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An Examination of the Effects of a Research-Based Instructional Model on Students' Critical Thinking Abilities in an Introductory Science Course

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***Abstract:** The purpose of this research was to examine how well the RBL model is being used to teach science to high school students in order to foster critical thinking. The research strategy for this investigation was sequential and exploratory, using a combination of methods. Quantitative data were collected after initially focusing on qualitative information. Quantitative data was gathered using essay examinations, while qualitative data was gathered through observation and interviews. There was a sampling phase before the actual study began. Thirty-five aspiring primary school teachers from throughout the nation served as samples. The investigation occurred during the spring 2019 semester. A quasi-experimental design with a pre- and post-test for a single group was used for the quantitative data analysis. The average rating for the research treatments across four separate observations was 5.625 (preliminary activities: 4.736, core activities: 4.625, and closing activities: 4.66; rating scale: very excellent; range: 1-4). The N-gain score was 57.60% in the medium category, demonstrating that introducing the RBL model to the study of energy in the natural sciences might boost students' capacity for critical thought. The average of the pre- and post-test ratings (47.95 and 778.2) was used to calculate this improvement (0-100). The results of this study may help professors and researchers develop new ways of teaching about energy that are more effective in developing students' capacity for critical thinking and analysis.*

***Keywords:** Concept of Energy, Mixed-Method, Natural Sciences, and Research-Based Learning, Analytical Thinking Abilities.*

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1. INTRODUCTION

Students' ability to think critically and solve issues analytically is essential (Thompson & Markovits, 2021). Students who develop their analytical thinking abilities are more equipped to think for themselves and produce original work (Setianingsih et al., 2019). In addition, analytical thinking is a fundamental higher-order thinking talent that lays the groundwork for other competencies including critical thinking, problem-solving, creativity, and decision-making (Liu & Pásztor, 2022). Effective problem-solving in the real world relies on the capacity to think analytically, which is why teaching children these abilities is so crucial (Liu & Pásztor, 2022). But the data with three indications of analytical thinking abilities, including the ability to differentiate (17.7), organize (47.7), and attribute (8.3), on a rating scale from 0 to 100, revealed that the pupils' analytical thinking skills remained poor. The results of the Program for International Student Assessment (PISA) examinations for students in the natural sciences, which ranked 60 out of 75 countries examined, provided further support for these findings.

Students' lack of ability to think critically is often attributed to the way they are taught. Active learning has the potential to create pupils with critical thinking abilities, whereas traditional passive learning restricts students' exposure to such chances. The phases of the Research-Based Learning (RBL) model require students to constantly learn via research, which is one reason why this learning framework may be effective in engaging students (Dai & Ke, 2022). As an added bonus, the RBL approach emphasizes student agency and incorporates research into relevant lessons. As a result, the RBL model is an educational approach that may help students build their understanding via repeated exposure to a variety of learning activities that emphasize observation and analysis.

Because of the RBL model's adaptability, scientific education may include science as a process, a product, and a way of thinking (Newton & Tonelli Jr, 2020). The steps involved in a scientific investigation—such as spotting a problem, measuring it, analyzing the results, and drawing a conclusion—are collectively known as the scientific method. In addition, information in science is gathered via experiments and observations. Furthermore, it seeks to provide an explanation for the issue at hand (Huang et al., 2020). To further develop the ability to think critically and analytically, students of science should study a wide variety of scientific disciplines. That is to say, students' abilities to apply the steps of the scientific method to the solution of vexing, unstructured situations are closely linked to their analytical thinking abilities (Khamhaengpol et al., 2021). In a nutshell, the RBL model may stimulate students' analytic thinking in the context of scientific education, namely in the areas of inquiry, data collection, and explanation of the solution.

Motivated by these issues, this research will examine how the RBL model may be used in scientific education to foster critical thinking among students. The results should inspire and inform educators to try new approaches to teaching energy concepts like the RBL model, which has been shown to boost students' ability to think critically about complex problems.

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Literature Review

RBL Model

The RBL model is a problem-based learning approach that provides a realistic scenario within which students may practice and improve their problem-solving abilities and acquire fundamental subject-matter understanding (Mindayula & Sutrisno,2021). In order to improve their comprehension and knowledge, students may use the RBL model's search, hypothesis, data collection, and conclusion drafting exercise (Martn-Garin et al., 2021). The goals of the RBL approach to education are to instill in pupils a mindset characteristic of scientists—one that is curious, open to new ideas and evidence, and constantly on the lookout for the truth—and the skills necessary to achieve these goals (Chen & Xiao, 2021). The syntax in Table 1 is what is meant by "RBL model application in learning."

Table 1. Syntax of RBL models

No	Stages	Activities
1	Stage I	Create your own issues
2	Stage II	Analyze the theoretical underpinnings
3	Stage III	Provide a problem statement that describes the issue
4	Stage IV	Establishing a Strategy for Investigation
5	Stage V	Conduct research and statistical analysis
6	Stage VI	Briefly outline the findings of your study.
7	Stage VII	Make results-based reporting and displays

Competence in Analytical Thinking

Analytical thinking entails the capacity to recognize and make connections among many types of information presented in a variety of formats, such as assertions, ideas, descriptions, and so on. To analyze anything, one must first break it down into smaller chunks before making any connections between those chunks or the whole. Students that have analytical thinking abilities are able to break down complex problems into its component elements and identify the relationships among them.

Indicators of analytical thinking were created in this research by (Lau et al., 2018) focusing on the ability to differentiate between, organize, and attribute (Lau et al., 2018). Table 2 displays the relevant data. Analytical thinking indicators and their definitions are included in Table 2. Students' capacity for critical thought may be evaluated with the use of these markers.

Table 2. Cognitive process dimension

Cognitive processes and categorizations	Possible Substitutes	Description
I. Differentiating	Identifying, singling out, honing in	Identifying what information in a given set is crucial and what may be ignored.

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II. Organizing	Creating order, incorporating, and outlining	Figuring out the role certain parts play in a larger whole.
III. Attributing	Deconstructing	The process of identifying an author's perspective, prejudice, values, or purpose in a piece of writing

2. METHODOLOGY

Research Objective
The purpose of this research was to examine the efficacy of using the RBL paradigm in the hard sciences in fostering critical thinking. In addition, the purpose of this research was to prepare future primary school science instructors.

Research Design
An exploratory sequential mixed-methods approach was employed for this study, adapted from (Strijker et al., 2020). To begin, this study used a qualitative approach by way of qualitative data collection and analysis. Figure 1 shows that second, a quantitative approach was used by gathering and evaluating data statistically after the qualitative findings were established.

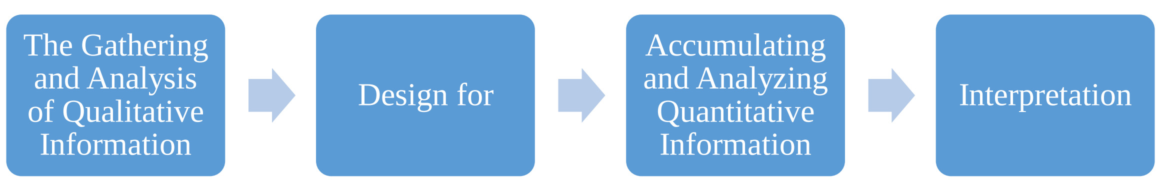

Figure 1. Research that combines qualitative and quantitative techniques

Qualitative data were prioritized, while quantitative approaches were used to supplement the qualitative data. In order to learn how the RBL model may be used to enhance critical thinking, qualitative research approaches were used. In addition, quantitative approaches were used to collect information on students' critical thinking capacities via the use of a pre- and post-essay exam. Both the pre- and post-test findings were based on students' performance on critical thinking skills essays related to the idea of energy. (Liao & Hitchcock, 2018) The quantitative study was designed as a quasi-experiment, with participants being tested before and after the intervention (see Table 3).

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Table 3**.** One group pretest-posttest design.

Pre-test	Treatment	Post-test
OK	NO	OK

Research Sample

Thirty-five Country Study Program participants were used as the study sample. Primary Teacher Preparation via the PGMI Study. In terms of prior education, the sample is rather diverse, with members hailing from a wide range of disciplines and fields (including physics, social sciences, electrical engineering, fashion, multimedia, administration, accounting, marketing, religion, and the automobile industry, to mention a few). The study included third-semester students aged 18 to 21 during the 2019–20 academic year's odd semester.

Research Instruments

We used a critical thinking exam, observation sheets, and interview guides to conduct this research. The critical thinking skills exam consisted of 15 questions. Ninety students participated in a trial to test the items' reliability and validity. The findings of the study were assessed for validity with application, and all 10 items were valid. Meanwhile, observation sheets and interview sheets were evaluated by five professionals in assessment. The findings of the observation sheet and the interview sheet were all valid.

Modality of the RBL Model

The RBL model's process included 7 steps: 1) This activity begins with a problem formulation phase, during which participants explore and debate existing natural events in order to discover challenges. 2) Students examine and evaluate theories pertinent to the experiment's subject, 3) identifying issues formation, students debated in groups to construct problems, 4) Organizing the research, gathering the necessary equipment and supplies, 5) examining and evaluating data, done out in groups and directed by the experimental methods in the Experiment Guide book, 6) Defining the significance of the study's findings, Following step 7 (writing up reports and presenting results), each group shared their work with the rest of the class.

The RBL model's seven phases, the heart of inquiry-based learning, are gleaned through many empirical process findings via the use of scientific methodologies. Students conducted the experiments in Table 4 to learn more about energy-changing materials.

Table 4. Investigational equipment and supplies

No	Tool's name	Total
1	1.5 volts Battery	2pcs
2	Toggle Switch	1pc
3	10mm Cable	appropriately
4	Lamp bulb	2pcs

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5	SteelChain Board	1pc
5	6volts Electric Motor	1pc
6	Ball Yarn	appropriately

3. RESULTS

The Outcomes of Putting What We've Learned into Practice

The RBL approach of scientific education was applied to the study of the energy concept over the course of four sessions, during which time the whole process was observed and recorded. There was always a kickoff, main content, and wrap up at each meeting. The speaker transmitted the learning goals and made connections between the content that had been covered and the material that would be covered at that time in the context of preparation exercises. Investigative processes, from the outset of an inquiry through its final report, were the focus of most effort. At the end of the lesson, the instructor had the pupils compile the results of their research. Table 5 displays the observable outcomes. The RBL model's use in the classroom is outlined in Table 5, which details the actions of the instructor and the students.

Table 5. Results of observations

No	Instructional Exercises	Educational Activities
I	The professor instructed the class to identify and describe difficulties.	Through collaborative group work, students were able to pinpoint issues.
II	The speaker guided the students through their research while they conducted the experiment.	In order to carry out their experimental tasks, students engaged in two-way communication with both the professor and their peers.
III	The instructor instructed pupils on how to interpret experimental results.	As a group, the students being mentored studied and inferred results from an experiment.
IV	Students were instructed to draw conclusions and submit reports after the lecture's experimental activities.	The results of the experiments were discussed among the students in small groups.
V	The class was able to start conversations and give presentations because of the instructor's efforts.	In order to get feedback from the instructor and the rest of the class, students presented the outcomes of their group talks to the whole assembly.

The rater assigns a four if it's excellent, three if it's good, two if it's sufficient, and a one if it's poor. Table 6 shows the outcomes of the observations.

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Table 6. Outcomes from RBL model training based on observations

No	Activities	Assessment				Mean Score	Category value	Information
	Preliminary	I	II	III	IV			
I	Try to make connections between what you're learning now and what you already know	4	3	3	3	4.66	4.536	Very Good
II	Provide the objectives of the learning.	3	4	4	3	4.41		
	Core							
III	Develop your own issues	4	3	3	4	4.61	4.625	Very Good
IV	Analyze the theoretical underpinnings	4	3	3	4	4.41		
V	Provide a problem statement that describes the issue.	3	4	3	3	4.64		
VI	Formulate a strategy for conducting investigations	3	4	3	4	4.41		
VII	Find out things and look at data	3	3	3	3	3.11		
VIII	Describe the findings of the study.	3	3	4	3	4.11		
IX	Make presentations and reports on the findings.	3	3	3	3	4.22		
	Closing							
X	Accumulate tasks	4	3	3	3	4.66	4.86	Very Good

The observer's evaluations from the first, second, third, and fourth meetings throughout the RBL model implementation are shown in Table 6 in roman numerals I, II, III, and IV. In terms of the lecturer's and students' participation in teaching and learning, the data obtained indicates that the mean score is extremely excellent. The RBL model was used to carry out these exercises over the course of four gatherings. There was a maximum score of 4, with the preliminaries getting 4.536, the meat of the project getting 4.625, and the wrap-up a solid 4.86.

Conversations with Students and Their Responses
Once the RBL instructional strategy had been fully implemented, interviews with three students had been scheduled at random. Table 7 provides a synopsis of our in-depth interview's findings.

Table 7. Feedback from RBL-taught classes

Question	**Answer**
When you listen to the professor, did you have a good time? Why?	Absolutely, as it had a lot of variety and didn't put you to sleep.

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Does this lesson lead to any novel experiences? Then what?	Sure, get some experience with research and data analysis.
Did you encounter any problems when taking part in the learning activities? Assuming there were any components at all.	In truth, there were, but the issues were amenable to being discussed between friends. The component, investigation, and results.
In your opinion, what lesson did you like the most? The question is, what exactly was boring?	Finding out more or doing something new was a lot of fun. There was never a dull moment, but writing up the details required a lot of time.
Do you think innovative approaches to education were used in classroom lectures?	It was novel, and it got the students involved in the lectures.

Table 7 shows that the researcher's impressions of the students' attitudes about the RBL model were supported by their responses to the interviews. The students were exposed to new methods of teaching, learning, and interpreting information. Students said this was the most intriguing part of the lesson despite the challenges they had before discussing it with their peers. However, when asked "What are the drawbacks of the RBL model?" students often provide lengthy lists of criticisms. The responses from the students differed. This is because there are several obstacles, such as the length of time required for preparation, the expense involved, and the difficulty in acquiring the necessary equipment.

Results of Analytical Thinking Skills Test

The statistical analysis of exam scores revealed that, on average, pupils had high levels of analytical thinking ability. In terms of the criteria used, the range is as follows: dan 0 X 43.75 (very low), 71.50 X 81.25 (extremely high), 62.50 X 71.50 (middle), and 71.50 X 62.50 (low) (very low). Table 8 displays the mean scores for each indication of students' analytical thinking abilities on a scale from 0 to 100.

Table 8. Data analysis showing outcomes for analytical thinking indicators

Test of Your Ability to Analyze and Evaluate	Overall Indicator Score	Classification Indicator
Differentiate	78.69	extremely high
Organize	77.87	extremely high
Attribute	74.38	extremely high
Mean Score	77.72	extremely high

Table 9 displays the results of the study of the 35 students' pre- and post-test data.

Table 9. Summary of the Pre- and Post-Test Findings

Score	Total	Ideal	Minimum	Maximum	Mean
Pretest	35	100	33.61	61.11	47.95
Posttest	35	100	66.49	88.40	77. 82

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4. DISCUSSION

With a mean score of 4.625 over four observations, the statistics show that using the RBL paradigm in scientific education has been fruitful. According to the RBL model proposed by (Behnamnia et al., 2020), the following processes were used in the learning activities: (1) posing a broad question; (2) reviewing relevant literature; (3) refining the question; (4) developing a strategy for conducting research and clarifying relevant methods; (5) conducting research and analyzing data; (6) reflecting on and making sense of the findings; and (7) communicating the findings (Behnamnia et al., 2020).

Students are given the freedom to investigate and discover in RBL implementations. Learners may be taught via this exercise how to learn independently and build upon existing information. Students may gain information, skills, and a scientific disposition via the RBL paradigm, making it a viable alternative to the applied learning model. Students worked in groups of three or four to conduct their investigations, since the RBL approach emphasizes collaborative instruction and discovery-based education (Behnamnia et al., 2020).

Understanding, learning via social contact, and meaningful, applicable learning were all fostered by the RBL approach (Singh et al., 2019). In addition, the RBL model helped because 1) it got students involved in their own education, 2) it familiarized them with the scientific method of thinking, 3) it fostered their development as autonomous, rational, critical thinkers, and creative individuals, and 4) it provided them with a foundation in ethical principles (Hartshorne et al., 2018).

Learning via research was emphasized in the RBL framework. Students may learn to think critically and do research by using the RBL model (Martin-Garin et al., 2021). This includes skills like performing searches, constructing hypotheses, gathering data, analyzing data, and drawing conclusions. The RBL approach allows students to construct their knowledge via hands-on experience with a variety of observation and analysis tasks, such as the last step in analyzing their own experimental data (Nursofah et al., 2018).

Students' enthusiasm for learning seems to be fostered by the RBL method, as shown by interviews with current students. The RBL structure has the potential to foster a climate where questions are encouraged, different points of view are valued, and new ideas are developed. The RBL paradigm may improve children's academic outcomes, students' capacities for learning, and the quantity and quality of knowledge children learn on their own initiative (Srikoon et al., 2014). Learners are introduced to cutting-edge approaches to pedagogy, study, and data analysis. Students found it difficult to make conclusions before having a group discussion, but they all felt that this was the most interesting part of the lesson. It has been suggested that the RBL method may help students develop skills in critical thinking, scientific habituation, and ethical conduct (Hartshorne et al., 2018).

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The N-gain value of 57.68% in the medium category demonstrates that using the RBL model in scientific education may increase students' capacity for analytical thinking; conversely, a higher N-gain value indicates a bigger increase in students' capacity for analytical thinking. The median pre- and post-test scores, 47.75 and 77.82, respectively, further attest to this improvement. The average student scored 77.72 on a scale from 0 to 100, placing them in the "high" range for their analytical thinking abilities. The kids' command of the energy concept was evident here. Sequentially high scores of 78.69, 77.87, and 74.38 were found for the markers of being able to discriminate between, organize, and ascribe. A paired t-test showed that having students use the RBL model led to greater improvement in their ability to think analytically about the topic of energy.

Training students in the art of discriminating, categorizing, and attributing are just some of the ways in which the RBL model might affect their capacity for critical thought. With the RBL paradigm in place, these abilities may be cultivated over time. Aspects of analytical thinking are honed at every stage of the RBL paradigm. These findings demonstrated that using the RBL approach boosted academic performance, taught students to learn, and allowed them to independently construct new information (Srikoon et al., 2014). In conclusion, the RBL model may be used as an alternative model of education since it allows students to independently investigate, evaluate, and synthesize data in order to acquire a wide range of knowledge, skills, and attitudes.

5. CONCLUSION

On the basis of the data analysis and the subsequent discussion, the following can be deduced: 1) The RBL model in science learning with the concept of energy functions very well, as shown by the score of preliminary activities being 4.536, the score of core activities being 4.625, and the score of closing activities being 4.86 out of a possible 4, with 4 being the highest possible score; 2) The RBL model in science learning with the concept of energy functions very well; and 3) The RBL model in science learning with the concept 2) The actions of the lecturer throughout the learning process, by implementing the RBL model, may motivate students to take out research activities. This conclusion is based on the favorable reaction that students gave when they were interviewed. 3) The adoption of the RBL model in scientific lectures on topics related to energy materials may help students enhance their ability to think analytically. 4) The findings of this research presented lecturers and researchers with general information on the implementation of RBL model lectures at tertiary institutions for the purpose of scientific learning in energy material.

Recommendations

In the future, scientists who also want to assess logical reasoning abilities will likely use a different learning model than the one under investigation. The purpose of this study is to examine how well various learning paradigms enhance critical thinking. The researcher also mentions a problem-

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based learning paradigm and other inquiry-based learning models. Sufficient labs and equipment are necessary to facilitate studies in problem-based learning and research-based learning.

Limitations

The scope of this study is confined to how children in this nation understand the term "Energy." In particular, the findings provide light on the state of students' critical thinking abilities in relation to their understanding of the scientific notion of "Energy" and give valuable insight for educators and researchers in the field. The small sample size (5 students) and the lack of a control group to compare with the experimental group are further problems with this research. Future studies could deepen the analysis of the issue at hand, use a control group to contrast the experimental group, and conduct additional interviews with participants to get unbiased feedback on the instructional process.

6. REFERENCES

1. Behnamnia, N., Kamsin, A., Ismail, M. A. B., & Hayati, A. (2020). The effective components of creativity in digital game-based learning among young children: A case study. Children and Youth Services Review, 116, 105227. https://doi.org/10.1016/j.childyouth.2020.105227
2. Chen, L., & Xiao, S. (2021). Perceptions, challenges and coping strategies of science teachers in teaching socioscientific issues: A systematic review. Educational Research Review, 32, 100377. https://doi.org/10.1016/j.edurev.2020.100377
3. Dai, C. P., & Ke, F. (2022). Educational applications of artificial intelligence in simulation-based learning: A systematic mapping review. Computers and Education: Artificial Intelligence, 100087. https://doi.org/10.1016/j.caeai.2022.100087
4. Hartshorne, J. K., Tenenbaum, J. B., & Pinker, S. (2018). A critical period for second language acquisition: Evidence from 2/3 million English speakers. Cognition, 177, 263-277. https://doi.org/10.1016/j.system.2020.102352
5. Huang, S. Y., Kuo, Y. H., & Chen, H. C. (2020). Applying digital escape rooms infused with science teaching in elementary school: Learning performance, learning motivation, and problem-solving ability. Thinking Skills and Creativity, 37, 100681. https://doi.org/10.1016/j.tsc.2020.100681
6. Khamhaengpol, A., Sriprom, M., & Chuamchaitrakool, P. (2021). Development of STEAM activity on nanotechnology to determine basic science process skills and engineering design process for high school students. Thinking Skills and Creativity, 39, 100796. https://doi.org/10.1016/j.tsc.2021.100796
7. Lau, K. H., Lam, T., Kam, B. H., Nkhoma, M., Richardson, J., & Thomas, S. (2018). The role of textbook learning resources in e-learning: A taxonomic study. Computers & Education, 118, 10-24. https://doi.org/10.1016/j.compedu.2017.11.005

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8. Liao, H., & Hitchcock, J. (2018). Reported credibility techniques in higher education evaluation studies that use qualitative methods: A research synthesis. Evaluation and program planning, 68, 157-165. https://doi.org/10.1016/j.evalprogplan.2018.03.005
9. Liu, Y., & Pásztor, A. (2022). Effects of problem-based learning instructional intervention on critical thinking in higher education: A meta-analysis. Thinking Skills and Creativity, 45, 101069. https://doi.org/10.1016/j.tsc.2022.101069
10. Martín-Garin, A., Millán-García, J. A., Leon, I., Oregi, X., Estevez, J., & Marieta, C. (2021). Pedagogical Approaches for Sustainable Development in Building in Higher Education. Sustainability, 13(18), 10203. https://doi.org/10.3390/su131810203
11. Mindayula, E., & Sutrisno, H. (2021, March). Motivation Level of Student After Implementation Learning Media Based on 3D-Pageflip. In 6th International Seminar on Science Education (ISSE 2020) (pp. 283-288). Atlantis Press. https://dx.doi.org/10.2991/assehr.k.210326.040
12. Newton, X. A., & Tonelli Jr, E. P. (2020). Building undergraduate STEM majors' capacity for delivering inquiry-based mathematics and science lessons: An exploratory evaluation study. Studies in Educational Evaluation, 64, 100833. https://doi.org/10.1016/j.stueduc.2019.100833
13. Ramirez, L. F., & Belcher, B. M. (2020). Crossing the science-policy interface: Lessons from a research project on Brazil nut management in Peru. Forest Policy and Economics, 114, 101789. https://doi.org/10.1016/j.forpol.2018.07.018
14. Setianingsih, R., Marianti, A., & Ngabekti, S. (2019). Analysis of Critical Thinking Skills High School Students in the District of Semarang Material Environmental Change Curriculum 2013. Journal of Biology Education, 8(3), 315-321. https://doi.org/10.15294/jbe.v8i3.27056
15. Singh, R., Herrmann, C., Thiede, S., & Sangwan, K. S. (2019). based learning for skill development of engineering graduates: an empirical study. Procedia Manufacturing, 31, 323-329. https://doi.org/10.1016/j.promfg.2019.03.051
16. Strijker, D., Bosworth, G., & Bouter, G. (2020). Research methods in rural studies: Qualitative, quantitative and mixed methods. Journal of Rural Studies, 78, 262-270. https://doi.org/10.1016/j.jrurstud.2020.06.007
17. Thompson, V. A., & Markovits, H. (2021). Reasoning strategy vs cognitive capacity as predictors of individual differences in reasoning performance. Cognition, 217, 104866. https://doi.org/10.1016/j.cognition.2021.104866