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Profile of High School Students' Critical Thinking Skills about Renewable Energy Materials

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Abstract: This study aims to determine the critical thinking profile of high school students on renewable energy materials using a mixed method consisting of qualitative descriptive in the form of interview results and quantitative descriptive in the form of test result analysis at SMA Negeri 1 Sembawa, South Sumatra Province. The interview results stated that students are not used to doing critical thinking problems and rarely do activities that can stimulate their critical thinking skills. The test for the learners showed a low average score of 35.12. The average score obtained for the indicator giving a simple explanation was 33.80, the indicator building basic skills was 38.19, and the indicator giving further explanation was 21.53. All three include critical thinking skills categorized as lacking. As for the indicators inferring and organizing strategies (tactics) included in the category enough with average scores of 43.75 and 40.97. The results indicate that students' critical thinking skills fall into the category of being less proficient. This is due to students' lack of literacy regarding renewable energy and their unfamiliarity with working on questions with high-level thinking skills. Another cause is that physics learning is less varied and experiments are rarely carried out.

Keywords: Critical thinking skills; Profile of high school students; Renewable energy

Introduction

Critical thinking skills are one of four skills that learners must master in this information age and globalization for them to be prepared to face the demands of an increasingly complex world. The other three skills are creative, communicative, and collaborative (Agmita et al., 2021; Negari et al., 2021).

Critical thinking skills are reflective ways of thinking when deciding to do something, solve problems, or receive information based on appropriate, logical, non-subjective, and careful reasons. A person who thinks critically can examine, question, understand, analyze, assess, evaluate, self-correct, and reconstruct skillfully as a blend of emerging knowledge, skills, and attitudes (Fikriyatii et al., 2022; Maison et al., 2022; Shao et al., 2022; Temel, 2022). Summarized by Robert Ennis (Agmita et al., 2021; Chairani et al., 2022; Ennis, 2011; Fisher, 2000; Marlina et al., 2022) students' critical thinking skills can be measured by paying attention to five indicators, namely the ability to provide simple explanations, build basic skills, skills in concluding, providing further explanations; and skills in managing strategies and tactics.

Improving the critical thinking skills of learners in schools is a challenge because improving critical thinking skills requires continuous practice and cannot be learned instantly (Anggraito et al., 2023). Therefore, effective steps must be taken to produce graduates with high-level critical thinking skills (Ali & Awan, 2021; Alotaibi, 2013; Ulger, 2018). The learning process in Indonesia still emphasizes memorization and has not focused on improving students' critical thinking skills (Sukarmin & Sani, 2023). It can be seen from some of the latest research results, including those conducted on students, it was found that 33.75% of students have low critical thinking skills. In fact, 36.25% of students are at a very low level of critical thinking (Djufri et al., 2022). If the average student's critical thinking skills are still low,

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it is necessary to examine how the critical thinking skills of students at the level below.

In the context of physics, one of the important aspects that must be mastered by learners is the understanding of renewable energy. As is known, that fossil-sourced fuels are increasingly limited in availability. Fossil fuels have a negative impact on the environment and health (Curtin et al., 2019; Yang et al., 2021). Greenhouse gases including nitrogen oxides, carbon dioxide, and methane are produced during the fossil burning process. This process increases in frequency as the human population and production activities increase. Emissions from fossil fuels also have an adverse impact on the environment, including uncontrolled climate change (UNESCO-UNEVOC, 2020), the onset of health problems, changes in ecosystems, and so on (Olabi et al., 2022). The negative impacts caused by fossil fuels can threaten living things, especially humans (Gustavsson et al., 2021; He et al., 2021). This is certainly very troubling for the world community. So efforts to produce renewable energy are very relevant and urgent topics to address environmental problems and global climate change. It is very important to develop environmentally friendly alternative and renewable energy sources (Susilayati et al., 2022). High school students as the next generation must be ready to face this challenge.

The results of open interviews with several high school physics teachers in South Sumatra Province show that critical thinking is an important topic that needs special attention and needs to be included in the physics learning process as one of the 21st-century skills that students must master. Critical thinking skills must be present in every lesson (Ningrum & Murti, 2023). Based on the discussion above, it is important to carry out this research with the aim of finding out the characteristics of high school student's critical thinking skills related to renewable energy material. This research will reveal the extent to which high school students are able to apply their critical thinking skills in understanding, analyzing, and applying the concept of renewable energy. The results of the analysis are expected to be a guide for education practitioners to improve and develop a learning system, classroom, and product that can support programs to improve students' critical thinking skills. In this era of globalization, access to communication and information is connected very widely and quickly. Therefore, improving students' critical thinking skills is not only for their academic success but is important to prepare students to become high-quality future leaders in an increasingly complex and sustainable society (Andayani, 2020). So that this research has high relevance and presents valuable insights for future educational development.

Method

The method used in this study is descriptive with a mixed method, namely a qualitative descriptive method through interviews (Fadli, 2021) and quantitative tests (Nazhifah, Wiyono, Ismet, & Azairok, 2023) which was carried out by South Sumatra Province, precisely SMA Negeri 1 Sembawa. SMA Negeri 1 Sembawa is the first batch of mover schools in South Sumatra, so it is considered to have better experience in implementing an independent curriculum, especially renewable energy materials. Sampling is carried out by grouping students into three groups, namely low, medium, and high categories. Grouping refers to their values in the process of learning physics. Then, 36 students were selected as samples in the study. The flow of this research can be seen in the following Figure 1.

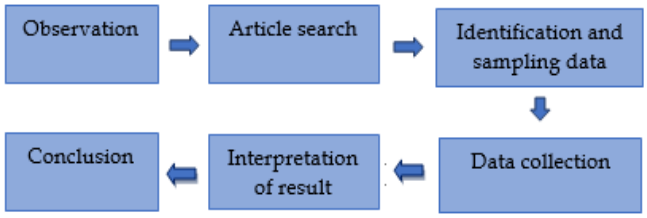

Figure 1. Research flow

Interview data was taken directly to physics subject teachers related to learning activities that had been carried out. The questions given to the teacher refer to the interview grid in Table 1.

Table 1. Interview Grid

Aspects	Question items
Learning process	Enthusiasm of students toward physics learning
	The frequency of experimental methods
	Application of varied learning models
Assessment	Types of assessments performed
	Difficulty level of assessment instruments for learners
Learning outcomes	Assess student learning outcomes

The results of the interview were analyzed qualitatively. In this study, interviews with teachers are one of the important data because the results of this study are based on facts and not fabricated by researchers (Fadli, 2021).

The test questions in this study were developed by referring to indicators of critical thinking skills according to Robert Ennis, namely the ability to provide simple explanations, build basic skills, inference skills, skills to provide advanced explanations, and skills in determining strategies and tactics (Ennis, 2011). There are five essay-shaped questions that must be answered by including the reason. The five questions have been

validated by experts before use. Assessment of students' test results uses scoring which is divided into five categories. The first category with a score of 0 is if there is no answer at all. The second category with a score of 1 is if students are wrong in answering and giving reasons. The third category with a score of 2 is if only one of the learners' answers or reasons is correct. The fourth category with a score of 3 is if the answer is correct but the reason is not right. The last category with a score of 4 is if the answers and reasons given are correct. The distribution of the test questions is shown in Table 2.

Table 2. Distribution of Critical Thinking Skills Test Questions for Renewable Energy Materials

Critical Thinking Skills Indicators	Critical Thinking Sub-Indicators	Renewable Energy Materials	Number of Questions
Provide simple explanations	Students can analyze questions	Forms of energy	1
Build basic skills	Students can observe and consider observation reports	Renewable energy sources	1
Inference skills	Students can create and define value considerations	Development of renewable energy sources	1
Provide advanced explanations	Students can identify assumptions	Renewable energy power plants	1
Skills in determining strategies and tactics	Students can define an Action	Design of renewable energy sources	1

Test data collection is carried out on a computer-based basis where questions are presented in a platform called Google Form which can be accessed from smartphones or laptops/computers easily. Then the researcher analyzed the students' answers and classified them into 5 types of critical thinking skills by modifying from M. Muntaha et al (Muntaha et al., 2021) as Table 3.

Table 3. Classification of critical thinking skills

Range of values	Category
80.00 – 100.00	Excellent
60.00 – 79.99	Good
40.00 – 59.99	Enough
20.00 – 39.99	Less
0.00 – 19.99	Very Lacking

Result and Discussion

Categories Students' Critical Thinking Skills

The written test was given to 36 class X students directly at SMA Negeri 1 Sembawa. A total of five essay questions representing five indicators of critical thinking skills are given in the form of google form via link https://bit.ly/TesKBKEnergiTerbarukan. Then the researcher analyzes the answers of the learners who have been collected. The results look like in Tables 4 and 5.

Table 4. Recapitulation of Students' Critical Thinking Skills Test Results

Categories	Value
Maximum score	50.00
Minimum score	10.71
Average Rating	35.12
Standard Deviation	10.82

Table 5. Recapitulation of Student Value Analysis on Each Category of Critical Thinking Skills

Categories	Value	Number of Students	Percentage (%)
Excellent	80.00 – 100.00	0	0.00
Good	60.00 – 79.99	0	0.00
Keep	40.00 – 59.99	13	36.11
Less	20.00 – 39.99	17	47.22
Very Lacking	0.00 – 19.99	6	16.67

Based on Table 4, the average score achieved by students is 35.12. The highest value was 50.00 and the low was 10.71. Table 5 shows that no one was able to achieve a score of 60.00 on this test. In other words, no one can achieve the good and excellent category in this study. Most of the 17 students (47.22%) fell into the less category with a score range of 20.00 to 39.99. While 13 students (36.11%) were in the medium category with scores between 40.00 to 59.99 and the remaining 6 students (16.67%) obtained scores between 0.00 to 19.99 in the very less category. Almost all students in this study obtained scores of 1 and 2 on each question. Only a very few are able to achieve a score of 3. This means, that most students have not been able to give answers correctly. Or they can answer the question correctly but have not been able to give a reason correctly.

Renewable energy materials are still relatively new materials for students in Indonesia. They still feel unfamiliar and have difficulty understanding it. Even the results of Abdul Aziz Rahman et all research stated that the understanding of science teachers about renewable energy is still low (Rahman, Kaniawati, Riandi, & Hendayana, 2023). If the understanding of science teachers is still low on this material, of course, students will also have difficulty understanding it.

Average Critical Thinking Skills Scores of Students for Each Indicator

Students' critical thinking skills can be seen from five indicators, namely providing simple explanations, building basic skills, inferring, providing further explanations and organizing strategies and tactics (Ennis, 2011). The average value of students in each of these indicators can be seen through the graph in Figure 2.

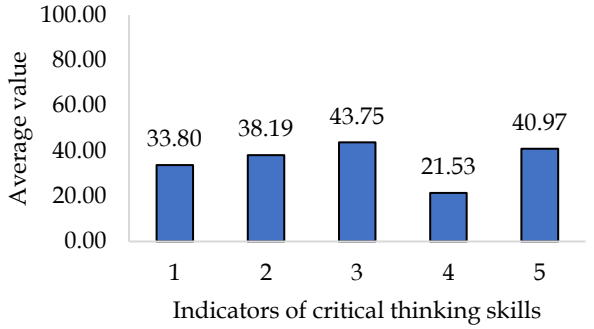

Figure 2. Graph of the average value of each indicator's critical thinking skills

Figure 2 describes the average score of students' critical thinking skills for each indicator. Number 1 on the vertical axis states that the indicator provides a simple explanation, number 2 states that the indicator builds basic skills, number 3 states that the indicator concludes, number 4 states that the indicator provides a further explanation, and number 5 states that the indicator sets strategies and tactics.

Based on Figure 2 above, it can be seen that the average score of learners' test results for all indicators of critical thinking skills is below 59. In detail, the average score obtained by students for the indicator giving a simple explanation was 33.80, the indicator building basic skills was 38.19, and the indicator giving further explanation was 21.53. All three include critical thinking skills categorized as lacking. As for the indicators "inferring" and "organizing strategies and tactics" are included in the category of sufficient critical thinking skills with average scores of 43.75 and 40.97. When viewed from the average scores of the five indicators of critical thinking skills, no one has reached the good category.

The profile of critical thinking skills of high school students, especially on renewable energy materials, can be known after the data obtained is analyzed. In short, critical thinking skills are logical and reflective thinking and focus on believing decision-making (Fisher, 2000). A person is declared to have good critical thinking skills if he strives to do a job correctly, honestly, and clearly, and cares for others. Critical thinkers can also clarify, look for, and judge things well before concluding (Fisher, 2000). This critical thinking skill is not immediately possessed by a person since he was born, therefore it needs to be trained continuously so that later it can develop well in him (Virijai et al., 2022). The accuracy of an educator in choosing learning strategies for the learning process can encourage students to hone their critical thinking skills (Wayudi et al., 2020). For that, we need to know in advance how to profile students' critical thinking skills.

Based on quantitative data collection through tests to students at SMA Negeri 1 Sembawa, in general, the level of critical thinking skills of students is classified as not good. The results of previous research using the Rasch model also showed that students' skills in solving critical thinking problems were included in the low category (Karoror & Jalmo, 2022; Nugroho et al., 2022). The results of a meta-analysis of several scientific articles from national journals that have been accredited in sinta 1 to sinta 4 also show that the value of critical thinking skills included in higher-order thinking skills is also still low (Sugianto et al., 2020). The questions given refer to five indicators of critical thinking skills, namely the ability to provide simple explanations, build basic skills, inference skills, skills to provide further explanations, as well as skills to organize strategies and tactics (Chairani et al., 2022; Ennis, 2011; Fisher, 2000; Marlina et al., 2021). The results of quantitative data collection are in line with the results of qualitative data collection, namely through interviews with physics subject teachers.

Figure 3. Photos of students taking the test

Interview with Physics Teacher

The physics teacher who was the sample of this study stated that the interest or enthusiasm of students towards this subject was not high. The inactivity of most learners is one of the indicators. They also have difficulty in understanding the concept of physics and still consider that physics is one of the subjects that is not easy. This is in accordance with the opinion of Cynthia et all who state that physics is a science that discusses phenomena in the universe in everyday life. The level of

abstractness in physics learning is relatively high for learners (Cynthia et al., 2023).

The application of various learning models has been done by teachers, but teacher-centered learning as a source of information is still quite often done. Students are rarely invited to explore information independently related to the materials studied. In addition, teachers also stated that it is rare to conduct experiments in schools.

The results of interviews with teachers related to assessment in physics learning, teachers stated that they had conducted an assessment of knowledge and skills. To assess the extent of students' knowledge of the material, teachers provide test questions both orally and in writing. While skill assessment is carried out when students carry out practicum or experiments. The knowledge test questions given to learners mostly ask learners to recall, understand, and apply the concepts that have been learned. Sometimes teachers also provide questions that encourage students to analyze the questions. While the ability to evaluate concepts and create or engineer a concept is almost never given to learners. Based on Bloom's taxonomy, the ability to analyze, evaluate, and create is a category of higher-order thinking skills that can improve the dimensions of students' cognitive abilities (Zorluoglu & Guven, 2020). Indicators of critical thinking skills correspond to dimensions of high-level cognitive abilities. So it needs habituation in doing questions with a high level of cognitive ability so that students get used to thinking critically. The results of meta-analysis research state that there is a significant relationship between critical thinking skills and learning outcomes in physics, chemistry, biology, and mathematics (Sultan et al., 2023). Previous research also stated that there was an increase in critical thinking skills in students who were used to working on HOTS questions (Cantona, Suastra, & Ardana, 2023). Implementing appropriate assessment models can also improve critical thinking skills (Rahayu & Bandjarjani, 2021).

Regarding the learning outcomes that have been collected by teachers, their average scores are still low. In fact, it is not uncommon not to achieve the planned learning objectives' indicators. In the opinion of teachers, this is closely related to the teaching and learning activities that have been passed and students' cognitive level. For this reason, various ways need to be designed and implemented so that the physics learning process is fun and students are motivated to get used to thinking critically. The application of the Tri Hita Karana-based problem-based learning model can improve students' critical thinking skills (Nirmayani & Suastra, 2023). The discovery learning model can also be used by educators because it has been proven to be effective in improving students' critical thinking skills (Saputri & Rusnilawati, 2023). This is also in accordance with previous research which states the application of various learning models including problem-based learning and discovery learning models can improve students' critical thinking skills (Harianja et al., 2023; Palinussa et al., 2023). The combination of problem-based learning models with inquiry is also effective in improving students' critical thinking skills (Safitri et al., 2022). Electronic-based learning models such as the Moodle platform can also improve students' critical thinking skills (Wiyono et al., 2020). Apart from using varied learning models, choosing interesting learning media such as comics will also improve students' critical thinking skills (Aditia, Muhlisin, & Singgih, 2022; Maghfiroh & Kuswanto, 2022; Pyatt, 2021).

Figure 4. Photo interview with teacher

Critical Thinking Skills Based on Indicators Provide Simple Explanations

Test question number 1 is a question about critical thinking skills based on the first indicator, namely the skill to provide simple explanations with sub-indicators of analyzing questions (Hidayati et al., 2021; Wayudi et al., 2020). In the problem, pictures and a little introductory sentence are presented and then students are asked to analyze the forms of energy at three positions of objects. The average score of students for questions on the position of the first, second, and third objects respectively was 1.3; 1,3; and 1.4. If converted into grades, then the average score of students is 33.80. Based on Table 3, the indicator provides a simple explanation of the level of critical thinking skills of students included in the category of not good. These results are in line with previous findings that concluded that learners' skills in analyzing questions fall into the low category (Wayudi et al., 2020; Widyapuraya et al., 2023) and very low (Khoirunnisa & Sabekti, 2020). Basically, students can answer the questions given, but cannot describe and analyze them properly. Difficulties in the process of analyzing questions can be influenced by several factors including limited ability and interest

in reading (literacy), reluctance to find reasons for the answers to what problems are observed, and environmental factors such as interference from friends when doing questions so that students lack concentration (Hidayati et al., 2021).

Critical Thinking Skills Based on Indicators Building Basic Skills

Then students are given critical thinking skills questions to see how they can build their basic skills by having them observe and consider the observational reports of others. Question number 2 presents data in the form of stories and pictures, then students are asked to make observations from these data. The result is an average student score of 1.5 with a score of 38.19. This score is more than question number 1, but it is still in the low category for critical thinking skills. Previous research has also stated that learners' critical thinking skills for this sub-indicator are in the very low category (Khoirunnisa & Sabekti, 2020). The reason is that they rarely make observations on a problem. The results of interviews with teachers also stated that they rarely conduct experiments. Even though one of the activities in the experiment is observation. Through experimentation, students' observation skills will be honed. Students can make observations using the project-based learning model which has been proven to improve their critical thinking skills (Trisnowati et al., 2022).

Critical Thinking Skills Based on Indicators Inference Skills

Test number 3 is a question based on inferring indicators and sub-indicators determining the value of consideration. The question is presented in the form of a story about the surge in fuel prices. Students are asked to determine consideration steps to support renewable energy policies. The average score obtained on question number 3 is 1.8 and is converted into a score of 43.75. This value is higher than the first and second indicators and is even the highest value among the five indicators of critical thinking skills measured. If guided by Table 3, the critical thinking skills of learners for this sub-indicator are in the medium category. That is, some students can already draw conclusions from a problem, especially in determining the value of consideration. These results are in line with the results of the analysis of critical thinking skills of previous High School students (Wayudi et al., 2020). Learners' critical thinking skills for this sub-indicator still need to be improved in order to achieve the good category.

Critical Thinking Skills Based on Indicators Provide Further Explanation

Test question number 4 based on skill indicators provides further explanations and sub-indicators identify assumptions. In this study, the average score of students on this question was 0.9 or if converted the score to 21.53. This score is in the low category and is even the lowest average score on the entire test. In line with previous research by Wijayanti et al. this indicator provides further explanation obtaining the lowest average compared to other indicators of critical thinking skills (Wijayanti & Siswanto, 2020). Research conducted by Afriana et al. also gave very low results in this indicator, which is 15.9% (Afriana et al., 2021). Serious attention is needed in developing the skills of students in order to be able to meet this indicator well.

Critical Thinking Skills Based on Indicators of Organizing Strategies and Tactics

Test question number 5 based on indicators set strategies and tactics with sub-indicators of skills determining an action. The average score obtained by students is 1.6 with a conversion value of 40.97. When viewed in Table 3, it includes the category of moderate critical thinking skills and ranks second highest after the third indicator (concluded). In line with previous research which states that students' skills in managing strategies and tactics are the second-best indicator that students can master (Wijayanti & Siswanto, 2020). These results provide a good opportunity for the development of critical thinking skills because if learners have been able to determine the right actions in managing strategies and tactics, it will be easier for them to be directed to achieve other indicators.

Conclusion

Based on the research conducted on high school students regarding renewable energy topics, the results indicate that their critical thinking skills fall into the category of being less proficient. This is due to students' lack of literacy regarding renewable energy and their unfamiliarity with working on questions with high-level thinking skills. Another cause is that physics learning is less varied and experiments are rarely carried out. This signifies the need for serious efforts to enhance the critical thinking skills of high school students. Initial information about the profile of high school students' critical thinking skills is crucial to be known as a reference for education policymakers in determining the next course of action. Increasing student literacy on renewable energy materials also needs special attention given the importance and complexity of current energy and environmental challenges. Therefore, educators need to improve their understanding of renewable energy and integrate renewable energy literacy into learning activities so that students' understanding of this material is better.

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Conflicts of Interest
The authors declare no conflict of interest.

References

Aditia, K., Muhlisin, A., & Singgih, S. (2022). The development of a local wisdom-based natural science comic through a webtoon to improve students' critical thinking skills. *Indonesian Journal of Science and Education*, *6*(1), 18–28. https://doi.org/10.31002/ijose.v6i1.60

Afriana, N., Halim, A., & Syukri, M. (2021). Analysis of the characteristics of students' critical thinking skills in completing national exam questions. *Jurnal Penelitian Pendidikan IPA*, *7*(2), 196. https://doi.org/10.29303/jppipa.v7i2.627

Agmita, N., Suyana, I., & Feranie, S. (2021). Desain LKPD berbasis masalah untuk melatihkan keterampilan abad 21. *Journal of Teaching and Learning Physics*, *6*(2), 90–99. https://doi.org/10.15575/jotalp.v6i2.10984

Ali, G., & Awan, R.-N. (2021). Thinking based instructional practices and academic achievement of undergraduate science students: exploring the role of critical thinking skills and dispositions. *Journal of Innovative Sciences*, *7*(1), 56–70. https://doi.org/10.17582/journal.jis/2021/7.1.56.70

Alotaibi, K. N. R. (2013). The effect of blended learning on developing critical thinking skills. *Education Journal*, *2*(4), 176–185. https://doi.org/10.11648/j.edu.20130204.21

Andayani, S. (2020). Development of learning tools based on discovery learning models combined with cognitive conflict approaches to improve students' critical thinking ability. *Jurnal Penelitian Pendidikan IPA*, *6*(2), 238. https://doi.org/10.29303/jppipa.v6i2.438

Anggraito, Y. U., Ridlo, S., & Harahap, F. (2023). STEM-PjBL learning: the impacts on Students' critical thinking, creative thinking, communication, and collaboration Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 1–4. https://doi.org/10.29303/jppipa.v9i7.2985

Cantona, I. G. E., Suastra, I. W., & Ardana, I. M. (2023). HOTS Oriented Problem-Based Learning Model: Improving Critical Thinking Skills and Learning Outcomes of Fifth Grade Students in Science Learning. T*hinking Skills and Creativity Journal, 6*(1), 19-26. https://doi.org/10.23887/tscj.v6i1.61654

Chairani, P., Siahaan, S. M., & Fathurohman, A. (2022). Encourage student's critical thinking skills through questioning on simple machine materials. *Jurnal Pembelajaran Fisika*, *10*(2), 153–164. http://dx.doi.org/10.23960/jpf.v10.n2.202201

Curtin, J., McInerney, C., Ó Gallachóir, B., Hickey, C., Deane, P., & Deeney, P. (2019). Quantifying stranding risk for fossil fuel assets and implications for renewable energy investment: A review of the literature. *Renewable and Sustainable Energy Reviews*, *116*(January), 109402. https://doi.org/10.1016/j.rser.2019.109402

Cynthia, C., Arafah, K., & Palloan, P. (2023). Development of interactive physics e-module to improve critical thinking skills. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 3943–3952. https://doi.org/10.29303/jppipa.v9i5.2302

Djufri, E., Septiani, D., & Hidayatullah, A. S. (2022). Analisis profil keterampilan berpikir kritis konsep sains mahasiswa PGSD. *Jurnal Ilmiah Pendidikan Dasar*, *07*(02), 363–372. https://doi.org/10.23969/jp.v7i2.6383

Ennis, R. H. (2011). *The nature of critical thinking : an outline of critical thinking dispositions*. 1–8. Retrieved from http://faculty.ed.uiuc.edu/rhennis

Fadli, M. R. (2021). Memahami desain metode penelitian kualitatif. *Humanika*, *21*(1), 33–54. https://doi.org/10.21831/hum.v21i1.38075

Fikriyatii, A., Agustini, R., & Sutoyo, S. (2022). Critical thinking cycle model to promote critical thinking disposition and critical thinking skills of pre-service science teacher. *Cypriot Journal of Educational Sciences*, *17*(1), 120–133. https://doi.org/10.18844/cjes.v17i1.6690

Fisher, A. (2000). Robert H. Ennis (1996), critical thinking. *Argumentation*, *14*(1), 48–51. https://doi.org/10.1023/A:1007850227823

Gustavsson, L., Nguyen, T., Sathre, R., & Tettey, U. Y. A. (2021). Climate effects of forestry and substitution

of concrete buildings and fossil energy. *Renewable and Sustainable Energy Reviews*, *136*(September 2020), 110435. https://doi.org/10.1016/j.rser.2020.110435

Harianja, R., Tampubolon, T., & Manalu, L. (2023). Analysis of problem-based learning model on mathematical critical thinking skills of elementary school students. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *13*(1), 101–108. https://doi.org/10.30998/formatif.v13i1.17251

He, X., Wang, F., Wallington, T. J., Shen, W., Melaina, M. W., Kim, H. C., … Wu, Y. (2021). Well-to-wheels emissions, costs, and feedstock potentials for light-duty hydrogen fuel cell vehicles in China in 2017 and 2030. *Renewable and Sustainable Energy Reviews*, *137*(October 2020). https://doi.org/10.1016/j.rser.2020.110477

Hidayati, A. R., Fadly, W., & Ekapti, R. F. (2021). Analisis keterampilan berpikir kritis siswa pada pembelajaran IPA materi bioteknologi. *Jurnal Tadris IPA Indonesia*, *1*(1), 34–48. https://doi.org/10.21154/jtii.v1i1.68

Karoror, I., & Jalmo, T. (2022). Profile of critical thinking ability in ecosystem materials using the Rasch model. *Jurnal Penelitian Pendidikan IPA*, *8*(3), 1599–1604. https://doi.org/10.29303/jppipa.v8i3.1394

Khoirunnisa, F., & Sabekti, A. W. (2020). Profil keterampilan berpikir kritis siswa pada materi ikatan kimia. *Jurnal Pendidikan Kimia Indoensia*, *4*(1), 26–31. Retrieved from https://ejournal.undiksha.ac.id/index.php/JPK/article/view/25635

Maghfiroh, A., & Kuswanto, H. (2022). Benthik android physics comic effectiveness for vector representation and critical thinking students' improvement. *International Journal of Instruction*, *15*(2), 623–640. https://doi.org/10.29333/iji.2022.15234a

Maison, M., Hidayat, M., Kurniawan, D. A., Yolviansyah, F., Sandra, R. O., & Iqbal, M. (2022). How critical thinking skills influence misconception in electric field. *International Journal of Educational Methodology*, *8*(2), 377–390. https://doi.org/10.12973/ijem.8.2.377

Marlina, L., Meiwandari, M., Sriyanti, I., & Jauhari, J. (2021). Developing student worksheet of natural science for the eighth-grade junior high school students based on critical thinking skills. *Journal of Physiscs: Conference Series*, *1796*(1). https://doi.org/10.1088/1742-6596/1796/1/012089

Marlina, L., Paramitha, G. P., & Sriyanti, I. (2022). Development of electronic modules based on critical thinking skills on vibration, waves, and sound materials for junior high school students. *Jurnal Pendidikan Sains Indonesia*, *10*(2), 342–354. https://doi.org/10.24815/jpsi.v10i2.23844

Muntaha, M., Masykuri, M., & Prayitno, B. A. (2021). Content analysis of critical-rand creative-thinking skills in middle-school science books on environmental pollution material. *Journal of Physics: Conference Series*, *1806*(1). https://doi.org/10.1088/1742-6596/1806/1/012138

Nazhifah, N., Wiyono, K., Ismet, & Azairok, M. (2023). Profile of physics creative thinking skills for high school students in the 21st century. *JIPFRI (Jurnal Inovasi Pendidikan Fisika Dan Riset Ilmiah)*, *7*(1), 1–11. https://doi.org/10.30599/jipfri.v7i1.2131

Negari, N. A., Sabdaningtyas, L., & Nurhanurawati, N. (2021). The development of E-LKPD through problem-based learning to improve the sixth-grade students' mathematics mastery. *International Journal of Educational Studies in Social Sciences (IJESSS)*, *1*(3), 124–128. https://doi.org/10.53402/ijesss.v1i3.27

Ningrum, A. W., & Murti, R. C. (2023). Contextual learning models in improving elementary school critical thinking skills. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 48–53. https://doi.org/10.29303/jppipa.v9i5.2360

Nirmayani, L. H., & Suastra, I. W. (2023). The impact of problem based learning with Tri Hita Karana on scientific literacy and critical thinking skills. *Thinking Skills and Creativity Journal*, *6*(1), 35–43. https://doi.org/10.23887/tscj.v6i1.57279

Nugroho, A. T., Karyanto, P., & Sugiharto, B. (2022). Profile of critical thinking ability of high school students on animalia material during hybrid learning in the pandemic era. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 2635–2640. https://doi.org/10.29303/jppipa.v8i6.1809

Olabi, A. G., Obaideen, K., Elsaid, K., Wilberforce, T., Sayed, E. T., Maghrabie, H. M., & Abdelkareem, M. A. (2022). Assessment of the pre-combustion carbon capture contribution into sustainable development goals SDGs using novel indicators. *Renewable and Sustainable Energy Reviews*, *153*(August 2021), 111710. https://doi.org/10.1016/j.rser.2021.111710

Palinussa, A. L., Lakusa, J. S., & Moma, L. (2023). Comparison of problem-based learning and discovery learning to improve students' mathematical critical thinking skills. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *13*(1), 109–122. https://doi.org/10.30998/formatif.v13i1.15205

Pyatt, K. (2021). The effect of the use of indigenous knowledge-based physics comics of android-based marbles games on verbal representation and critical thinking abilities in physics teaching.

Journal of Technology and Science Education, *11*(2), 581–593. https://doi.org/10.3926/jotse.1142

Rahayu, E. M., & Bandjarjani, W. (2021). Assessment of Indonesian higher education students' critical thinking based on Merrill's first principles of instruction. *JPI (Jurnal Pendidikan Indonesia)*, *10*(4), 732–741. https://doi.org/10.23887/jpi-undiksha.v10i4.30863

Rahman, A. A., Kaniawati, I., Riandi, R., & Hendayana, S. (2023). Secondary science teachers perception on STEM learning for sustainable development. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1297–1303. https://doi.org/10.29303/jppipa.v9i3.2776

Safitri, D., Yustika Rukman, W., Magfirah, N., & Bachtiar, S. (2022). Indonesian journal of science and education critical thinking skills through integration of problem-based learning with inquiry in science learning. *Indonesian Journal of Science and Education*, *6*(1), 12–17. https://doi.org/10.31002/ijose.v6i1.79

Saputri, Y. E., & Rusnilawati. (2023). Discovery learning through educandy: its effectiveness on students' critical thinking ability and self-confidence. *Thinking Skills and Creativity Journal*, *6*(1), 27–34. https://doi.org/10.23887/tscj.v6i1.61737

Shao, X., Qi, R., Kawaguchi, S., & Li, H. (2022). Early critical thinking in a Mandarin-speaking child: an exploratory case study. *Education Sciences*, *12*(2). https://doi.org/10.3390/educsci12020126

Sugianto, R., Permana P, N. D., & Diniya, D. (2020). Meta-analysis: enhancing junior high school students' higher order thinking skills through problem solving learning model in natural sciences-physics. *Jurnal Geliga Sains: Jurnal Pendidikan Fisika*, *8*(1), 55. https://doi.org/10.31258/jgs.8.1.55-63

Sukarmin, S., & Sani, D. M. (2023). Analysis student critical thinking skill on physic learning with e-modules type information search during the covid 19 pandemic. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4130–4134. https://doi.org/10.29303/jppipa.v9i6.2652

Sultan, J., Suyanto, S., & Ibrahim, Z. S. (2023). Relationship between critical thinking and learning outcomes in science and mathematics subjects reviewed from meta analysis. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 493–498. https://doi.org/10.29303/jppipa.v9i8.3862

Susilayati, M., Marwoto, P., & Priatmoko, S. (2022). Characterization of spent coffee grounds in the community as supporting materials for renewable energy. *Jurnal Penelitian Pendidikan IPA*, *8*(2), 918–924. https://doi.org/10.29303/jppipa.v8i2.1227

Temel, H. (2022). The effect of critical thinking course carry out with distance education on critical thinking skills and dispositions. *International Journal of Psychology and Educational Studies*, *9*(3), 792–808. https://doi.org/10.52380/ijpes.2022.9.3.894

Trisnowati, E., Ismawati, R., & D. (2022). Hybrid project-based instructional model: fostering critical thinking skills and creative thinking skills. *Indonesian Journal of Science and Education*, *6*(1), 29–35. https://doi.org/10.31002/ijose.v6i1.92

Ulger, K. (2018). The effect of problem-based learning on the creative thinking and critical thinking disposition of students in visual arts education. *Interdisciplinary Journal of Problem-Based Learning*, *12*(1), 3–6. https://doi.org/10.7771/1541-5015.1649

UNESCO-UNEVOC. (2020). Skills development for renewable energy and energy efficient jobs. *UNESCO-UNEVOC International Centre for TVET*, 56. Retrieved from https://unevoc.unesco.org/i/697

Virijai, F., Asrizal, A., & Festiyed, F. (2022). Meta analisis pengaruh bahan ajar terhadap kemampuan berpikir kritis siswa Dalam menghadapi era revolusi 4.0. *Jurnal Penelitian Pembelajaran Fisika*, *8*(1), 54. https://doi.org/10.24036/jppf.v8i1.115806

Wayudi, M., Suwatno, S., & Santoso, B. (2020). Kajian analisis keterampilan berpikir kritis siswa Sekolah Menengah Atas. *Jurnal Pendidikan Manajemen Perkantoran*, *5*(1), 67–82. https://doi.org/10.17509/jpm.v5i1.25853

Widyapuraya, N. W., Suryana, A. L., Suyanta, S., & Wilujeng, I. (2023). Profil keterampilan berpikir kritis siswa SMP Negeri 1 Juwangi pada pembelajaran IPA. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1368–1374. https://doi.org/10.29303/jppipa.v9i3.1723

Wijayanti, R., & Siswanto, J. (2020). Profil kemampuan berpikir kritis siswa SMA pada materi sumber-sumber energi. *Jurnal Penelitian Pembelajaran Fisika*, *11*(1), 109–113. https://doi.org/10.26877/jp2f.v11i1.5533

Wiyono, K., Zulherman, Z., Saparini, S., Ariska, M., Khoirunnisa, R., & Zakiyah, S. (2020). Moodle-based e-learning model for critical thinking in the lesson of electromagnetic induction. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *6*(2), 237–246. https://doi.org/10.21009/1.06210

Yang, X., Pang, J., Teng, F., Gong, R., & Springer, C. (2021). The environmental co-benefit and economic impact of China's low-carbon pathways: Evidence from linking bottom-up and top-down models. *Renewable and Sustainable Energy Reviews*, *136*(September 2020), 110438. https://doi.org/10.1016/j.rser.2020.110438

Zorluoglu, S. L., & Guven, C. (2020). Analysis of 5th grade science learning outcomes and exam questions according to revised Bloom taxonomy. *Journal of Education Issues*, *6*(1), 58–69. https://doi.org/10.5296/jei.v6i1.16197