International Journal of Essential Competencies in Education
https://journal-center.litpam.com/index.php/ijece/index

Dec. 2022 Vol. 1, No. 2
e-ISSN: 2962-2131
pp. 84-94

Efforts to Drill the Critical Thinking Skills on Momentum and Impulse Phenomena Using Discovery Learning Model

Baiq Hanum Ekayanti, Saiful Prayogi, Syifa'ul Gummah *

Department of Physics Education, Mandalika University of Education, Mataram, Indonesia

*Correspondence: syifaulgummah@undikma.ac.id

Article Info

Article History
Received: August 2022;
Revised: October 2022;
Published: December 2022

Keywords
Discovery learning model;
Traditional teaching;
Critical thinking skills;
Momentum and impulse

Abstract

Critical thinking is needed as a guarantee of student success in solving a problem, and critical thinking training starts from students' learning experiences when they are in school. It is believed that one's skills in critical thinking influence student success in a broader spectrum of learning outcomes. It's just that the facts on the ground show that students are less well-established in critical thinking in science learning, this is based on the results of observations on teaching relating to the phenomenon of momentum and impulse. Overcoming this, it is important to provide learning experiences for students to train their critical thinking skills. The current study aims to implement the discovery learning model on materials related to momentum and impulse phenomena, and evaluate its impact on students' critical thinking skills. Through experimentation (nonequivalent control group design) studies have been carried out by including a control group (traditional teaching) as a comparison. Students' critical thinking skills are measured using adequate instruments and have met the elements of validity. Study data were analyzed descriptively and statistically. The results of the study show that students' critical thinking skills have increased after learning using the discovery learning model. Based on the size of the pre-post test, students' critical thinking skills increased from quite critical to critical, the increase (gain) was in the moderate category. Unlike the case with traditional teaching, students' critical thinking skills remain with less critical criteria. The difference in the improvement of critical thinking between the two groups (discovery learning vs. traditional teaching) was statistically analyzed. The results of the analysis confirm the research hypothesis tested that there are significant differences in critical thinking skills between groups (discovery learning model vs. traditional teaching) in the material of momentum and impulse.

https://doi.org/10.36312/ijece.v1i2.1250

How to Cite

Ekayanti, B. H., Prayogi, S., & Gummah, S. (2022). Efforts to Drill the Critical Thinking Skills on Momentum and Impulse Phenomena Using Discovery Learning Model. *International Journal of Essential Competencies in Education*, *1*(2), 84–94. https://doi.org/10.36312/ijece.v1i2.1250

INTRODUCTION

Learning science in the 21st century demands a drastic development of students in critical thinking. This is in line with the demand for and also the world's demand that is growing faster and faster, which wants every individual who is engaged in science to be able to think critically in solving routine problems (Forawi, 2016). On the one hand, the current science curriculum also requires students to play an active role in the learning process (Salaria, 2017). The activeness of students is assessed from their role in the learning process, such as

asking questions, answering questions, and giving responses. Student activity is a form of support in their role as independent learners (Li et al., 2021), where students try to learn everything of their own free will and ability or effort. In this case the teacher plays an important role as a guide, motivator, and facilitator. In the science learning process, teachers have an important role in creating learning conditions that encourage students' active roles and sharpen students' critical thinking (Hajhosseini et al., 2016).

The current teaching paradigm is oriented towards the construction of activities that invite students to think (Pollarolo et al., 2022). One's skills in critical thinking affect student success in a broader spectrum of learning outcomes (Erikson & Erikson, 2019). Critical thinking is a cognitive process that refers to rational and reflective ways of thinking that focus on deciding what to believe or do (Ennis, 2018). Someone who has critical thinking is indicated by the skills of interpretation, analysis, inference, evaluation, explanation, and self-regulation (Facione, 2020). Practicing critical thinking in students must be done and its success is an indication that the learning process has been carried out perfectly. However, leading students to think critically is not easy. Even in developed countries, such as in the United States, teachers' efforts to grow and develop students' critical thinking skills are still experiencing difficulties (Enabulele, 2011). The main factors that are most suspected of being an obstacle to students' critical thinking training are the teacher's teaching methods that do not lead students to think critically (Alwadai, 2014), and curriculum designs that do not promote a student-centered collaborative environment (Boholano, 2017). Concern about students' failure to think critically has been reviewed in detail in previous studies, this is mainly addressed to the teacher's inadequate background knowledge about critical thinking training to students (Khalid et al., 2021).

To ensure conditions are similar to the findings of previous studies (e.g., Alwadai, 2014; Enabulele, 2011; Khalid et al., 2021), we conducted observations of science learning in schools on momentum and impulse material, and conducted interviews with teachers. Several problems were identified, including the teacher's teaching method in conveying learning material which was still not innovative, monotonous, lack of involvement or role of students as independent learners, and lack of stimulation for students to think deeply. It should be noted that critical thinking is a consequence of the results of learning methods and learning content (Bataineh & Alazzi, 2009). That mean, if the ways of teaching a material content do not lead to the goal of developing students' critical thinking, students tend to be unable to think critically. The phenomena studied in momentum and impulse material are closely related to everyday life, so they are often used as predictors in uncovering problem solving skills (Yuberti et al., 2019). However, misconceptions are often found in teaching, especially when learning is done using traditional methods (Sarıoğlan & Küçüközer, 2014). Students' critical thinking skills in momentum and impulse material have been analyzed in a previous study (Dalila et al., 2022), where the findings were that the acquisition of critical thinking skills in the percentage parameter was 37.48% (in the low category). This finding is certainly contrary to expectations related to the achievement of critical thinking competence in students.

Referring to these conditions, it takes great effort to create learning conditions that invite students to think critically. This is where the need for the intervention of an innovative learning model. In training and improving students' critical thinking skills, it is necessary to apply innovative learning models that are able to create an interactive learning atmosphere (Prayogi et al., 2018a), and encourage students to think deeply to be able to solve problems (Evendi et al., 2022). One learning model that meets these criteria is discovery learning. Another study calls it scientific discovery learning, if it is learned in a scientific environment

(Kistner et al., 2016). In discovery learning, students have the opportunity to be actively involved in learning. The teacher encourages students to gain experience by doing activities that allow them to discover concepts and principles related to learning materials.

Discovery learning occurs when students have to find knowledge about the target concept (in learning materials) in a way that is self-regulated by students (Bruner, 1961 in Künsting et al., 2013). Discovery learning involves asserting and testing hypotheses in self-regulated cycles of planning, executing, and evaluating scientific experiments (Künsting et al., 2011). Previous studies have recommended the application of discovery learning to foster critical thinking skills (Sukartiningsih et al., 2019). Discovery learning shows a promising average effect on students' critical thinking skills and conceptual understanding (Muhali et al., 2021). Other studies reveal its feasibility in training students' critical thinking skills and scientific processes (Syahmel & Jumadi, 2019). The combination with interactive multi-media has been researched and has the potential to train students' critical thinking (Yosefa et al., 2021). In the current study, we seek intensive training for students to be able to think critically on momentum and impulse phenomena by implementing a discovery learning model.

Specifically, the purpose of this research is to implement the discovery learning model in material related to the phenomenon of momentum and impulse, and evaluate its impact on students' critical thinking skills. Referring to these objectives, the hypothesis in this study is that the discovery learning model has a significant impact on improving students' critical thinking skills in the material of momentum and impulse.

METHOD

Study design

This study is a quasi-experimental research with nonequivalent control group design. In this design the experimental group and the control group were not randomly selected. Participants were selected purposively, then they were members of the experimental and control groups. The experimental group treatment is teaching with the discovery learning model, while the control group treatment is traditional teaching. Both groups were given a pre-test to determine critical thinking skills at the beginning, and after further treatment both groups were given a post-test to determine critical thinking skills at the end. Research design as follows.

Group	Pretest	Treatment	Postest
Experimental	O_1	X_1 (discovery learning)	O_2
Control	O_1	X_2 (traditional teaching)	O_2

Participants

The research participants were 44 students of class X-science, they were divided into two groups and each group consisted of 22 students. Both groups followed a series of learning programs on momentum and impulse material. The learning program is carried out in four meetings for 2 weeks. The duration of learning activities for one meeting is 2 x 45 minutes.

Instruments

To support the implementation of the research, research instruments and learning tools were prepared for two types of treatment (discovery learning and traditional teaching). The research instrument in the form of an essay test was employed to measure students' critical thinking skills. The test instrument contains indicators according to (Facione, 2020), namely: interpretation, analysis, inference, evaluation, explanation, and self-regulation. The

learning device prepared is the learning implementation plan. Instruments for testing critical thinking skills and learning tools, both of which were tested for validity (expert validation). The result is that critical thinking skills test instruments and learning tools are valid and feasible to be used in research. These results are supported by the empirical validity test of the critical thinking skills test instrument. Instrument validity data were analyzed using the Pearson correlation test. The instrument is declared valid if the results of the analysis (r count) > r table (r_{26} = 0.388) and or sig. (2-tailed) < .05. The results of the validity test are summarized in Table 1.

Table 1. The results of the instrument validity test used the Pearson correlation

	Item	Int.	Ana.	Inf.	Eva.	Exp.	Self-reg.
1	Pearson Corr.						
	Sig. (2-tailed)						
2	Pearson Corr.	.515**					
	Sig. (2-tailed)	.007					
3	Pearson Corr.	.155	.375				
	Sig. (2-tailed)	.451	.059				
4	Pearson Corr.	.205	.130	.604**			
	Sig. (2-tailed)	.315	.527	.001			
5	Pearson Corr.	.583**	.798**	.197	.063		
	Sig. (2-tailed)	.002	.000	.335	.761		
6	Pearson Corr.	.730**	.321	.199	.038	.290	
	Sig. (2-tailed)	.000	.109	.330	.852	.151	
Total score	Pearson Corr.	.770**	.689**	.642**	.481*	.707**	.649**
	Sig. (2-tailed)	.000	.000	.000	.013	.000	.000
Descripton		Valid	Valid	Valid	Valid	Valid	Valid

Furthermore, critical thinking data collection is carried out by providing valid test instruments to students as a pre-post test. The test is given at the same time.

Data analysis

Critical thinking skills data were analyzed descriptively and statistically. The range of scores for each test item is 0 (answers not found) to 4 (answers correct and supported by adequate conceptual arguments). The score per item is then calculated in its entirety and produces critical thinking score intervals from the six indicators measured, ranging from not critical to critical. Critical thinking indicator score intervals are presented in Table 2.

Table 2. Interval scores and criteria for critical thinking skills

Interval formulation	Interval score of CT (X)	Criteria
$X > X_i + Sd_i$	X > 3,21	Very critical
$X_i + 0,6\ Sd_i < X < X_i + 1,8\ Sd_i$	2,40 < X < 3,21	Critical
$X_i - 0,6\ Sd_i < X < X_i + 1,8\ Sd_i$	1,60 < X < 2,40	Quite critical
$X_i - 1,8\ Sd_i < X < X_i + 0,6\ Sd_i$	0,80 < X < 1,60	Less critical
$X < X_i - 1,8\ Sd_i$	X < 0,80	Not critical

annotation: X_i = average ideal score; Sd_i = ideal standard deviation

The score interval in Table 2 becomes a parameter to measure the criteria for critical thinking skills based on indicators. While the increase uses the Hake formulation (Hake, 1999), where the criteria for increasing the score (gain) are categorized into: low (0.00 < g < 0.30), moderate (0.30 ≤ g < 0.70), and high (0.70 ≤ g < 1.00). Statistically, different tests were employed

to analyze the difference in score increase between groups after treatment, and between groups (comparison of post-test scores).

RESULTS AND DISCUSSION

The discovery learning model has been implemented on material related to momentum and impulse phenomena. Next, the results regarding the impact on students' critical thinking skills have been analyzed. The results of the descriptive analysis of critical thinking scores and gains for the experimental group are presented in Table 3, while those for the control group are presented in Table 4.

Table 3. The results of the analysis of critical thinking skills in the experimental group

CT indicators	Pretest	Posttest	Gain	Gain criteria
Interpretation	2.59	3.20	0.43	Moderate
Analysis	2.48	3.02	0.36	Moderate
Inference	2.05	3.23	0.61	Moderate
Explanation	1.32	3.05	0.65	Moderate
Evaluation	2.00	3.09	0.55	Moderate
Self-regulation	1.09	1.86	0.26	Moderate
Average	1.92 (Quite critical)	2.91 (Critical)	0.47 (Moderate)	

In the experimental group that was taught using the discovery learning model, it was found that there was an increase in students' critical thinking skills from the pre-test to the post-test. The average increase score is 0.47 with moderate criteria. The critical thinking indicator with the highest increase was explanation (gain = 0.65), while the lowest increase compared to the other five indicators was self-regulation (gain = 0.26). However, all indicators fall on the moderate criteria. If evaluated from the results of the post-test, the highest score is not on the explanation indicator but falls on the inference indicator with a posttest score of 3.23. Calculations based on Hake's formulation (Hake, 1999), the factors that influence the increase in this score are not only in the post-test but also in the achievement of the pre-test scores. The average critical thinking score in the pre-test was 1.92 (quite critical), this increased in the post-test to 2.91 (critical) after the discovery learning model intervention.

Table 4. The results of the analysis of critical thinking skills in the control group

CT indicators	Pretest	Posttest	Gain	Gain-criteria
Interpretation	1.36	1.52	0.06	Low
Analysis	1.34	1.55	0.08	Low
Inference	1.32	2.02	0.26	Low
Explanation	1.09	1.50	0.14	Low
Evaluation	1.16	1.59	0.15	Low
Self-regulation	0.91	1.07	0.05	Low
Average	1.20 (Less critical)	1.54 (Less critical)	0.12 (Low)	

In the control group that was taught by traditional teaching found unconvincing results on improving students' critical thinking skills. The average increase score is 0.12 with moderate criteria. The critical thinking indicator with the highest increase in the control group was inference (gain = 0.26), while the lowest increase compared to the other five indicators

was self-regulation (gain = 0.05). Each indicator experienced an increase in the score of critical thinking skills with a low category. In the control group, the pretest and posttest scores both fell into the less critical criteria. This means that there is no change in students' critical thinking performance after traditional teaching interventions. Differences in students' critical thinking skills between the two learning intervention modes are presented in Figure 1.

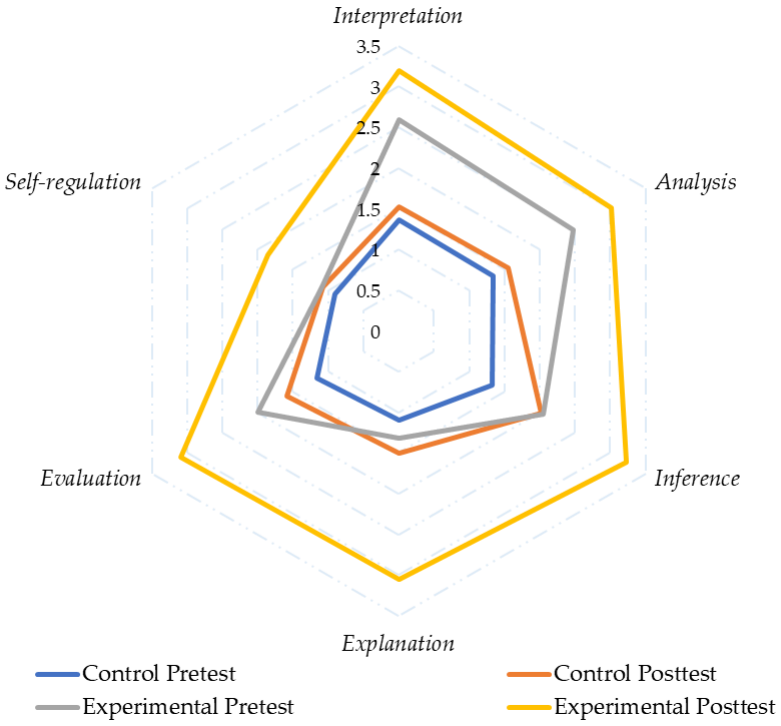

Figure 1. Differences in the range of critical thinking skills results in the pre-post test between the experimental and control groups

The results in Figure 1 show the performance of critical thinking between indicators in each group. The range of the line curve on the posttest of the experimental group outperformed the control group. The posttest score range for the experimental group ranged from 1.86 to 3.23, with an average indicator score of 2.91 (critical criteria). Unlike the control group, the range of posttest scores for the control group ranged from 1.07 to 2.02, with an average indicator score of 1.54 (less critical criteria). Furthermore, differences in individual critical thinking scores in each group were analyzed statistically. Statistical test using pair t-test and independent sample t-test. This test was employed because each group of data tested met the assumption of normality. The normality test results are presented in Table 5.

Table 5. Normality test results, p > .05

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	**Df**	**p**	**Statistic**	**df**	**p**
Pretest - experimental	.175	22	.080	.933	22	.140
Posttest - experimental	.153	22	.197	.934	22	.149
Pretest - control	.190	22	.039	.932	22	.133
Posttest - control	.143	22	.200*	.961	22	.510

The normality test results for all test group data showed p > .05, this indicated that they were normally distributed. The statistical test results using the paired t-test and independent sample t-test are presented in Table 6 and Table 7 respectively.

Table 6. Paired t-test control and experimental groups, p < .05

Pair	Test	Mean	N	Std. Dev.	t	df	p
Control	Pretest	1.1967	22	.21173	-3.991	21	.010
	Postest	1.5417	22				
Experimental	Pretest	1.9217	22	.44473	-5.434	21	.003
	Postest	2.9083	22				

Table 7. Independent sample t-test (posttest), p < .05

Group	Test	Mean	N	Std. Dev.	t	df	p
Control	Posttest	1.5417	22	.30195	-5.566	43	.000
Experimental	Posttest	2.9083	22	.52021			

The results of the paired t-test (Table 6) in the control and experimental groups both showed p <.05, meaning that in the two groups there was a significant difference between the critical thinking scores in the pre-test and post-test. The results of the independent sample t-test (Table 7) on the post-test scores of the control and experimental groups indicate that there is a significant difference in the critical thinking scores between the two. These results confirm the findings as shown in Figure 1, that the experimental group that was treated with discovery learning had a higher critical thinking score when compared to the control group that was treated with traditional teaching. The study findings have confirmed the hypothesis built in this research that the discovery learning model has a significant impact on improving students' critical thinking skills in the material of momentum and impulse.

The results of this study ensure that discovery learning is a model that can train students' critical thinking skills. In terms of its function, discovery learning has a function according to Bruner (in (Shi, 2021), one of which is to increase students' intellectual potential. One of the increases in students' intellectual potential is in the aspect of critical thinking, as the findings in this study show that the discovery processes carried out by students on momentum and impulse material have increased students' critical thinking skills. The findings in this study are in line with results in other studies. For example, (Rahmawati et al., 2021) who found an increase in students' critical thinking in the moderate category after implementing discovery learning in science learning at school. In addition to increasing aspects of students' critical thinking, discovery learning also increases learning process activities and student involvement in learning (Hidayatul et al., 2020). The advantages of the discovery learning model make it suitable as a support for implementing a scientific-based learning curriculum (Ilmi et al., 2022).

The increase in students' critical thinking skills is due to the learning experience in discovery learning which seeks to form deep understanding (Mukherjee, 2015). Discovery learning can be an effective pedagogical tool that can help teachers to increase the chances of success in achieving learning goals (Mukherjee, 2015). Discovery learning is closely related to the ways teachers teach students to explore like scientists. Several previous studies have recommended the exploratory process as a way of honing students' critical thinking skills (Prayogi et al., 2018b, 2022; Prayogi & Verawati, 2020). Inviting students to explore in scientific investigations has been shown to improve skills in analyzing, inferring, evaluating, and decision-making (Verawati et al., 2020, 2021), these four aspects of skills are the main indicators of a critical thinker (Bilad et al., 2022).

Momentum and impulse are fundamental concepts in physics. They describe the motion of objects and how forces affect that motion. By applying the discovery learning model to these phenomena, students can develop a deeper understanding and enhance their critical thinking skills. When it comes to scientific phenomena such as momentum and impulse, critical thinking skills play a vital role in understanding and applying these concepts effectively. In the current study, one effective approach to enhancing critical thinking skills is through the implementation of the discovery learning model.

The discovery learning model offers a valuable approach to enhancing critical thinking skills in the context of momentum and impulse phenomena. By engaging students in active exploration, encouraging inquiry and questioning, facilitating conceptual understanding, promoting collaboration and discussion, and applying knowledge to real-world scenarios, this model enables students to develop and refine their critical thinking skills. As a result, students not only gain a deeper understanding of momentum and impulse but also acquire essential skills for lifelong learning and problem-solving in various domains.

CONCLUSION

The discovery learning model has been implemented in material related to the phenomenon of momentum and impulse, and evaluated its impact on students' critical thinking skills. The results of the study show that students' critical thinking skills have increased after learning using the discovery learning model. Based on the size of the pre-post test, students' critical thinking skills increased from quite critical to critical, the increase (gain) was in the moderate category. Unlike the case with the control group (as a comparison) which uses traditional teaching. Based on the size of the pre-post test, students' critical thinking skills remain with less critical criteria. The difference in the improvement of critical thinking between the two groups (discovery learning vs. traditional teaching) was statistically analyzed. The results of the analysis confirm the research hypothesis tested that there are significant differences in critical thinking skills between groups taught by discovery learning models and traditional teaching on momentum and impulse material.

RECOMMENDATION

Discovery learning can be an effective pedagogical tool to help teachers increase the chances of success in achieving learning goals, especially students' critical thinking. Massive and consistent implementation needs to be done in regular learning. Future research is important to confirm the success of students with this model not only in aspects of critical thinking but in aspects of other thinking skills, such as creative thinking.

Author Contributions

The authors have sufficiently contributed to the study, and have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Acknowledgement

No specific grant or funding was given to this educational research from any private institution, public organization or nonprofit corporation.

Declaration of Interest

The authors declare no conflict of interest.

REFERENCES

Alwadai, M. (2014). Islamic Teachers' Perceptions of Improving Critical Thinking Skills in Saudi Arabian Elementary Schools. *Journal of Education and Learning*, *3*(4), Article 4. https://doi.org/10.5539/jel.v3n4p37

Bataineh, O., & Alazzi, K. (2009). Perceptions of Jordanian Secondary Schools Teachers towards Critical Thinking. *International Education*, *38*(2), 56–72.

Bilad, M. R., Anwar, K., & Hayati, S. (2022). Nurturing Prospective STEM Teachers' Critical Thinking Skill through Virtual Simulation-Assisted Remote Inquiry in Fourier Transform Courses. *International Journal of Essential Competencies in Education*, *1*(1), Article 1. https://doi.org/10.36312/ijece.v1i1.728

Boholano, H. B. (2017). Smart Social Networking: 21st Century Teaching and Learning Skills. *Research in Pedagogy*, *7*(1), 21–29.

Dalila, A. A., Sinaga, P., Liliawati, W., Setiawan, A., Sa'diyah, L. H., Komalasari, K., & Umar, F. A. (2022). Inventory of high school students' critical thinking skills in online learning during the Covid-19 pandemic on momentum and impulse material in Subang Regency. *AIP Conference Proceedings*, *2468*(1), 020040. https://doi.org/10.1063/5.0102517

Enabulele, A. (2011). Critical Thinking in Secondary Language Arts: Teacher Perceptions and Relevant Strategies. In *Online Submission*. https://eric.ed.gov/?id=ED521706

Ennis, R. (2018). Critical Thinking Across the Curriculum: A Vision. *Topoi*, *37*(1), Article 1.

Erikson, M. G., & Erikson, M. (2019). Learning outcomes and critical thinking – good intentions in conflict. *Studies in Higher Education*, *44*(12), Article 12. https://doi.org/10.1080/03075079.2018.1486813

Evendi, E., Kusaeri, A. K. A., Pardi, M. H. H., Sucipto, L., Bayani, F., & Prayogi, S. (2022). Assessing students' critical thinking skills viewed from cognitive style: Study on implementation of problem-based e-learning model in mathematics courses. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(7), em2129. https://doi.org/10.29333/ejmste/12161

Facione, P. A. (2020). *Critical Thinking: What It Is and Why It Counts*. Measured Reasons LCC. https://www.insightassessment.com/wp-content/uploads/ia/pdf/whatwhy.pdf

Forawi, S. A. (2016). Standard-based science education and critical thinking. *Thinking Skills and Creativity*, *20*, 52–62. https://doi.org/10.1016/j.tsc.2016.02.005

Hajhosseini, M., Zandi, S., Hosseini Shabanan, S., & Madani, Y. (2016). Critical thinking and social interaction in active learning: A conceptual analysis of class discussion from Iranian students' perspective. *Cogent Education*, *3*(1), 1175051. https://doi.org/10.1080/2331186X.2016.1175051

Hake, R., R. (1999). *Analyzing change/gain scores*. Indiana University: Woodland Hills, CA - USA.

Hidayatul, A., Nasution, N., & Nugroho, P. H. (2020). The Impact of Discovery Learning Models on The Critical Thinking Ability of Students at Middle-School. *International Journal for Educational and Vocational Studies*, *2*(4), Article 4. https://doi.org/10.29103/ijevs.v2i4.2275

Ilmi, S. M., Soekamto, H., & Astina, I. K. (2022). The Effect of the Discovery Learning Model on the Critical Thinking Abilities of Geography Students. *KnE Social Sciences*, 109–123. https://doi.org/10.18502/kss.v7i16.12159

Khalid, L., Bucheerei, J., & Issah, M. (2021). Pre-Service Teachers' Perceptions of Barriers to Promoting Critical Thinking Skills in the Classroom. *SAGE Open*, *11*(3), 21582440211036096. https://doi.org/10.1177/21582440211036094

Kistner, S., Vollmeyer, R., Burns, B. D., & Kortenkamp, U. (2016). Model development in scientific discovery learning with a computer-based physics task. *Computers in Human Behavior*, *59*, 446–455. https://doi.org/10.1016/j.chb.2016.02.041

Künsting, J., Kempf, J., & Wirth, J. (2013). Enhancing scientific discovery learning through metacognitive support. *Contemporary Educational Psychology*, *38*(4), 349–360. https://doi.org/10.1016/j.cedpsych.2013.07.001

Künsting, J., Wirth, J., & Paas, F. (2011). The goal specificity effect on strategy use and instructional efficiency during computer-based scientific discovery learning. *Computers & Education*, *56*(3), 668–679. https://doi.org/10.1016/j.compedu.2010.10.009

Li, R., Lund, A., & Nordsteien, A. (2021). The link between flipped and active learning: A scoping review. *Teaching in Higher Education*, *0*(0), 1–35. https://doi.org/10.1080/13562517.2021.1943655

Muhali, M., Prahani, B. K., Mubarok, H., Kurnia, N., & Asy'ari, M. (2021). The Impact of Guided-Discovery-Learning Model on Students' Conceptual Understanding and Critical Thinking Skills. *Jurnal Penelitian Dan Pengkajian Ilmu Pendidikan: E-Saintika*, *5*(3), Article 3. https://doi.org/10.36312/esaintika.v5i3.581

Mukherjee, A. (2015). Effective Use of Discovery Learning to Improve Understanding of Factors That Affect Quality. *Journal of Education for Business*, *90*(8), 413–419. https://doi.org/10.1080/08832323.2015.1081866

Pollarolo, E., Størksen, I., Skarstein, T. H., & Kucirkova, N. (2022). Children's critical thinking skills: Perceptions of Norwegian early childhood educators. *European Early Childhood Education Research Journal*, *0*(0), 1–13. https://doi.org/10.1080/1350293X.2022.2081349

Prayogi, S., Ahzan, S., Indriaturrahmi, I., & Rokhmat, J. (2022). Opportunities to Stimulate the Critical Thinking Performance of Preservice Science Teachers Through the Ethno-Inquiry Model in an E Learning Platform. *International Journal of Learning, Teaching and Educational Research*, *21*(9), Article 9. https://www.ijlter.org/index.php/ijlter/article/view/5818

Prayogi, S., & Verawati, N. N. S. P. (2020). The Effect of Conflict Cognitive Strategy in Inquiry-based Learning on Preservice Teachers' Critical Thinking Ability. *Journal of Educational, Cultural and Psychological Studies (ECPS Journal)*, *21*, Article 21. https://doi.org/10.7358/ecps-2020-021-pray

Prayogi, S., Yuanita, L., & Wasis. (2018a). Critical Inquiry Based Learning: A Model of Learning to Promote Critical Thinking Among Prospective Teachers of Physic. *Journal of Turkish Science Education*, *15*(1), Article 1.

Prayogi, S., Yuanita, L., & Wasis. (2018b). Critical-Inquiry-Based-Learning: Model of Learning to Promote Critical Thinking Ability of Pre-service Teachers. *Journal of Physics: Conference Series*, *947*, 012013. https://doi.org/10.1088/1742-6596/947/1/012013

Rahmawati, S., Masykuri, M., & Sarwanto, S. (2021). The effectiveness of discovery learning module classification of materials and its changes to enhance critical thinking skills. *Jurnal Inovasi Pendidikan IPA*, *7*(1), Article 1. https://doi.org/10.21831/jipi.v7i1.33253

Salaria, M. (2017). Views on an active learning curriculum improving knowledge. *Advances in Medical Education and Practice*, *8*, 599–601. https://doi.org/10.2147/AMEP.S144190

Sarıoğlan, A. B., & Küçüközer, H. (2014). Comparison of High School Students' Ideas About Momentum and Impulse Conceptions before and after Instruction. *Procedia - Social and Behavioral Sciences*, *116*, 3771–3775. https://doi.org/10.1016/j.sbspro.2014.01.839

Shi, Z. (2021). Chapter 7—Learning. In Z. Shi (Ed.), *Intelligence Science* (pp. 267–330). Elsevier. https://doi.org/10.1016/B978-0-323-85380-4.00007-5

Sukartiningsih, S., Sarmini, S., & Jacky, M. (2019). What is Discovery Learning Can Grow Critical Thinking Skills? *The Indonesian Journal of Social Studies*, *2*(2), Article 2. https://doi.org/10.26740/ijss.v2n2.p87-94

Syahmel, S., & Jumadi, J. (2019). Discovery Learning using Multiple Representation model for enhancing scientific processing and critical thinking skills of the students. *Jurnal Inovasi Pendidikan IPA*, *5*(2), Article 2. https://doi.org/10.21831/jipi.v5i2.26704

Verawati, N. N. S. P., Hikmawati, H., Prayogi, S., & Bilad, M. R. (2021). Reflective Practices in Inquiry Learning: Its Effectiveness in Training Pre-Service Teachers' Critical Thinking Viewed from Cognitive Styles. *Jurnal Pendidikan IPA Indonesia*, *10*(4), Article 4. https://doi.org/10.15294/jpii.v10i4.31814

Verawati, N. N. S. P., Wahyudi, W., & Ayub, S. (2020). Pengaruh Model Pembelajaran Inquiry-Creative-Process (ICP) terhadap Kemampuan Berpikir Kritis Mahasiswa Calon Guru. *Jurnal Penelitian dan Pengkajian Ilmu Pendidikan: e-Saintika*, *4*(1), Article 1. https://doi.org/10.36312/e-saintika.v4i1.151

Yosefa, V. M., Lumbantobing, S. S., Faradiba, & Malau, N. D. (2021). *The Influence of the Learning Discovery Learning Model Multi-interactive Media Assistance Against Improved Learner's Critical Thinking Skills*. 2nd Annual Conference on blended learning, educational technology and Innovation (ACBLETI 2020), Padang, Indonesia. https://doi.org/10.2991/assehr.k.210615.071

Yuberti, Latifah, S., Anugrah, A., Saregar, A., Misbah, & Jermsittiparsert*, K. (2019). Approaching Problem-Solving Skills of Momentum and Impulse Phenomena Using Context and Problem-Based Learning. *Approaching Problem-Solving Skills of Momentum and Impulse Phenomena Using Context and Problem-Based Learning*, *8*(4), 1217–1227.