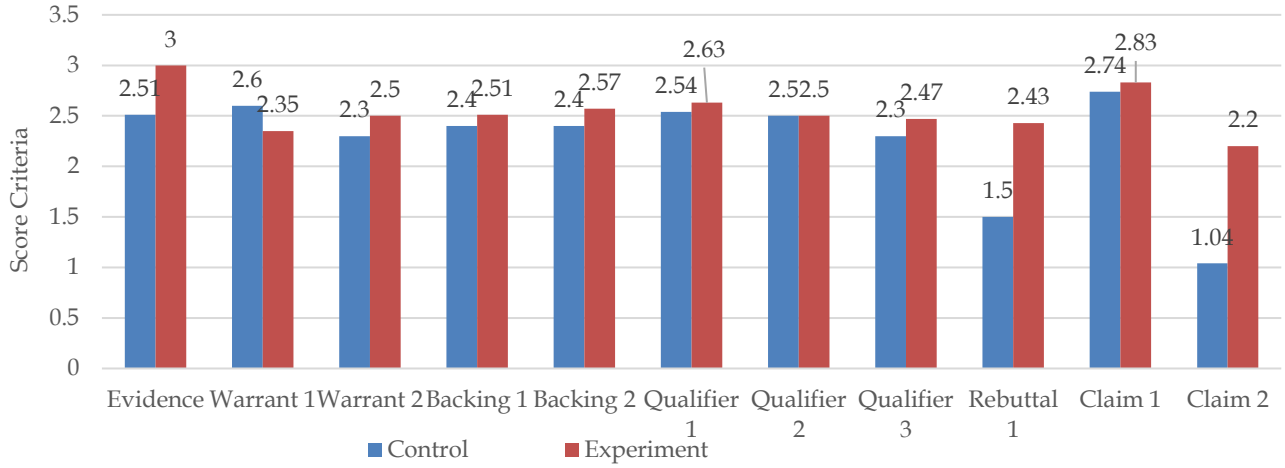

Figure 1. Student Argumentation Skills Score

Based on Figure 1, scores of students' argumentation skills on the components of evidence, warrant 2, backing 1, backing 2, qualifier 1, qualifier 3, rebuttal, claim 1, and claim 2 in the experimental class are superior to the control class. The score of argumentation skills on warrant 1 and qualifier 2 components in the control class is better than the experimental class.

Percentage of Earned Score of Argumentation Skills in Each Component

Table 3. Percentage (%) of Students on Each in Each Argumentation Componen

Question Number	Argumentation Component	3		2.5		2		1.5		1		Score 0.5	
1.	Evidence	50	100	14.71	0	17.65	0	5.88	0	8.82	0	2.94	0
2.	Warrant 1	50	61.11	20.59	5.56	26.47	13.89	2.94	0	0	0	0	19.44
3.	Warrant 2	44.12	61.11	11.76	5.56	29.41	19.44	0	2.78	5.88	2.78	8.82	8.33
4.	Backing 1	38.24	52.78	26.47	8.33	29.41	33.33	2.94	0	2.94	5.56	0	0
5.	Backing 2	38.24	50	20.59	13.89	26.47	36.11	8.82	0	5.88	0	0	0
6.	Qualifier 1	29.41	61.11	55.88	2.78	11.76	36.11	0	0	2.94	0	0	0
7.	Qualifier 2	61.76	33.33	11.76	2.78	26.47	41.67	0	2.78	0	16.67	0	0
8.	Qualifier 3	2.94	55.56	64.71	5.56	25.53	33.33	0	0	8.82	0	0	5.56
9.	Rebuttal	0	11.11	0	75	8.82	11.11	73.53	0	17.65	0	0	2.78
10.	Claim 1	73.53	83.33	5.88	0	17.65	16.67	0	0	2.94	0	0	0
11.	Claim 2	17.65	61.11	0	2.78	2.94	8.33	2.94	0	5.88	0	70.59	27.78

Hypothesis Test Results

Test the hypothesis using SPSS 26 through an independent sample T-test to prove differences in argumentation skills scores between the control class and the experimental class. The basis for decision making on the T-test is that if the value of Sig. < 0.05, there is a significant difference in the scores of argumentation skills between the control class and the experimental class, so that the role of the instructional concept map technique at the stage of deciding the study group the way of collecting data and data analysis - project based learning is known on students' argumentation skills. The results of the argumentation skill hypothesis test are presented in Table 4.

Table 4. Differences in Argumentation Skill Scores

Differences	Control	Experiment	Description	Decision
Total Minimum Score	65.15	68.18	Control < Experiment	Experiment is higher
Total Maximum Score	87.88	98.48	Control < Experiment	Experiment is higher
Average Total Score	75.53	84.81	Control < Experiment	Experiment is higher
Normality test	0.098	0.200	> 0.05	Normal distribution
Homogeneity test		0.179	> 0.05	Homogeneous data
T-Test		0.001	< 0.05	Significantly different

The results of the hypothesis test showed that the argumentation skills were significantly different between the control and experimental classes because the significance value was less than 0.05. Based on Table 12, the use of the concept map instructional technique at the deciding stage had aspects that were able to increase students' argumentation skill scores.

Discussion

Analysis of the Argumentation Skills Score

Based on Figure 1, there are three clusters of differences in students' argumentation skill scores, namely: 1) The first cluster, shows a real difference in argumentation skill scores in the experimental class compared to the control class with a difference in scores of 0.5 to 1.5 with the result of argumentation skill scores in a class experiment is higher than the control class; 2) The second cluster, showing a less significant difference in argumentation skill scores in the experimental class compared to the control class with a score difference of less than 0.5 with the results of the argumentation skills score in the experimental class being higher than the control class; 3) The third cluster, shows the scores of students' argumentation skills in the experimental class are lower than the control class.

The argumentation components contained in the first cluster were: evidence, rebuttal, and claim 2. The instructional concept map technique at the deciding stage was able to increase the score of argumentation skills in the component evidence because the questions on the instructional concept map technique helped students make observations around them about ecosystem components and types of interactions between components. The instructional concept map technique at the deciding stage facilitates students in compiling claims according to the evidence collected and the data analyzed by the topic being studied (Ural & Gençoğlan, 2019).

Based on Figure 1, the claims made by students in the experimental class are better than those in the control class. The concept map instructional technique that is specifically applied at the deciding stage emphasizes students to focus on finding or identifying evidence and connecting concepts with the data found to make claims (Si et al., 2018).

Claims that are prepared to be correct require students' reasoning and understanding (Gràcia et al., 2021), including students' skills in giving rebuttals (Watson et al., 2020). The argumentation skill scores in the Component rebuttal increased in the experimental class because students were able to make objections or justifications based on the evidence collected and the data analyzed in the deciding stage (Hasnunidah et al., 2019).

The argument components in the second cluster are: warrant 2, backing 1, backing 2, qualifier 1, and qualifier 3. Warrants are justifications that explain the relationship between evidence and claims (Anita et al., 2021). The concept map instructional technique at the deciding stage does not facilitate students to obtain warrants, because the questions do not focus on events. The teacher's questions are carried out at the deciding stage as the core of thinking require student answers in data acquisition activities that are less effective, because data is different from events (Saenab et al., 2017). Warrant as a reason connecting evidence with claims requires a reference called backing (Si et al., 2018).

Backing as a theoretical basis is a component that supports warrants (Rahman, 2018), if warrants are not optimal, then the score of argumentation skills on Component backing experiences an unclear increase (Saracaloglu et al., 2011). The backing is the basic assumption that provides justification for warrants (Erduran et al., 2018) and requires specific information in stating claims which are called qualifiers (Rahman, 2018).

Qualifiers are prerequisites or limits for claims (Stede, 2020). Qualifiers function to strengthen claims that have been built through warrants and backing (Toulmin, 2003) if warrants and backing are not optimal, then the score of argumentation skills for the Component qualifier experiences an unclear increase (Amiroh & Admoko, 2020). The relationship between argumentation components: warrants, backing, qualifiers, and claims determine the score of argumentation skills (Saracaloglu et al., 2011), that is, the control class is higher than the experimental class in the third cluster.

The argumentation components contained in the third cluster are warrants 1 and qualifier 2. The argumentation skill scores that contain the component

warrants and qualifiers tend to be the same because they are included in the second and third clusters. The instructional concept map technique at the deciding stage should be followed by questions that are more focused on stimulating the collection and analysis of data rather than events (Sasson et al., 2018), but in fact, the questions used do not facilitate students in obtaining warrants. The argumentation skill score on the component warrant which is less than optimal affects the qualifier because the qualifier functions to strengthen claims that have been built through warrants (Gultepe & Kilic, 2015).

Analysis of the Percentage of Scores of Argumentation Skills in Each Component

Based on Table 3, question number 1 is a matter of component argumentation in the form of evidence which asks students to explain the meaning of ecosystems. Students are expected to be able to provide evidence that ecosystems are systems that exist in ecology because they are composed of many systems including communities and biogeochemical cycles. The percentage of students who got a score of 3 in the experimental class was more than in the control class because the instructional concept map technique at the deciding stage could stimulate students in carrying out investigations to collect evidence in the form of data related to the material of ecosystem components and the types of interactions between their components in the surrounding environment (Ural & Gençoğlan, 2019).

Question number 2 is warrant 1 which asks students to provide justification that the community is a reciprocal relationship between ecosystem components because it is composed of interactions, food chains, and ecological pyramids. Question number 3 is warrant 2 which asks students to give reasons why not all chemical elements can undergo biogeochemical cycles. The scores of argumentation skills in component warrant 1 and warrant 2 in the control and experimental classes tend to be the same, students in the experimental class get a score of 3 more than the control class but students in the control class get a score of 0.5 less than the experimental class. The score of argumentation skills in component warrant 1 in the control class was better, while the experimental class was superior in component warrant 2. This means that the instructional concept map technique at the deciding stage has not optimized students' focus in stimulating data collection and analysis (Sasson et al., 2018). Questions do not help students to obtain warrants (Gultepe & Kilic, 2015).

Question number 4 is backing 1 which asks students to justify warrants that interactions between all ecosystem components are neutral, beneficial, and detrimental. Question number 5 is backing 2 which asks students to analyze the constituents of food chains in ecosystems. Students in the experimental class scored 3 more on number questions 4 (backing 1) and 5 (backing 2) than the control class but the average score in the experimental class did not experience a clear increase compared to the control class. The backing is the theoretical basis that supports warrants, if warrants are not optimal, the increase in argumentation skill scores that contain backing is less clear (Rahman, 2018).

Question number 6 is qualifier 1 which asks students to strengthen claims that have been built through warrants and backing about an ecological pyramid which is a sequential arrangement of trophic levels both nutrient levels and energy levels in an ecosystem. Question number 7 contains qualifier 2 which asks students to analyze the process of changing the form of phosphorus in the phosphorus cycle. Question number 8 contains qualifier 3 which asks students to analyze the process of changing the form of water in the hydrological cycle. The percentage of students who answered correctly on question number 6 (qualifier 1) and 8 (qualifier 3) in the experimental class was more than the control class, while the percentage of students who answered correctly in Question number 7 (qualifier 2) of students in the control class was more than the control class experiment.

The instructional concept map technique in the deciding stage should be followed by questions that are more focused on helping students in the investigative process during collection and analysis (Sasson et al., 2018), but in fact, the questions used do not help students in increasing warrant scores. Obtaining warrants that are less than optimal affects the score of argumentation skills in the component qualifier because the qualifier functions to strengthen claims that have been built through warrants (Gultepe & Kilic, 2015).

Question number 9 (rebuttal) asks students to provide rebuttals regarding carbon compounds that experience the carbon cycle. The percentage of students who answered correctly on question number 9 (rebuttal) in the experimental class was higher than in the control class. The score of argumentation skills in component rebuttal increased in the experimental class because students were able to make objections or justifications based on the evidence collected and the data analyzed in the deciding stage during the data collection and analysis process (Hasnunidah et al., 2019).

Question number 10 (claim 1) asks students to describe the stages of the nitrogen cycle. Question number 11 asks students to analyze the sulfur cycle in ecosystems. The percentage of students who answered correctly in the experimental class was higher than in the control class on number questions 10 and 11. The concept map instructional technique at the deciding stage helps students to construct claims that are tailored to the evidence during data collection and analysis (Ural

& Gençoğlan, 2019). The concept map instructional technique that is specifically applied at the deciding stage emphasizes students to focus on identifying evidence and connecting concepts with the data found to make claims (Si et al., 2018).

Difference in Argumentation Skills Scores

Based on Table 4, there are differences in students' argumentation skills between the experimental class and the control class. The instructional concept map technique applied at the deciding stage in the experimental class had aspects that were able to significantly increase the score of argumentation skills seen from the difference in scores between classes. The deciding stage - project based learning accommodates students conducting investigations, discussing various topics in group forums, seeking knowledge from various sources through practicum or observation, making decisions, and analyzing data (Setiono et al., 2021). Data collection and analysis activities support students to draw conclusions based on the results of their reasoning Almulla (2020), so that students can communicate the results of their reasoning in the form of arguments (MacLeod & van der Veen, 2020). Deciding stage – project-based learning is the stage that facilitates students to carry out investigations based on project designs. The project was completed using observation to collect data (Turgut, 2008).

Observation results serve as a basis for compiling claims that are considered with evidence, warrants, backing, qualifiers, and rebuttals. The investigations facilitated at the deciding stage - project based learning according to Sumarni & Kadarwati (2020) help students analyze data based on evidence and data obtained by students during the learning process. Activities at the deciding stage according to Turgut (2008) emphasize the collection and analysis of data that can build understanding and stimulate the ability to connect concepts logically (Sasson et al., 2018).

The ability to connect logical concepts is optimized by adding an instructional concept map technique at the deciding stage. The function of adding the concept map instructional technique is to guide students to explore critical thinking skills through activities of organizing, categorizing, analyzing, and reasoning to be able to stimulate argumentation skills (Su, 2020). Aydeniz & Kaya (2012) stated that the better the argumentation skills, the better the understanding of a concept.

Conclusion

The results of the hypothesis test show that the significance value is 0.001 (<0.05), so there are differences in students' argumentation skills from the use of the instructional concept map technique in the deciding stage – project-based learning. Concept map instructional technique in the deciding - project based learning stage had the potential to improve students' argumentation skills, because it helped students focus on finding and connecting concepts based on evidence and data as a result of investigations. The theoretical implication of the research is to increase knowledge related to the use of argumentation skills with the help of concept map instructional techniques at the stage of deciding on a project-based learning model on ecosystem materials. Practically, we can add skills using concept maps in deciding stage which project-based learning model to use for future research references.

Acknowledgments

Research can be done because of the grant funds from LPPM UNS in 2022/2023, thanks to LPPM UNS, supervisors, biology teachers, high school students as respondents, and other parties related to research and cannot be mentioned one by one so that research can run smoothly.

Author Contribution

Rakhmatdi: main author, original draft preparation, results, analysis, discussion, methodology, conclusions; Sri Widoretno: main author, analysis, review, proofreading, project owner and corresponding author; Joko Ariyanto: main author, analysis, review, and editing; Bowo Sugiharto, Sri Dwiastuti, Chandra Adi Prabowo: coauthor, research members. All authors have read and agreed to the published version of the manuscript.

Funding

LPPM UNS through UNS 2022 PNBP grant financing with number contract 254/UN27.22/PT.01.03/2022 entitled "Efektivitas Concept Map dalam Membangun Kemampuan Argumentasi melalui Materi Biologi SMA"

Conflicts of Interest

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

References

Acar, O., & Patton, B. R. (2012). Argumentation and Formal Reasoning Skillsin an Argumentation-Based Guided Inquiry Course. *Procedia - Social and Behavioral Sciences*, *6*, 4756–4760. https://doi.org/10.1016/j.sbspro.2012.0.

Almulla, M. A. (2020). The Effectiveness of the Project-Based Learning (PBL) Approach as a Way to Engage Students in Learning. *SAGE Open*, *10*(3), 1–15. https://doi.org/10.1177/2158244020938702

Amiroh, F., & Admoko, S. (2020). Tinjauan Terhadap Model- Model Pembelajaran Argumentasi Berbasis TAP Dalam Meningkatkan Keterampilan Argumentasi dan Pemahaman Konsep Fisika Dengan Metode Library Research. *Inovasi*

Pendidikan Fisika, *9*(2), 207–214. Retrieved from https://ejournal.unesa.ac.id/index.php/inovasi-pendidikan-fisika/article/view/34545

Anita, Afandi, Tenriawaru, A. B., & Putra, D. A. (2021). Profile of Argumentation Skills using Toulmin's Argumentation Pattern (TAP) in Senior High School Students in Biology Learning: Preliminary Research. *Journal of Physics: Conference Series*, *1842*(1). https://doi.org/10.1088/1742-6596/1842/1/012065

Aydeniz, M., & Kaya, E. (2012). Argumentation and Students' Conceptual Understanding of Properties and Behaviors of Gases. *International Journal of Science and Mathematics Education*, *10*(6), 1303–1324. https://doi.org/10.1007/s10763-012-9336-1

Dack, H., van Hover, S., & Hicks, D. (2016). "Try Not to Giggle if You Can Help It": The implementation of experiential instructional techniques in social studies classrooms. *The Journal of Social Studies Research*, *40*(1), 39–52. https://doi.org/10.1016/j.jssr.2015.04.002

Deane, P., & Song, Y. (2015). The Key Practice, Discuss and Debate Ideas: Conceptual Framework, Literature Review, and Provisional Learning Progressions for Argumentation. *ETS Research Report Series*, *2015*(2), 1–21. https://doi.org/10.1002/ets2.12079

Erduran, S., Simon, S., & Osborne, J. (2018). 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

Gràcia, M., Vega, F., Jarque, S., Adam, A. L., & Jarque, M. J. (2021). Teaching practices for developing oral language skills in Catalan schools. *Cogent Education*, *8*(1), 1–20. https://doi.org/10.1080/2331186X.2021.1935647

Gultepe, N., & Kilic, Z. (2015). Effect of scientific argumentation on the development of scientific process skills in the context of teaching chemistry. *International Journal of Environmental and Science Education*, *10*(1), 111–132. https://doi.org/10.12973/ijese.2015.234a

Handayani, E. P., & Ayub, S. (2021). Optimalisasi Kompetensi Guru dalam Penerapan PjBL Berbasis STEM melalui IHT. *Jurnal Pendidikan, Sains, Geologi, Dan Geofisika (GeoScienceEd Journal)*, *2*(2), 47–54. https://doi.org/10.29303/goescienceedu.v2i2.148

Handayani, P., & Sardianto, M. (2015). Analisis Argumentasi Peserta Didik Kelas X Sma Muhammadiyah 1 Palembang Dengan Menggunakan Model Argumentasi Toulmin. *Jurnal Inovasi Dan Pembelajaran Fisika*, *69*(2), 34–37. Retrieved from https://ejournal.unsri.ac.id/index.php/jipf/article/view/2355

Hardiana, N., Widoretno, S., Dwiastuti, S., Sajidan, & Nurmiyati. (2019). Instructional technique question application in stage of deciding in project based learning to increase score concept map. *Journal of Physics: Conference Series*, *1241*(1). https://doi.org/10.1088/1742-6596/1241/1/012030

Hasnunidah, N., Susilo, H., Irawati, M., & Suwono, H. (2019). The contribution of argumentation and critical thinking skills on students' concept understanding in different learning models. *Journal of University Teaching and Learning Practice*, *17*(1). https://doi.org/10.53761/1.17.1.6

Kalelioğlu, F., & Gülbahar, Y. (2013). The effect of instructional techniques on critical thinking and critical thinking dispositions in online discussion. *Educational Technology and Society*, *17*(1), 248–258. Retrieved from https://www.jstor.org/stable/jeductechsoci.17.1.248

MacLeod, M., & van der Veen, J. T. (2020). Scaffolding interdisciplinary project-based learning: a case study. *European Journal of Engineering Education*, *45*(3), 363–377. https://doi.org/10.1080/03043797.2019.1646210

Ng, S. E., Yeo, K. J., & Mohd, Kosnin, A. B. (2018). Item Analysis for the Adapted Motivation Scale Using Rasch Model. *International Journal of Evaluation and Research in Education (IJERE)*, *7*(4), 264. Retrieved from https://eric.ed.gov/?id=EJ1198607

Nouwens, F., Mark, J., Keleher, P., & Clark, K. (2007). Evaluating use of an online concept mapping tool to support collaborative project based learning. *Proceedings of the 2007 AaeE Conference*, *January*, 1–8. Retrieved from https://conference.eng.unimelb.edu.au/aaee2007/papers/paper-90.pdf

Novak, J. D. (2010). *Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations*. New York, NY: Routledge.

Novak, J. D., & Cañas, a J. (2008). The Theory Underlying Concept Maps and How to Construct and Use Them. *IHMC CmapTools*, 1–36. https://doi.org/Technical Report IHMC CmapTo.

Pandey, R. (2017). Understanding and use of Non-verbal communication in classroom by teacher educator of secondary teacher training institutions of Ranchi, Jharkhand. *Research Journal of Social Sciences*, *8*(9).

Permana, N. N., Setiani, A., & Nurcahyono, N. A. (2020). Analysis of Students' Adaptive Reasoning Ability in Solving Higher Order Thinking Skills (Hots) Problems. *Jurnal Pengembangan Pembelajaran Matematika (JPPM SUKA)*, *2*(2), 51–60. https://doi.org/10.14421/jppm.2020.22.51-60

Puspita, L., Suciati, & Maridi. (2014). Pengaruh Model Problem Based Learning Dengan Metode Eksperimen Disertai Teknik Concept Map Dan Mind Map Terhadap Prestasi Belajar Biologi Ditinjau Dari Motivasi Belajar Dan Aktivitas Belajar Siswa. *Jurnal Inkuiri*, *3*(1), 85–95. Retrieved from https://jurnal.uns.ac.id/inkuiri/article/view/9676

Puspitasari, Y., Widoretno, S., Ariyanto, J., Sugiharto, B., Dwiastuti, S., & Adi, C. (2022). *Profile of High School Students' Arguments on Environmental Pollution Materials in the Covid-19 Era*. *14*(4), 6483–6492. https://doi.org/10.35445/alishlah.v14i4.1989

Rahman, D. F. (2018). Analisis Argumentasi dalam Isu Sosiosaintifik Siswa SMP. *Thabiea: Journal of Natural Science Teaching*, *1*(1), 9–13. Retrieved from http://journal.iainkudus.ac.id/index.php/Thabiea/article/view/3868

Saenab, S., Yunus, S. R., & Virninda, A. N. (2017). PjBL untuk pengembangan keterampilan mahasiswa: sebuah kajian deskriptif tentang peran PjBL dalam melejitkan keterampilan komunikasi dan kolaborasi mahasiswa. *Seminar Nasional Lembaga Penelitian UNM*, *2*(1), 45–50. Retrieved from http://eprints.unm.ac.id/31642/

Saracaloglu, A. S., Aktamis, H., & Delioglu, Y. (2011). The impact of the development of prospective teachers' critical thinking skills on scientific argumentation training and on their ability to construct an argument. *Journal of Baltic Science Education*, *10*(4), 243–260. Retrieved from http://www.scientiasocialis.lt/jbse/files/pdf/vol10/243-260.Saracaloglu_Vol.10.4.pdf

Sasson, I., Yehuda, I., & Malkinson, N. (2018). Fostering the skills of critical thinking and question-posing in a project-based learning environment. *Thinking Skills and Creativity*, *29*, 203–212. Retrieved from https://doi.org/10.1016/j.tsc.2018.08.001

Setiono, P., Yuliantini, N., Wurjinem, W., & Anggraini, D. (2021). Kemampuan Argumentasi Ilmiah Mahasiswa Melalui Penerapan Model Pembelajaran Project Based Learning. *ELSE (Elementary School Education Journal): Jurnal Pendidikan Dan Pembelajaran Sekolah Dasar*, *5*(1), 101. https://doi.org/10.30651/else.v5i1.7039

Si, J., Kong, H. H., & Lee, S. H. (2018). Developing clinical reasoning skills through argumentation with the concept map method in medical problem-based learning. *Interdisciplinary Journal of Problem-Based Learning*, *13*(1), 1–11. https://doi.org/10.7771/1541-5015.1776

Stede, M. (2020). (2020). Automatic argumentation mining and the role of stance and sentiment. *Journal of Argumentation in Context*, *9*(1), 19–41. https://doi.org/10.1075/jaic.00006.ste

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). https://doi.org/10.29333/ijese/8544

Sumarni, W., & Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia*, *9*(1), 11–21. https://doi.org/10.15294/jpii.v9i1.21754

Sumintono, B., & Widhiarso, W. (2015). *Aplikasi Pemodelan RASCH Pada Assessment Pendidikan.* Yogyakarta: Trim Komunikata.

Thomas, J. W. (2000). *A Review of Research on Project Based Learning*. Report Prepared for The Autodesk Foundation. Retrieved from http://www.bie.org/research/study/review_of_project_based_learning_2000

Toulmin, S. (2003). *The Uses of Argument (2nd ed.)*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511840005.

Turgut, H. (2008). Prospective Science Teachers' Conceptualizations About Project Based. *International Journal of Instruction*, *1*(1), 62–79. Retrieved from https://eric.ed.gov/?id=ED524155

Ural, E., & Gençoğlan, D. M. (2019). The Effect of Argumentation-Based Science Teaching Approach on 8th Graders' Learning in the Subject of Acids-Bases, their Attitudes towards Science Class and Scientific Process Skills. *Interdisciplinary Journal of Environmental and Science Education*, *16*(1), 1–15. https://doi.org/10.29333/ijese/6369

Watson, M. K., Barrella, E., Wall, T., Noyes, C., & Rodgers, M. (2020). Comparing measures of student sustainable design skills using a project-level rubric and surveys. *Sustainability (Switzerland)*, *12*(18), 1–14. https://doi.org/10.3390/SU12187308

Widoretno, S., Prabowo, C. A., & Hardiana, N. (2023). Teacher' s questions in project-based learning: the impact on the quality of student' s concept map components. *Research and Practice in Technology Enhanced Learning*, *18*(31), 1–27. https://doi.org/10.58459/rptel.2023.18031

Yin, Y., Vanides, J., Ruiz-primo, M. A., Ayala, C. C., & Shavelson, R. J. (2005). Comparison of two concept-mapping techniques: Implications for scoring, interpretation, and use. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *42*(2), 166–184. Retrieved from https://files.eric.ed.gov/fulltext/ED483390.pdf

York, P., & Ertmer, P. A. (2016). Examining instructional design principles applied by experienced designers in practice 29(2), 169-192. *Performance Improvement Quarterly*, *29*(2), 169–192. https://doi.org/10.1002/piq.21220