



Contribution of critical thinking skills on concept understanding biology students at the implementation learning model



Bea Hana Siswati ^{*}, Primadya Anantyartha², Ahmad Humaidi³, Iwan Wicaksono¹

¹University of Jember, Jember, Indonesia

²University of Insan Budi Utomo Malang, Malang, Indonesia

³Hamzanwadi University, Lombok, Indonesia

* Corresponding author: beahana.fkip@unej.ac.id

Article Info

Article History:

Received 23 August 2023

Revised 02 October 2023

Accepted 12 November 2023

Published 30 November 2023

Keywords:

Critical Thinking skills
Concept Understanding
5E Instructional Model
Case Method



ABSTRACT

Gaining insight into how critical thinking influences the comprehension of concepts can facilitate students in achieving a more profound and meaningful learning experience. This study aims to investigate the contribution of critical thinking skills to the concept understanding of Class X Senior High School Students at the implementation of the 5E Instructional Model accompanied by the Case Method. This research method uses a correlational research design. The research sample consisted of one Class X Senior High School Student who applied the 5E Instructional Model accompanied by the Case Method. Data analysis using a simple regression correlation test with the help of SPSS for Windows 23. The results showed that students involved in the 5E Instructional Model accompanied by the Case Method experienced significant improvement in their critical thinking skills and concept understanding. This research provides a significant understanding of the dynamic connection between the abilities of critical thinking and the comprehension of concepts among students in senior high school.

Copyright © 2023, Siswati et al

This is an open access article under the [CC-BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license



Citation: Siswati, B.H., Anantyartha, P., Humaidi, A., & Wicaksono, I. (2023). Contribution of critical thinking skills on concept understanding biology students at the implementation learning model. *JPBIO (Jurnal Pendidikan Biologi)*, 8(2), 283-292. DOI: <https://doi.org/10.31932/jpbio.v8i2.2756>

INTRODUCTION

In the era of rapid technological advancement and the abundance of information, the significance of critical thinking skills within the realm of education has become paramount. These skills encompass a student's capacity to meticulously analyze, assess, and amalgamate information in a coherent and reasoned manner. This equips students to cultivate profound comprehension,

tackle intricate predicaments, and make well-founded decisions (Elmawati & Juandi, 2022; Ho et al., 2023).

Critical thinking skills play a pivotal role in education and the maturation of learners. They empower learners to delve deeply into information. This enables them to scrutinize prevailing arguments, data, facts, and evidence, thereby identifying strengths and vulnerabilities in thoughts or viewpoints (Febliza et al., 2023). This adeptness aids them in achieving a superior grasp of situations before formulating conclusions or choices. The acquisition of critical thinking skills furnishes learners with the adeptness to tackle challenges and quandaries effectively (Saleem & Masadeh, 2021). This ability permits them to methodically dissect situations, recognize alternative remedies, appraise potential outcomes, and select the optimal approach to attain desired outcomes (Changwong et al., 2018).

Furthermore, alongside critical thinking, a robust comprehension of concepts establishes a sturdy foundation for subsequent learning endeavors. When learners possess a firm grip on fundamental concepts, they are better poised to grasp and master more intricate material at advanced stages (Setiyoadji et al., 2021). Profound comprehension often fosters self-assurance and enthusiasm within learners, propelling them to engage in further learning. A sound understanding engenders sentiments of contentment and accomplishment, thereby heightening their enthusiasm and motivation to explore (Dumitru, 2019).

The 5E Instructional Model accompanied by the Case Method in this research is applied to virus material. This model was implemented because it would make learning about viruses more relevant and real for students. They can see how viruses impact everyday life, such as pandemics, disease outbreaks, or specific viral infections relevant to their environment. Case study models can help students understand more deeply about viruses, including how they spread, control, impact on human health, and economic impact. They can see the social, economic, and health impacts of a particular virus outbreak (Sankaran, 2021).

In the contemporary landscape of education, innovation, and efficacious learning methodologies take center stage. One such pedagogical model that has demonstrated effectiveness in cultivating critical thinking skills is the 5E Instructional Model (Ruiz-Martín & Bybee, 2022). This model comprises the phases of Engage, Explore, Explain, Elaborate, and Evaluate, strategically designed to galvanize active comprehension and problem-solving among students (Ahmad et al., 2018).

The 5E learning model nurtures critical thinking, collaboration, communication, and creativity among students. It serves as a conduit for fostering crucial 21st-century competencies such as analytical thinking, problem-solving, teamwork, and ingenuity (Jummiah et al., 2021). This model emphasizes diverse pedagogical techniques, encompassing experiments, simulations, group discussions, projects, and presentations (Cahyarini et al., 2016). By infusing variety into the learning process, it kindles students' interest and enthusiasm, ultimately augmenting their motivation and active participation. The expectation is that the 5E learning model can hone students' critical thinking skills, thereby cascading into an enhancement of their grasp on concepts (Turan, 2021).

In addition, several studies reveal the effectiveness of case method learning (Andayani et al., 2022). The case method learning approach has also been proven effective in developing students' critical thinking skills (Hodijah et al., 2022). In Case Method, students are given case studies or real situations that require them to apply their knowledge and critical thinking skills to analyze problems, find good solutions, and make the right decisions (Ananda, 2018; Kusumantoro et al., 2022).

Although many studies have been conducted on critical thinking skills and innovative learning models, there have not been many studies investigating the contribution of critical thinking

skills to Concept Understanding of high school grade X students at the implementation of the 5E Instructional Model accompanied by Case Method. Therefore, this study aims to fill this knowledge gap by analyzing the contribution of critical thinking skills to students' Concept Understanding using the approach.

With a better understanding of the relationship between critical thinking skills and Concept Understanding, teachers and policymakers can develop more effective learning strategies to improve the quality of education. This research is expected to provide new insights into curriculum development and learning practices that can improve critical thinking skills and Concept Understanding of class X Senior High School students.

RESEARCH METHODS

Research Design

students' Critical Thinking Skills and their ability to Concept Understanding. Assessment of Critical Thinking Skills and Concept Understanding was conducted through a written test. The depiction of the connection between the predictors and the criteria is illustrated in Figure I.



Figure I. The relationship between Critical Thinking Skills and Concept Understanding

Population and Samples

The total number of participants in this research encompassed 145 students enrolled in Class X Senior High School SMAN 1 Jember during the second semester of the academic year 2022/2023. The selected sample consisted of 32 students from class X Science, chosen through a random sampling method. Random sampling can increase the researcher's ability to generalize research results to a larger population. If these samples are selected randomly, researchers have a better chance of producing results that can be applied to a broader population.

Instruments

Critical Thinking Skills Test: This instrument consists of a series of questions designed to measure students' ability to think critically. Critical thinking skills questions involve the following indicators, namely students' ability to analyze, evaluate, and synthesize information logically and rationally. There are 8 critical thinking skills and concept understanding questions in the form of essay tests. This instrument has been tested for validity and reliability before use. The results of the validity test show that the 8 questions used in this research are valid and based on the results of the reliability test using Cronbach's Alpha analysis, it shows the number 0.812, which means the questions have high reliability. A Student Concept Understanding Test was also designed in this study. The class applies the 5E Instructional Model accompanied by the Case Method in the learning process. Teachers design and implement learning activities that refer to the stages of engaging, exploring, explaining, elaborating, and evaluating. Case studies or real situations will be used as the basis to develop students' critical thinking skills.

Procedures

This study was structured into two distinct phases: the preparatory phase and the implementation phase. The initial preparation stage encompassed activities such as observation, obtaining research permits, and developing educational materials like syllabi, lesson plans, worksheets, rubrics, and implementation guidelines. The subsequent implementation phase entailed

executing the learning process in alignment with the lesson plan, employing the guided inquiry approach, and administering a posttest. The research was carried out over 3 meetings on virus material. Following data collection, an analysis of the data was conducted, comprising both preliminary assessments and hypothesis testing. An image of the research chart can be seen in Figure 2.

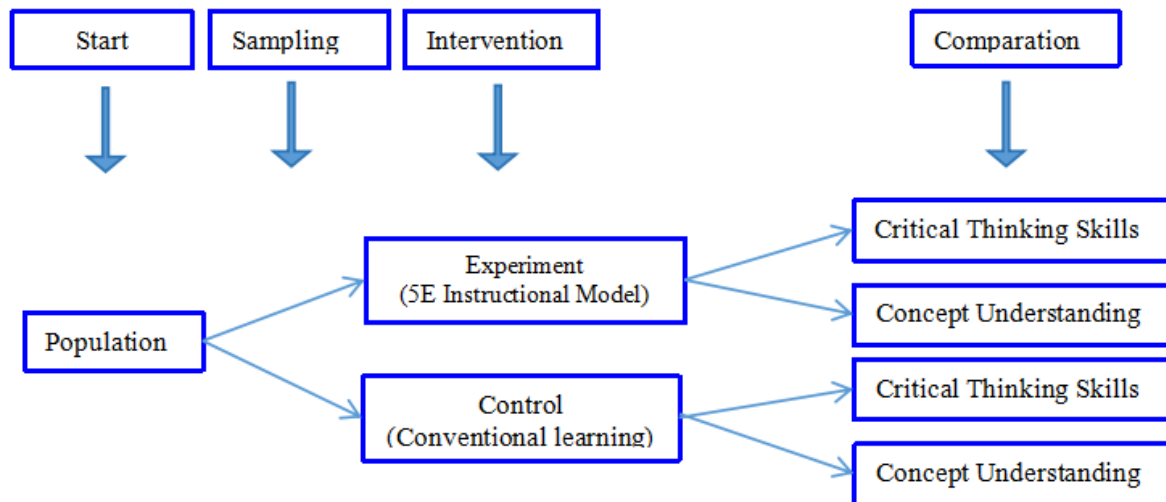


Figure 2. Research flow chart

Data Analysis

The initial assessments involved conducting tests to ensure the fulfillment of prerequisites, which encompassed examining the normality, linearity, and homoscedasticity of the data. Subsequent to confirming the normal and linear distribution of the data, the next step involved hypothesis testing. In this regard, the analysis employed a regression correlation test utilizing SPSS Version 23.0.

RESULTS

After conducting research on the contribution of critical thinking skills to the Concept Understanding of high school grade X students at the implementation of the 5E Instructional Model accompanied by the Case Method, the research results show interesting findings. Data analysis also revealed a positive relationship between critical thinking skills and students' concept understanding. The higher the level of students' critical thinking skills, the higher the Concept Understanding they achieve. This shows the importance of developing critical thinking skills in improving students' understanding and academic achievement. Table I-3 shows the summary of the simple linear regression test between critical thinking skills and concept understanding of grade X high school students.

Table I. Summary of the contribution of critical thinking skills with students' concept understanding

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
I	.543 ^a	.295	.272	4.91928

a. Predictors: (Constant), critical thinking

Table 2. Anova test of the relationship between critical thinking skills and students' concept understanding

ANOVA ^a						
	Model	Sum of Squares	df	Mean Square	F	Sig.
I	Regression	304.239	1	304.239	12.572	.001 ^b
	Residual	725.980	30	24.199		
	Total	1030.219	31			

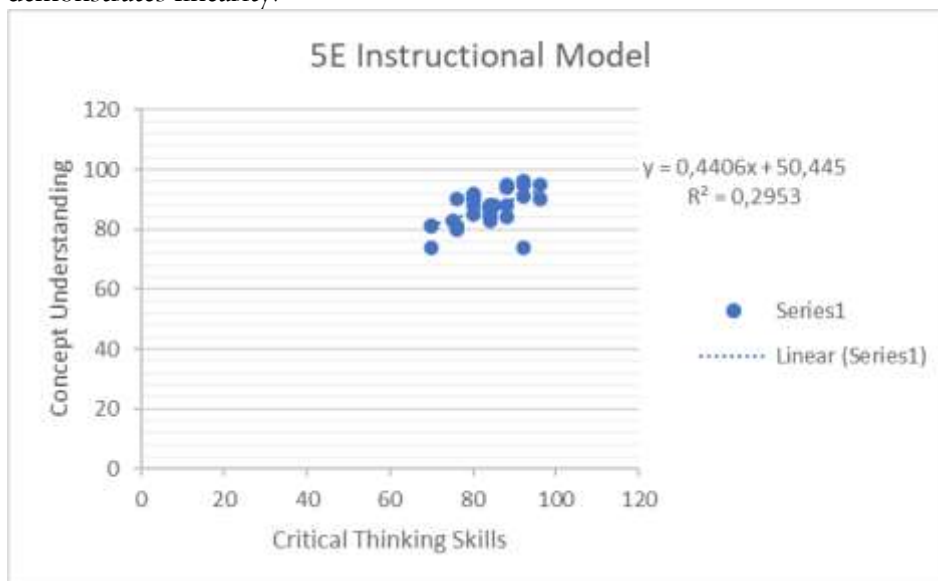
a. Dependent Variable: ConceptUnderstanding
b. Predictors: (Constant), critical thinking

Table 3. The correlation coefficient between critical thinking skills and students' concept understanding

Coefficients					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
I	(Constant)	50.445	10.390		4.855 .000
	CriticalThinking	.441	.124	.543	3.546 .001

a. Dependent Variable: ConceptUnderstanding

Table 1. This shows that the R square value is 0.295, this means that the contribution of critical thinking skills to students' concept understanding is 29.5%. While the other 70.5% is the contribution of other factors that are not measured in this study. Table 2 shows that the sig. value is 0.001 which means <0.05 which means that the research hypothesis is accepted. There is a significant relationship between critical thinking skills and concept understanding of X-grade high school students at the implementation of the 5E Instructional Model accompanied by the Case Method. Table 3 shows the value of the regression equation for the relationship between critical thinking skills and concept understanding is $Y = 0.441X + 50.445$. The results of this study provide strong support for the importance of applying the 5E Instructional. The assessment of the assumption of linearity was conducted to ascertain the linear distribution of data between the X and Y variables. As depicted in Figure 1, the data's distribution or the correlation between X and Y demonstrates linearity.

**Figure 3.** Linearity in data distribution

DISCUSSION

The results of the research on the contribution of critical thinking skills to the concept understanding of high school grade X students at the implementation of the 5E Instructional Model accompanied by the Case Method provide significant insight into the importance of critical thinking skills in improving students' concept understanding. In this discourse, we will delve into specific key points that have surfaced from the research findings. This is in line with research conducted by (Omotayo & Adeleke, 2017; Ong et al., 2020; Sotáková & Ganajová, 2023) who examined the effectiveness of the 5E instructional model in learning. This study underscores the effectiveness of employing the 5E Instructional Model in conjunction with the Case Method for enhancing students' grasp of concepts. The model furnishes a methodical and structured framework that involves students in tasks that foster active participation, problem resolution, and critical thinking (Ong et al., 2020). This leads to a more profound comprehension and the capacity of students to correlate concepts with real-world scenarios.

The utilization of the 5E Instructional Model accompanied by the Case Method bears substantial potential for heightening critical thinking skills and bolstering concept comprehension among students. Its efficacy arises from its cultivation of engaged student participation (Ünlü & Dökme, 2022). The 5E Learning Model—comprising the stages of Engage, Explore, Explain, Elaborate, and Evaluate—facilitates students' active immersion in the learning process (Naguib, 2019). During the Engage phase, students are presented with questions or challenges that pique their interest and curiosity, thereby motivating them to participate actively and employ their critical thinking abilities (Barik, 2022).

This educational approach also imparts Practical and Contextual Experience. Throughout the Explore and Elaborate stages, students are allowed to conduct experiments, explore real-life scenarios, or tackle problems that correlate with the concepts being taught. The integration of Case studies or real-world scenarios within the Case Method offers a comprehensive and pertinent context for students to apply their knowledge and employ their critical thinking skills. The Case Method prompts students to analyze diverse information sources, evaluate arguments, and make decisions grounded in critical thinking. This process contributes to the enhancement of students' capacity to scrutinize information in a more astute and unbiased manner (Ruiz-Martín & Bybee, 2022).

This instructional model also encourages collaborative group work, discussions, and knowledge sharing. In the context of the Case Method, students can articulate their viewpoints, juxtapose opinions, and collaborate in finding optimal solutions (Hu et al., 2017). This discourse stimulates critical thinking, embraces multiple perspectives, and broadens students' comprehension of concepts (Naguib, 2019). The Evaluation stage within the 5E model, coupled with the application of the Case Method, affords students the chance to reflect on their comprehension, synthesize information, and draw conclusions. This prompts them to link newly acquired concepts with prior knowledge and experiences, consequently deepening their understanding and fortifying their critical thinking prowess (Barik, 2022).

The outcomes of this study affirm the substantial role of critical thinking skills in augmenting students' concept comprehension (Febaliza et al., 2023). Case studies, or the Case Method, substantively contribute to the advancement of students' critical thinking abilities (Sutarto et al., 2022). This method introduces students to intricate scenarios that necessitate in-depth analysis, knowledge application, and problem resolution. As students grapple with multifaceted challenges, their critical thinking and reasoning abilities are exercised (Joharis et al., 2015). By incorporating the Case Method into the 5E Instructional Model, students are granted the opportunity to apply their critical thinking skills in a pertinent and captivating context (Ririen, 2020).



Critical thinking serves a pivotal role in enhancing students' concept comprehension. This cognitive process entails delving deeply into information (Rubiyanti, 2020). Students who possess strong critical thinking capabilities transcend the surface-level presentation of facts or data. They discern interconnections between concepts, deconstruct information into elemental components, and comprehend the implications of the information at hand (A'yun et al., 2020).

Furthermore, critical thinking entails the ability to assess and sift through pertinent information (Rahardhian, 2022). Students develop the faculty to gauge the credibility of information sources, differentiate between objective facts and subjective opinions, and discern biases or gaps within arguments (Trúsiková & Velmovská, 2022). By posing pertinent inquiries, students initiate a more comprehensive investigative process, thereby augmenting their conceptual understanding. By thinking critically, students don't merely accept information at face value; instead, they actively seek answers and cultivate a deeper comprehension (Suteja & Setiawan, 2022).

Equally, critical thinking encompasses the proficiency to tackle problems. Students with well-honed critical thinking abilities leverage their knowledge and insight to identify challenges, devise strategies for resolution, and apply pertinent concepts (Sari & Prasetyo, 2021). Throughout this process of problem-solving, students delve further into their understanding of concepts and witness their practical application within real-world contexts (Heard et al., 2020).

The findings of this study carry significant implications for educators and educational policymakers. Integrating the 5E Instructional Model alongside the Case Method into the curriculum presents a viable avenue for enhancing critical thinking abilities and solidifying concept comprehension among tenth-grade high school students. Educators must foster activities that elicit reflective thought, analytical assessment, and problem-solving endeavors within students. Likewise, the creation of learning materials that align with real-world situations emerges as a pertinent concern.

CONCLUSION

This research reaches the conclusion that the integration of critical thinking skills significantly contributes (sig. 0,001) to the comprehension of concepts among high school grade X students, especially when combined with the application of the 5E Instructional Model alongside the Case Method. The contribution of critical thinking skills to students' understanding of biological concepts is 29.5%. The study's findings underscore that honing critical thinking abilities can lead to an enhancement in students' grasp of academic subjects, their capacity to apply acquired knowledge to real-world situations, and their adeptness in resolving problems.

Furthermore, this study uncovers a positive correlation between students' critical thinking skills and their understanding of concepts. The research establishes a direct connection: as students' critical thinking skills advance, their proficiency in comprehending concepts also advances in tandem. This highlights the paramount importance of incorporating the fostering of critical thinking skills within the framework of educational design. Consequently, it is of utmost significance for educators and educational policymakers to allocate considerable attention to nurturing critical thinking competencies during the process of designing learning approaches.

REFERENCES

- A'yun, Q., Rusilowati, A., & Lisdiana. (2020). Improving Students' Critical Thinking Skills through the STEM Digital Book. *Journal of Innovative Science Education*, 9(2), 237–243. Retrieved from <https://journal.unnes.ac.id/sju/index.php/jise/article/view/35260>
- Ahmad, N., Shaheen, N., & Gohar, S. (2018). 5E Instructional Model: Enhancing Student's Academic Achievement in the Subject of General Science at Primary Level. *Sir Syed Journal*



- of Education & Social Research (SJESR), 1(January). Retrieved from <https://sjesr.org.pk/articles/01-v1-2018/issue-01/11-Vol-01-Issue-01-Jan-June-2018-P-169-181.pdf>
- Ananda, R. (2018). The Effectiveness of the Implementation of the Case Methods in the Learning Evaluation Course at the State Islamic University of North Sumatera. *Jurnal Ilmiah Peuradeun*, 6(1), 103. Retrieved from <https://doi.org/10.26811/peuradeun.v6i1.171>
- Andayani, E., Mustikowati, R. I., Wahyu, S., Setiyowati, & Firdaus, R. M. (2022). Case method: Mengoptimalkan critical thinking, creativity communication skills dan collaboratively mahasiswa sesuai MKKM di era abad 21. *Jurnal Penelitian Dan Pendidikan IPS (JPPI)*, 16(1), 52–60. Retrieved from <https://ejournal.unikama.ac.id/index.php/JPPI/article/view/6973/3460>
- Barik, S. (2022). *Reviews on Effectiveness of 5E Model in Teaching Science at Secondary Level*. 12(6), 25–28.
- Cahyarini, A., Rahayu, S., & Yahmin, Y. (2016). The effect of 5E learning cycle instructional model using socioscientific issues (SSI) learning context on students' critical thinking. *Jurnal Pendidikan IPA Indonesia*, 5(2), 222–229. Retrieved from <https://doi.org/10.15294/jpii.v5i2.7683>
- Changwong, K., Sukkamart, A., & Sisan, B. (2018). Critical thinking skill development: Analysis of a new learning management model for Thai high schools. *Journal of International Studies*, 11(2), 37–48. Retrieved from <https://doi.org/10.14254/2071-8330.2018/11-2/3>
- Dumitru, C. T. (2019). *Understanding learning. Exploring the concept of learning*. August.
- Elmawati, E., & Juandi, D. (2022). Mathematical Critical Thinking Ability In Indonesia: Systematic Literature Review (SLR). *Symmetry: Pasundan Journal of Research in Mathematics Learning and Education*, 7(2), 210–221. Retrieved from <https://doi.org/10.23969/symmetry.v7i2.6426>
- Febliza, A., Afdal, Z., & Copriady, J. (2023). Improving Students' Critical Thinking Skills: Is Interactive Video and Interactive Web Module Beneficial? *International Journal of Interactive Mobile Technologies*, 17(3), 70–86. Retrieved from <https://doi.org/10.3991/ijim.v17i03.34699>
- Heard, J., Scoular, C., Duckworth, D., Ramalingam, D., & Teo, I. (2020). Critical Thinking : Skill Development Framework. *Australian Council for Educational Research*, 1–23. Retrieved from <https://core.ac.uk/download/pdf/287816564.pdf>
- Ho, Y. R., Chen, B. Y., & Li, C. M. (2023). Thinking more wisely: using the Socratic method to develop critical thinking skills amongst healthcare students. *BMC Medical Education*, 23(1), 173. Retrieved from <https://doi.org/10.1186/s12909-023-04134-2>
- Hodijah, S., Hastuti, D., & Zevaya, F. (2022). Implementasi model case method dalam meningkatkan inovasi pembelajaran mahasiswa dan kemampuan berpikir kritis pada mata kuliah teknik perdagangan Internasional. *Jurnal Paradigma Ekonomika*, 17(2), 477–484. Retrieved from <https://doi.org/10.22437/jpe.v17i2.20895>
- Hu, J., Gao, C., & Liu, Y. (2017). Study of the 5E Instructional Model to Improve the Instructional Design Process of Novice Teachers. *Universal Journal of Educational Research*, 5(7), 1257–1267. Retrieved from <https://doi.org/10.13189/ujer.2017.050718>
- Joharis, M., Wasilah, A., Rahmah, T. A., & Gita, M. R. (2015). *The Designs of Case Method Based and Project Based Learnings in Indonesian Literature Course*. 395–400.
- Jummiah, R. S., Hutasuhut, S., & Rahmadana, M. F. (2021). The 5E Learning Cycle Model as Development of Booklet Teaching Materials at SMK BM Panca Budi 2 Medan. *Ekuitas: Jurnal Pendidikan Ekonomi*, 9(2), 399. Retrieved from <https://doi.org/10.23887/ekuitas.v9i2.40947>



- Kusumantoro, Jaenudin, A., & Melati, S.I. (2022). Case-Based Interactive E-Module: an Alternative Supplement to Increase Student Learning Motivation. *Journal of Education Technology*, 6(4), 674–684. Retrieved from <https://doi.org/10.23887/jet.v6i4.47254>
- Naguib, S. M. (2019). *Using the 5 E's Instructional Model to Enhance English Grammar Learning of Secondary Stage Students. 2019*, 1–37.
- Omotayo, S. A., & Adeleke, J. O. (2017). The 5e Instructional Model: a Constructivist Approach For Enhancing Students' Learning Outcomes In Mathematics Stephen Akinyemi Omotayo & Joshua Oluwatoyin Adeleke. *Jiste*, 21(2), 15–26. Retrieved from <https://files.eric.ed.gov/fulltext/EJ1176946.pdf>
- Ong, E. T., Keok, B. L., Yingprayoon, J., Singh, C. K. S., Borhan, M. T., & Tho, S. W. (2020). The effect of 5E inquiry learning model on the science achievement in the learning of “Magnet” among year 3 students. *Jurnal Pendidikan IPA Indonesia*, 9(1), 1–10. Retrieved from <https://doi.org/10.15294/jpii.v9i1.21330>
- Rahardhian, A. (2022). Kajian Kemampuan Berpikir Kritis (Critical Thinking Skill) Dari Sudut Pandang Filsafat. *Jurnal Filsafat Indonesia*, 5(2), 87–94. Retrieved from <https://ejournal.undiksha.ac.id/index.php/JFI/article/view/42092%0Ahttps://ejournal.undiksha.ac.id/index.php/JFI/article/download/42092/22276>
- Ririen, D. (2020). Implementasi Pembelajaran Berbasis Case Method Dalam Meningkatkan Kemampuan Berkomunikasi dan Critical Thinking. *Jurnal Dedikasi Pendidikan*, 5(3), 248–253.
- Rubiyanti, Badarudin, & Eka, K.I. Improving Critical Thinking Skills and Learning Independence Using Problem Based Learning Based On Science Literation. *Indonesian Journal of Educational Studies (IJES)*, 34-43. Retrieved from <http://ojs.unm.ac.id/index.php/Insani/index>
- Ruiz-Martín, H., & Bybee, R. W. (2022). The cognitive principles of learning underlying the 5E Model of Instruction. *International Journal of STEM Education*, 9(1). Retrieved from <https://doi.org/10.1186/s40594-022-00337-z>
- Saleem, T., & Masadeh, Y. (2021). *Journal of English Language Teaching UNP JOURNAL EFL Teachers Critical Thinking Behaviors and the Challenges Facing them in Classrooms. 10(2)*, 185–203. Retrieved from <https://doi.org/10.24036/jelt.v10i2.112215>
- Sankaran, N., & Weiss, R.A. (2021). Viruses: Impact on Science and Society, *Encyclopedia of Virology (Fourth Edition)*. Academic Press: 671-680. Retrieved from <https://doi.org/10.1016/B978-0-12-814515-9.00075-8>
- Sari, D. M. M., & Prasetyo, Y. (2021). Project-based-learning on critical reading course to enhance critical thinking skills. *Studies in English Language and Education*, 8(2), 442–456. Retrieved from <https://doi.org/10.24815/siele.v8i2.18407>
- Setiyoaji, W. T., Supriana, E., Latifah, E., Purwaningsih, E., & Praptama, S. S. (2021). *The Effect of Learning Simulation Media on the Students' Critical Thinking Skills in Vocational School during Online Learning in the Covid-19 Pandemic. 9(3)*, 243–252. Retrieved from <https://doi.org/10.26618/jpf.v9i3.5681>
- Sotáková, I., & Ganajová, M. (2023). The effect of the 5E instructional model on students' cognitive processes and their attitudes towards chemistry as a subject. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(9). Retrieved from <https://doi.org/10.29333/EJMSTE/13469>
- Sutarto, Hastuti, D.I., Fuster-Guillén, D., Palacios Garay, J. P., Hernández, R. M., & Namaziandost, E. (2022). The Effect of Problem-Based Learning on Metacognitive Ability in the Conjecturing Process of Junior High School Students. *Education Research International, 2022*. Retrieved from <https://doi.org/10.1155/2022/2313448>



- Suteja, S., & Setiawan, D. (2022). Students' Critical Thinking and Writing Skills in Project-Based Learning. *International Journal of Educational Qualitative Quantitative Research*, 1(1), 16–22. Retrieved from <https://doi.org/10.58418/ijeqqr.v1i1.5>
- Trúsiková, A., & Velmovská, K. (2022). Indicators of critical thinking and physics experiments. *Journal of Physics: Conference Series*, 2297(1). Retrieved from <https://doi.org/10.1088/1742-6596/2297/1/012011>
- Turan, S. (2021). Pre-Service Teacher Experiences of the 5E Instructional Model: A Systematic Review of Qualitative Studies. *Eurasia Journal of Mathematics, Science and Technology Education*, 17(8), 1–16. Retrieved from <https://doi.org/10.29333/EJMSTE/111102>
- Ünlü, Z. K., & Dökme, İ. (2022). *A systematic review of 5E model in science education : proposing a skill-based STEM instructional model within the 21-st century skills*. Retrieved from <https://doi.org/10.1080/09500693.2022.2114031>