Thinking Skills and Creativity Journal
Volume 5, Number 2, 2022 pp. 52-61
P-ISSN: 2615-4692 E-ISSN : 2615-6105
Open Access: https://doi.org/10.23887/tscj.v5i2.45465

The Relationship of Critical Thinking Skills and Misconceptions on Science Learning

Fauziah Yolviansyah[1*], Juita Siregar[2], Maison[3]
[1,3]Pendidikan Fisika, Universitas Jambi, Jambi, Indonesia
[2]SMA Negeri 8 Kota Jambi, Jambi, Indonesia

ARTICLE INFO

Article history:
Received March 11, 2022
Revised March 15, 2022
Accepted September 23, 2022
Available online October 25, 2022

Kata Kunci:
Five-Tier Test, Miskonsepsi, Kemampuan berpikir kritis

Keywords:
Five-Tier Test, Misconceptions, Critical Thinking Skills

ABSTRAK

Salah satu kemampuan yang dibutuhkan dalam pembelajaran adalah keterampilan berpikir kritis. Keterampilan berpikir kritis adalah keterampilan yang dapat menganalisis dan mengevaluasi informasi. Keterampilan berpikir kritis dapat berhubungan dengan terjadinya miskonsepsi. Hubungan ini bisa bersifat positif atau negatif bagi siswa. Tujuan penelitian adalah untuk menganalisis hubungan antara keterampilan berpikir kritis dan miskonsepsi dengan menggunakan instrumen lima tingkat. Metode yang digunakan dalam penelitian ini adalah korelasional. Teknik pengambilan sampel menggunakan simple random sampling, mengambil 25% dari populasi 80 siswa. Instrumen pengumpulan data menggunakan angket keterampilan berpikir kritis dan lembar tes miskonsepsi. Hasil deskriptif miskonsepsi sebesar 6,00 artinya miskonsepsi dikategorikan sedang. Hasil deskriptif keterampilan berpikir kritis menunjukkan rata-rata keterampilan berpikir kritis adalah 68,50, artinya keterampilan berpikir kritis tergolong baik. Kemudian dari hasil korelasi, terdapat hubungan yang signifikan antara kedua variabel. Artinya ada hubungan antara kemampuan berpikir kritis dengan miskonsepsi. Ketika miskonsepsi tinggi, kemampuan berpikir kritis siswa akan rendah. Sebaliknya, jika miskonsepsi yang dialami siswa rendah, maka kemampuan berpikir kritis yang dimiliki siswa tinggi.

ABSTRACT

One of the abilities needed in learning is critical thinking skills. Critical thinking skills are skills that can analyze and evaluate information. Critical thinking skills can relate to the occurrence of misconceptions. This relationship can be positive or negative for students. The research objective is to analyze the relationship between critical thinking skills and misconceptions using a five-tier instrument. The method used in this research is correlational. The sampling technique used simple random sampling, taking 25% of the population of 80 students. The data collection instrument used a questionnaire on critical thinking skills and a misconception test sheet. The descriptive results of misconceptions are 6.00, meaning that misconceptions are categorized as moderate. The descriptive results of critical thinking skills show that the mean of critical thinking skills is 68.50, meaning that critical thinking skills are considered good. Then from the correlation results, there is a significant relationship between the two variables. It means that there is a relationship between critical thinking skills and misconceptions. When misconceptions are high, students' critical thinking skills will be low. Conversely, if the misconceptions experienced by students are low, the critical thinking skills possessed by students are high.

1. INTRODUCTION

Physics learning is a branch of natural science that includes facts, concepts, principles, laws, and everyday life (Deta et al., 2021; Fayanto et al., 2019; Sugiarti & Ratnanigdyah, 2021). In this physics lesson, students must be more active in seeking, investigating, and developing to gain more meaningful and in-depth mastery of concepts (Astra et al., 2020; Rahayu et al., 2019; Widyaningsih et al., 2020). In learning physics, you do not only remember what you have learned, but you also have to have the right concept (Dewi et al., 2021; Didik & Aulia, 2019; Lin, 2016; Meilani, 2016). Conceptions held by students are

*Corresponding author
E-mail addresses: fauziahyolviansyah1@gmail.com (Fauziah Yolviansyah)

difficult to change because these conceptions have deviated from the conceptions put forward by experts (Halim et al., 2019; Kaltakci-Gurel et al., 2017; Triman et al., 2021). This deviation is called a misconception. Students need help understanding a concept to lead to misconceptions (Jayadi et al., 2020; Manunure et al., 2020). Misconceptions experienced by students are usually caused by the provision of incomplete initial concepts or facts from the teacher, so students need clarification or clarification when receiving concepts. It can also occur because of the students themselves (Didik, L. A. & Bahtiar, 2020; Octavia et al., 2021; Safriana & Irfan, 2021). It can happen due to the need for students' analytical skills. This analytical ability is needed because learning physics is related to one another. Thus it is necessary to identify misconceptions. One form of identifying misconceptions is giving a diagnostic test to students. This diagnostic test is a solution to finding student misunderstandings. Diagnostic tests have four levels (Khandagale & Chavan, 2017; Putra et al., 2020; Qonita et al., 2020). This study used a five-tier diagnostic test instrument The five-tier diagnostic test is a 5-level test (Dirman et al., 2022; Qonita et al., 2020).

The first level consists of multiple-choice questions (Caleon, 2010; Yusrizal & Halim, 2017). The second level is the belief in the answers at the first level (Taslidere, 2016; Yusrizal & Halim, 2017). The third level is the reason for answering questions. The fourth level is the reason to answer belief. Fifth, the information obtained by students to answer the question instrument questionnaire (Kaltakci-Gurel et al., 2017; Maison et al., 2019; Taslidere, 2016). This test develops the four-tier diagnostic test (Febriyana et al., 2020; Widiyanto et al., 2018). With this diagnostic test, it is easier for teachers to reduce the occurrence of misconceptions and to see the sources of information obtained by students on force and field material with sub-subjects of electricity, magnetism, and gravity. Electricity is one of the subjects of physics which is prone to misconceptions by students because this material is related to everyday life. Since electricity is so common in everyday life, it is natural for students to have misunderstandings about electricity. Magnets are materials that are abstract or difficult to imagine because they cannot be seen with the naked eye (Ramadhan et al., 2019). Meanwhile, gravity is a matter that is still abstract and studies movements in outer space and how celestial bodies can move (Wuryanti et al., 2017). Even though almost all books discuss electric, magnetic, and gravitational fields, students still cannot clearly understand the concepts of electricity, magnetism, and gravity (Başer & Geban, 2007). Another misunderstanding among students is about electric charge: charged objects only contain electrons or protons (Eryilmaz et al., 2015). Students experience many misconceptions about electric, magnetic and gravitational fields (Taşkın, 2021).

In the learning process, skills are needed so that misconceptions can be reduced substantially. Several studies have been carried out previously which have a bearing on the research that will be carried out. The first study explained that the misconceptions of students in Canada about heat and temperature were carried out using a two-tier format diagnostic test (Métioui & Trudel, 2021). Then the second study explained that in Turkey, one of the misconceptions could be reduced by using the PBL model on electrical circuit material (Şenyiğit, 2021). The third study describes the analysis of instructions for critical thinking in distance learning (Noordink & Naidu, 2014). Then other studies explain that improving students' critical thinking skills can be done with team-based learning (Espey, 2017). Other studies also analyze misconceptions in science textbooks (King, 2010). In this study, the teacher reduced misconceptions by giving students explanations and books that made students understand their lessons, especially on force and terrain material. Subsequent research was also conducted on critical thinking skills in physics education (Karakoc, 2016). This research was conducted in the educational process to improve students' critical thinking skills in learning physics. Then other studies observe efforts to build critical thinking skills to reduce misconceptions using concept maps (Negoro et al., 2018). Using concept maps, the teacher can improve students' critical thinking skills and reduce misconceptions. Furthermore, other research explains that critical thinking skills can reduce misunderstandings in learning physics, especially in electric field material (Bensley & Lilienfeld, 2017). Critical thinking skills can be related to the occurrence of misconceptions. This relationship can be positive or negative for students. The relationship that occurs in misconceptions is that when misconceptions are high, students' critical thinking skills are low. Conversely, if misconceptions are low, students' critical thinking skills are high (Gal-Ezer & Trakhtenbrot, 2016; Missa et al., 2020). When students need clarification, they need more analysis and problem-solving skills, which causes low students' critical thinking skills. It is usually due to the lack of student engagement in the learning process in class. For students who often join in student-centered learning, of course, they can analyze and be able to solve problems well (Kızılcık et al., 2021). Critical thinking skills can solve problems, consider making decisions, and reduce misconceptions about electric field material (Jolley et al., 2020; Živkovi, 2016). This study aimed to see the relationship between critical thinking skills and misconceptions using the Five-Tier Diagnostic Test instrument. That way, researchers can see the relationship and identify student misconceptions in the material of force and field with the sub-materials of electricity, magnetism, and gravity.

2. METHOD

The research method used is quantitative (Ashari et al., 2016). The research design used is Correlational. Quantitative research uses statistical analysis in the form of numbers (Sujito, S. et al., 2018). Quantitative research also explains correlation, where this correlational research aims to see the relationship between the independent and dependent variables. In this study, the data collected for the first time was quantitative data by distributing questionnaires on critical thinking skills and testing misconceptions about Force and Field material with sub-materials of electricity, magnetism, and gravity. In research, sampling is very noteworthy. The sampling technique in this study used a simple random sampling technique. This sampling technique takes random samples from the population so that each member of the population has the same opportunity to be taken as a research sample (Arieska & Herdiani, 2018; Osborn et al., 2017). The population used in this study was the twelfth grade at SMA Negeri 8 Jambi, with 200 students. The sample used in this study was 80 students who were taken randomly using a class lottery. In this study, the instruments used are very noteworthy.

The data collection instruments used in this study were questionnaires and misconception tests. The misconception test in this study was in the format of a five-tier diagnostic test on electricity, magnetism, and gravity. The use of this five-tier instrument is to find out the information or sources obtained by students to answer the first and third-tier questions. It is intended that the teacher can find out the information obtained by students to answer the questions provided. Educators will analyze sources of information obtained by students to find out where the errors result in misconceptions among students (Rosita et al., 2020). The grid of the five-tier format misconception test on force and field material with sub-materials electricity, magnetism, and gravity can be seen in Table 1.

Table 1. Grid of Material Misconceptions about Forces and Fields

Material	Concept
Electricity	The greater the distance between the two charges, the weaker the electric force
	The force experienced by the two charges is equal but always opposite.
	The closer the lines of electric force are, the greater the electric field in that area.
	The object that has a greater charge does not exert a greater force.
Magnets	The object that has a greater charge does not exert a greater force.
	The force on a charged particle moving in a magnetic field
	The magnetic field in a coiled wire carries a current
	Magnetic force
	The application of the resulting magnet concept
Gravity	The force of gravity on an object is proportional to the object.
	Comparison of gravity on the hill and at the foot of the hill
	Two satellites orbit with the same radius. Comparison of gravity and gravitational fields between satellites

From the instrument grid, the misconceptions about force and field have 11 question items. The instrument used in this study was in the format of a Five-Tier Diagnostic Test. The five-tier answer categories can be seen in Table 2. What explains the students' answers are students who understand concepts, do not understand concepts, and have misconceptions. This five-tier answer category is adopted from (Didik, L. A. & Bahtiar, 2020).

Table 2. Five-Tier Test Answer Categories

First level	Second level	Third level	Fourth level	Fifth level	Category
True	Convinced	True	Convinced	Teacher	Understand the concept
True	Convinced	False	Convinced	Peers	Misconceptions (false positives)
False	Convinced	True	Convinced	Internet	Misconceptions (false negatives)
True	Convinced	True	Not convinced	Internet	Guessing, lack of confidence
True	Not convinced	False	Not convinced	Book	Don't understand the concept
False	Convinced	False	Convinced	Internet	misconceptions
False	Convinced	True	Not convinced	Book	Don't understand the concept

The critical thinking skills questionnaire comprises 20 statement items divided into six indicators. The grid of the critical thinking skills questionnaire can be seen in Table 3.

Table 3. Critical Thinking Skills Grid

No	Critical Thinking Skills Indicator	Statement Items		Total
		Favourable	Unfavourable	
1	Analyze arguments	5,6	11, 14	4
2	Able to ask	1	3	2
3	Able to answer questions	4	8	2
4	Solve the problem	2,7,17	10, 15, 9	6
5	Draw conclusions	12	13	2
6	Skills evaluate and assess the results of observations	19,18	16, 20	4
Total				**20**

The Scale Used In The Critical Thinking Skills Questionnaire Is A Likert Scale With 5 Scales. Meanwhile, Strongly Agree Was Given A Score Of 5, Agreed Was Given A Score Of 4, Undecided Was Given A Score Of 3, Disagree Was Given A Score Of 2, And Strongly Disagree Was Given A Score Of 1. To See The Categories Of Students' Critical Thinking Skills Can Be Seen In Table 4.

Table 4. Categories of Students' Critical Thinking Skills

No	Convert The Score Of Critical Thinking Skills	Category
1	0-45	Less
2	46-50	Not Good
3	51-65	Neutral
4	66-75	Good
5	76-100	Very Good

The Categories Of Misconceptions Can Be Seen In Table 5.

Table 5. Categories of Misconceptions

Misconception Interval	Category
0 – 30	Low
30 – 70	Medium
70 – 100	High

(MINARNI ET AL., 2018)

Data Collection In This Study Began With Giving Students A Misconception Test In The Format Of A Five-Tier Test On Electric Field Material To Fill In. After That, The Critical Thinking Skills Questionnaire Was Redistributed Related To The Misconception Question To Obtain Data According To The Researcher's Needs. The Data Obtained In This Study Is In The Form Of Inferential Statistics Used As Hypothesis Testing. However, Before Carrying Out Hypothesis Testing, The First Step Is To Carry Out Normality And Homogeneity Tests As A Condition Of Analysis. The Normality Test Is Carried Out To Determine Whether The Data Is Normally Distributed. A Homogeneity Test Was Carried Out To Determine Whether The Data Variance Between The Independent Variable Group And The Dependent Variable. After Testing Normality And Homogeneity, They Test The Hypothesis Using A Simple Linear Regression Technique And A Simple Correlation Technique, Namely Pearson Product Moment.

3. RESULT AND DISCUSSION

Result

The results of the descriptive statistical analysis of critical thinking skills and misconceptions can be seen in Table 6.

Table 6. Data Description

Statistics	Critical Thinking Skills	Misconceptions
Number of students	80	80
Number of items	20	11
Means	68.50	6.00
Median	61.00	8.00
Standard deviation	9.91	0.24

The Normality Test Results For Students' Misconceptions And Critical Thinking Skills Can Be Seen In Table 7.

Table 7. Normality Test Results

Variable	Kolmogorov-Smirnov		
	Sig.	df	Conclusion
Misconceptions	0.180	80	Normal
Critical Thinking Skills	0.124	80	Normal

Based on Table 7, the results show that the data is normally distributed because the significance score is greater than 0.05 (Bungsu et al., 2019). The results of calculating the correlation between critical thinking skills (X) and misconceptions (Y) using SPSS are presented in Table 8.

Tabel 8. Correlation Value of Critical Thinking Skills and Misconceptions

		X	Y
X	Pearson Correlation	1	-0.390
	Sig. (2-tailed)		0.002
	N	80	80
Y	Pearson Correlation	-0.390	1
	Sig. (2-tailed)	0.002	
	N	80	80

Based on the data in Table 8, the p-score = 0.002 means ρ<α. It means that Ho is rejected and Ha is accepted. Therefore it is proven that there is a relationship between critical thinking skills and students' misconceptions at SMA N 8 Jambi city. Based on the results of the description of critical thinking skills and misconceptions, it was found that the mean was 68.50 and 6.00, which means that the student's critical thinking skills were neutral. The students' misconceptions were classified as moderate. From the explanation above, it was found that the five-tier test instrument saw students getting information to answer a questionnaire about misconceptions from various sources, namely textbooks, teachers, the internet, and peers. Students who experience misconceptions mostly get them from the internet. Therefore, students cannot immediately accept what they read but must understand what they are reading from the internet, especially the material of forces and fields that are still abstract. In critical thinking skills, students can analyze and understand the questions well.

Discussion

From the correlation test results, it was found that p-score = 0.002 means ρ<α, which means that Ho is rejected and Ha is accepted. These results show a relationship between students' critical thinking skills and misconceptions. This relationship can be seen when students study in class, where if the teacher explains that it is still teacher-centered, students will not understand what they are learning. However, if the teacher is teaching and teaching students to search and dig up the information they need, this can build students' critical thinking skills so that misconceptions can be reduced. If misconceptions are high, critical thinking skills are low. Conversely, if critical thinking skills are high, students' misconceptions are low (Gal-Ezer & Trakhtenbrot, 2016; Kızılcık et al., 2021; G. Liu & Fang, 2016). When critical thinking skills are high, it means that students understand and understand and can analyze the questions that have been given. Therefore critical thinking is needed to check the correctness of the information to decide whether information can be accepted or not. The same is true in working on questions given by educators. In the research conducted to identify these misconceptions, there is an update. This update can be seen from the analysis of the relationship of critical thinking skills to the level of students' understanding of concepts using a five-tier instrument to identify students' misconceptions about the style and terrain material. This

study aims to identify students' misconceptions by analyzing the confidence level in students' answers in answering the five-tier diagnostic test instruments at the second and fourth tiers. In contrast, the causes of misconceptions are identified from students' choices in answering reasons at the third tier, and the information students get in answering questions at the fifth tier.

One of the abilities needed in learning is critical thinking skills (Sujarwo et al., 2020; Zain & Jumadi, 2018). Critical thinking skills can analyze and evaluate information (Maknun, 2020; Purwati et al., 2016; Setiya Rini et al., 2020; Spector & Ma, 2019). Critical thinking skills are a top priority in education to achieve the learning objectives set (Diani et al., 2019; Gunawan, 2019; Hasnawati et al., 2021; Muhammadiyeva et al., 2020). With critical thinking skills, students can understand and be able to analyze problems properly to achieve learning objectives (Darmaji et al., 2020). It is easier for teachers to cultivate students' critical thinking skills if they are aware of the nature of critical thinking and how to cultivate it in classroom practice. The limitations of this study are that first, this study only identified misconceptions using a five-tier instrument. The second limitation is that the material contained in this study is only forces and fields contained in the electric, magnetic and gravitational sub-materials. Then thirdly, this study looks at the relationship between critical thinking skills and misconceptions. Critical thinking skills are related to the occurrence of misconceptions. Furthermore, recommendations for further research are where in the analysis of the relationship of critical thinking skills to misconceptions in the five-tier format, this test is only limited to identifying and knowing the information that students get to answer questions and the relationship of critical thinking skills to misconceptions in the material style and terrain. We already know that physics material in education is extensive, so it is not just about forces and fields. With this, further research can be carried out with other physics materials.

4. CONCLUSION

Based on the results of the data obtained with descriptive scores, misconceptions and critical thinking skills are still classified as moderate and good. For the results of the correlation test, it was found that there was a significant relationship between critical thinking skills and misconceptions in the matter of forces and fields with sub-materials, namely electricity, magnetism, and gravity. With this relationship, it can reduce the occurrence of misconceptions slowly, although it cannot simultaneously overcome the occurrence of misconceptions.

5. REFERENCES

Arieska, P. K., & Herdiani, N. (2018). Pemilihan teknik sampling berdasarkan perhitungan efisiensi relatif. *Jurnal Statistika Universitas Muhammadiyah Semarang*, *6*(2), 166–171. https://doi.org/10.26714/jsunimus.6.2.2018.%25p.

Ashari, L. H., Lestari, W., & Hidayat, T. (2016). Instrumen Penilaian Unjuk Kerja Siswa Smp Kelas Viii Dengan Model Peer Asssessment Berbasis Android Pada Pembelajaran Penjasorkes Dalam Permainan Bola Voli. *Journal of Research and Educational Research Evaluation*, *5*(1), 08–20. https://doi.org/10.15294/jrer.v5i1.14876.

Astra, I. M., Susanti, D., & Sakinah, S. (2020). The effects of cooperative learning model think pair share assisted by animation media on learning outcomes of physics in high school The effects of cooperative learning model think pair share assisted by animation media on learning outcomes of physics. *Journal of Physics: Conference Series*, *1521*(2), 1–7. https://doi.org/10.1088/1742-6596/1521/2/022005.

Başer, M., & Geban, Ö. (2007). Effect of instruction based on conceptual change activities on students' understanding of static electricity concepts. *Research in Science and Technological Education*, *25*(2), 243–267. https://doi.org/10.1080/02635140701250857.

Bensley, D. A., & Lilienfeld, S. O. (2017). Psychological Misconceptions: Recent Scientific Advances and Unresolved Issues. *Current Directions in Psychological Science*, *26*(4), 377–382. https://doi.org/10.1177/0963721417699026.

Bungsu, T. K., Vilardi, M., Akbar, P., & Bernard, M. (2019). Pengaruh Kemandirian Belajar Terhadap Hasil Belajar Matematika di SMKN 1 Cihampelas. *Journal on Education*, *1*(2), 382–389. https://doi.org/10.31004/joe.v1i2.78.

Caleon, I. (2010). Development and application of a three-tier diagnostic test to assess secondary students' understanding of waves. *International Journal of Science Education*, *32*(7), 939–961. https://doi.org/10.1080/09500690902890130.

Darmaji, D., Astalini, A., Kurniawan, D. A., Ningsi, A. P., Romadona, D. D., & Dari, R. W. (2020). Regression of Science Process Skills On Critical Thinking Skills In Two Junior High Schools In Jambi City. *JIPF*

(Jurnal Ilmu Pendidikan Fisika), *5*(3), 177. https://doi.org/10.26737/jipf.v5i3.1788.

Deta, U. A., Kurniawan, F. K., Lestari, N. A., Yantidewi, M., Jauhariyah, M. N. R., & Prahani, B. K. (2021). Literature review on the use of educational physics games in improving learning outcomes. *Journal of Physics: Conference Series*, *1805*(1), 1–11. https://doi.org/10.1088/1742-6596/1805/1/012038.

Dewi, N. P., Martini, & Purnomo, A. R. (2021). Analisis Miskonsepsi Peserta Didik materi Sistem Pernapasan Manusia. *Pensa: E-Jurnal Pendidikan Sains*, *9*(3), 422–428. https://ejournal.unesa.ac.id/index.php/pensa/article/view/40331.

Diani, R., Irwandani, I., Yetri, Y., Fujiani, D., Umam, R., Training, T., Islam, U., Raden, N., Lampung, I., Program, P., Islam, U., Raden, N., Lampung, I., & Training, T. (2019). Physics Learning through Active Learning Based Interactive Conceptual Instructions (ALBICI) to Improve Critical Thinking Ability. *Jurnal Penelitian Dan Pembelajaran IPA*, *5*(1), 48–58. https://doi.org/10.30870/jppi.v5i1.3469.

Didik, L. A., & Bahtiar, B. (2020). Analisis miskonsepsi tentang kemagnetan pada siswa MTS Ishalahul Muslimin senteluk kelas IX tahun ajaran 2018/2019. *Relativitas: Jurnal Riset Inovasi Pembelajaran Fisika*, *3*(1), 8–15. https://doi.org/10.29103/relativitas.v3i1.2022.

Didik, L. A., & Aulia, F. (2019). Analisis tingkat pemahaman dan miskonsepsi pada materi listrik statis mahasiswa tadris fisika menggunakan metode 3-tier multiple choices Diagnostic. *Phenomenon: Jurnal Pendidikan MIPA*, *9*(1), 99–111. https://doi.org/10.21580/phen.2019.9.1.2905.

Dirman, H. M., Mufit, F., & Festiyed, F. (2022). Review and Comparison of Four-Tier Multiple Choice and Five-Tier Multiple Choice Diagnostic Tests to Identify Mastery of Physics Concepts. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 1–12. https://doi.org/10.29303/jppipa.v8i1.838.

Eryilmaz, A., McDermott, L. C., & Gurel, D. K. (2015). A review and comparison of diagnostic instruments to identify students' misconceptions in science. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(5), 989–1008. https://doi.org/10.12973/eurasia.2015.1369a.

Espey, M. (2017). Enhancing critical thinking using team-based learning. *Higher Education Research and Development*, *37*(1), 15–29. https://doi.org/10.1080/07294360.2017.1344196.

Fayanto, S., Musria, Erniwati, Sukariaih, L., & Hunaidah. (2019). Implementation of Quantum Teaching Model on Improving Physics Learning Outcomes In The Cognitive Domain At Junior High School. *IJIS Edu: Indonesian Journal of Integrated Science Education*, *1*(2), 131–138. https://doi.org/10.29300/ijisedu.v1i2.1958.

Febriyana, S. A., Liliawati, W., & Kaniawati, I. (2020). Identifikasi miskonsepsi dan penyebabnya pada materi gelombang stasioner kelas XI menggunakan five-tier test. *Jurnal Fisika Dan Pendidikan Fisika*, *5*(2), 42–51. https://doi.org/10.20414/konstan.v5i2.53.

Gal-Ezer, J., & Trakhtenbrot, M. (2016). Identification and addressing reduction-related misconceptions. *Computer Science Education*, *26*(2–3), 89–103. https://doi.org/10.1080/08993408.2016.1171470.

Gunawan, G. (2019). Increasing Students ' Critical Thinking Skills In Physics Using A Guided Inquiry Model Combined With An Advanced Organizer. *Journal of Advanced Research in Dynamical and Control Systems (JARDCS)*, *11*(7), 313–320. http://eprints.unram.ac.id/23939/1/Dr. Gunawan JARDCS 2019 ARTIKEL C6.pdf.

Halim, A., Lestari, D., & Mustafa. (2019). Identification of the causes of misconception on the concept of dynamic electricity Identification of the causes of misconception on the concept of dynamic electricity. *Journal of Physics: Conference Series*, *1280*(5), 1–7. https://doi.org/10.1088/1742-6596/1280/5/052060.

Hasnawati, Niswatul, B., & Oktavianti, I. (2021). Analisis Hubungan Keterampilan Berpikir Kritis dengan Kecenderungan Berpikir Kritis Mahasiswa Calon Guru Sekolah Dasar. *Jurnal Syntax Transformation*, *2*(6), 768–773. https://doi.org/10.46799/jst.v2i6.305.

Jatmiko, B., Prahani, B. K., Munasir, S., Wicaksono, I., Erlina, N., & Pandiangan, P. (2018). The comparison of OR-IPA teaching model and problem based learning model effectiveness to improve critical thinking skills of pre-service physics teachers. *Journal of Baltic Science Education*, *17*(2), 300–320. https://www.proquest.com/docview/2344386563.

Jayadi, A., Putri, D. H., & Johan, H. (2020). Identifikasi Pembekalan Keterampilan Abad 21 Pada Aspek Keterampilan Pemecahan Masalah Siswa Sma Kota Bengkulu Dalam Mata Pelajaran Fisika. *Jurnal Kumparan Fisika*, *3*(1), 25–32. https://doi.org/10.33369/jkf.3.1.25-32.

Jolley, D., Davis, M., Lavender, A. P., & Roberts, L. (2020). An online critical thinking course reduces misconceptions in the knowledge of personal trainers. *Studies in Continuing Education*, *0*(0), 1–16. https://doi.org/10.1080/0158037X.2020.1738373.

Kaltakci-Gurel, D., Eryilmaz, A., & McDermott, L. C. (2017). Development and application of a four-tier test

to assess pre-service physics teachers' misconceptions about geometrical optics. *Research in Science and Technological Education*, *35*(2), 238–260. https://doi.org/10.1080/02635143.2017.1310094.

Karakoc, M. (2016). The Significance of Critical Thinking Ability in Terms of Education. *International Journal of Humanities and Social Science*, *6*(7), 81–84.

Khandagale, D. . S., & Chavan, R. (2017). Identification of Misconceptions for Gravity, Motion and Inertia among Secondary School Students. *Aayushi International Interdisciplinary Research Journal (AIIRJ)*, *IV*(XI), 196–205. https://eric.ed.gov/?id=ED593127.

King, C. J. H. (2010). An Analysis of misconceptions in science textbooks: Earth science in england and wales. *International Journal of Science Education*, *32*(5), 565–601. https://doi.org/10.1080/09500690902721681.

Kızılcık, H. Ş., Aygün, M., Şahin, E., Önder-Çelikkanlı, N., & Türk, O. (2021). Possible misconceptions about solid friction. *Physical Review Physics Education Research*, *023107*(17), 1–20. https://doi.org/10.1103/PhysRevPhysEducRes.17.023107.

Leasa, M., Corebima, A. D., & Batlolona, J. R. (2020). The effect of learning styles on elementary school students' critical thinking skills in natural science learning. *Elementary Education Online*, *19*(4), 2086–2097. https://doi.org/10.17051/ilkonline.2020.763449.

Lin, Y. (2016). Diagnosing Students' Misconceptions in Number Sense via a Web-Based Two-Tier Test. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(1), 41–55. https://doi.org/10.12973/eurasia.2016.1420a.

Liu, G., & Fang, N. (2016). Students need to be aware of force and acceleration in physics and engineering mechanics education. *International Journal of Engineering Education*, *32*(1), 19–29. https://doi.org/10.1088/1742-6596/1157/2/022034.

Liu, Gang, & Fang, N. (2021). The effects of enhanced hands-on experimentation on correcting student misconceptions about work and energy in engineering mechanics. *Research in Science & Technological Education*, *00*(00), 1–20. https://doi.org/10.1080/02635143.2021.1909555.

Maison, M., Safitri, I. C., & Wardana, R. W. (2019). Identification of misconception of high school students on temperature and calor topic using four-tier diagnostic instrument. *Edusains*, *11*(2), 195–202.

Maknun, J. (2020). Implementation of Guided Inquiry Learning Model to Improve Understanding Physics Concepts and Critical Thinking Skill of Vocational High School Students. *International Education Studies*, *13*(6), 117–130. https://doi.org/10.5539/ies.v13n6p117.

Manunure, K., Delserieys, A., & Castéra, J. (2020). The effects of combining simulations and laboratory experiments on Zimbabwean students' conceptual understanding of electric circuits. *Research in Science and Technological Education*, *38*(3), 289–307. https://doi.org/10.1080/02635143.2019.1629407.

Meilani, T. (2016). Pengembangan Animasi Simulasi Komputer Untuk mereduksi miskonsepsi pada konsep induksi elektromagnetik. *Teknika STTKD: Jurnal Teknik, Elektronik, Engine*, *3*(2), 56–74. https://jurnal.sttkd.ac.id/index.php/ts/article/view/144.

Métioui, A., & Trudel, L. (2021). Two-tier Multiple-choice Questionnaires to Detect the Students' Misconceptions about Heat and Temperature. *European Journal of Mathematics and Science Education*, *2*(1), 23–34. https://doi.org/10.12973/ejmse.2.1.23.

Minarni, Kurniawan, Y., & Muliyani, R. (2018). Identifikasi Kuantitas Siswa Yang Miskonsepsi Pada Materi Listik Dinamis Menggunakan Three Tier-Test (TTT). *Jurnal Pendidikan Matematika Indonesia*, *3*(2), 38–41. https://doi.org/10.26737/jipf.v3i2.578.

Missa, L., Mellu, R. N. K., & Langtang, D. (2020). Pengembangan Alat Evaluasi Fisika Untuk Mengidentifikasi Miskonsepsi Siswa Kelas VIII SMP Negeri Oenino. *Jurnal Fisika Indonesia*, *24*(3), 164. https://doi.org/10.22146/jfi.v24i3.57639.

Muhammadiyeva, H., Mahkamova, D., Valiyeva, S., & Tojiboyev, I. (2020). The role of critical thinking in developing speaking skills. *International Journal on Integrated Education*, *3*(1), 62–64. https://doi.org/10.31149/ijie.v3i1.273.

Negoro, R. A., Hidayah, H., Rusilowati, A., & Subali, B. (2018). Upaya Membangun Ketrampilan Berpikir Kritis Menggunakan Peta Konsep Untuk Mereduksi Miskonsepsi Fisika. *Jurnal Pendidikan (Teori Dan Praktik)*, *3*(1), 45. https://doi.org/10.26740/jp.v3n1.p45-51.

Noordink, P. J., & Naidu, S. (2014). Analysis of instruction for critical thinking in distance learning materials. *Distance Education*, *15*(1), 42–69. https://doi.org/10.1080/0158791940150105.

Octavia, E, R. A., & Z, D. K. (2021). Misconception Analysis of Static Electricity Materials in Class IX Junior High School. *ISER (Indonesian Science Education Research)*, *3*(2), 25–30. https://jurnal.unimed.ac.id/2012/index.php/iser/article/download/31239/17398.

Osborn, S., Vassilevski, P. S., & Villa, U. (2017). A multilevel, hierarchical sampling technique for spatially

correlated random fields. *SIAM Journal on Scientific Computing*, *39*(5), 543–562. https://doi.org/10.1137/16M1082688.

Purwati, R., Hobri, H., & Fatahillah, A. (2016). Analisis Kemampuan Bepikir Kritis dalam menyelesaikan masalah persamaan Kuadrat pada pembelajaran Model Creative Problem Solving. *KadikmA*, *7*(1), 84–93. https://doi.org/10.19184/kdma.v7i1.5471.

Putra, A., Hamidah, & Nahadi. (2020). The development of a five-tier diagnostic test to identify misconceptions and causes of students ' misconceptions in waves and optics materials The development of a five-tier diagnostic test to identify misconceptions and causes of students ' misconceptions i. *Journal of Physics: Conference Series*, *1521*(2), 1–11. https://doi.org/10.1088/1742-6596/1521/2/022020.

Putri, F. S., & Istiyono, E. (2017). The Development of Performance Assessment of Stem- Based Critical Thinking Skill in the High School Physics Lessons. *International Journal of Environmental And Science Education*, *12*(5), 1269–1281. https://eric.ed.gov/?id=EJ1278188.

Qonita, M., Ermawati, F. U., Departement, P., Sciences, N., & Surabaya, U. N. (2020). The Validity and Reliability of Five-tier Concrption Diagnostik Test for Vectoor Concepst. *IPF : Inovasi Pendidikan Fisika*, *09*(03), 459–465. https://ejournal.unesa.ac.id/index.php/inovasi-pendidikan-fisika/article/view/35743

Rahayu, A. Y., Syuhendri, S., & Sriyanti, I. (2019). Analisis Pemahaman Konsep Mahasiswa Pendidikan Fisika Universitas Sriwijaya pada Materi Gravitasi Newton dengan Menggunakan NGCI Dan CRI Termodifikasi. *Jurnal Eksakta Pendidikan (Jep)*, *3*(1), 65. https://doi.org/10.24036/jep/vol3-iss1/322.

Ramadhan, D., Bobby, I., Ashnam, M., Alfianda, R., Marpaung, M. A., & Sugihartono, I. (2019). Studi Miskonsepsi Medan Magnetik Menggunakan Metode Four Tier Test Untuk Siswa Sma Kelas Xii. *Prosiding Seminar Nasional Fisika*, *8*, 1–8. https://doi.org/10.21009/03.SNF2019.

Rosita, I., Liliawati, W., & Samsudin, A. (2020). Pengembangan Instrumen Five-Tier Newton's Laws Test (5TNLT) Untuk Mengidentifikasi Miskonsepsi dan Penyebab Miskonsepsi Siswa. *Jurnal Pendidikan Fisika Dan Teknologi*, *6*(2), 297. https://doi.org/10.29303/jpft.v6i2.2018.

Safriana, & Irfan, A. (2021). Identifikasi Miskonsepsi Siswa dengan Menggunakan Three Tier Multiple Choice Diagnostic Test Pada Materi Gerak dan Gaya. *Al-Madaris Jurnal Pendidikan Dan Studi Keislaman*, *2*(2), 2021. https://doi.org/10.47887/amd.v2i2.33.

Şenyiğit, Ç. (2021). The Effect of Problem-based Learning on Pre-service Primary School Teachers' Conceptual Understanding and Misconceptions. *International Online Journal of Primary Education*, *10*(1), 50–72. https://dergipark.org.tr/en/pub/iojpe/issue/69625/1110229.

Setiya Rini, E. F., Wibisono, G., Ramadhanti, A., Simamora, N. N., & Chen, D. (2020). Pengaruh Kemandirian Terhadap Prestasi Belajar Siswa Kelas XI di SMA Negeri 11 Kota Jambi. *Jurnal Pendidikan Fisika Dan Teknologi*, *6*(2), 256. https://doi.org/10.29303/jpft.v6i2.2211.

Spector, J. M., & Ma, S. (2019). Inquiry and critical thinking skills for the next generation: from artificial intelligence back to human intelligence. *Smart Learning Environments*, *6*(1). https://doi.org/10.1186/s40561-019-0088-z.

Sugiarti, S., & Ratnanigdyah, D. (2021). Analysis of student science process skills on electrical material using discovery model. *Journal of Physics: Conference Series*, *1731*(1). https://doi.org/10.1088/1742-6596/1731/1/012084.

Sujarwo, S., Sukmawati, S., Asdar, A., Siradjuddin, S., & Ariani, N. (2020). University Students' Perception of the Verbal Interaction through WhatsApp Chat Group. *Al-Ta Lim Journal*, *27*(3), 250–257. https://doi.org/10.15548/jt.v27i3.633.

Sujito, S., Pebriana, I. N., Pratiwi, H. Y., Hayyi, A., Masjkur, K., Asim, A., & Sutopo, S. (2018). Students misconception: The developing of Socratic Dialogue Media on Temperature and Heat. *Jurnal Pena Sains*, *5*(2), 87–95. https://doi.org/10.21107/jps.v5i2.4551.

Taşkın, T. (2021). Examination of prospective teachers' knowledge about capacitors and electric field lines. *Research in Science and Technological Education*, *40*(2), 272–289. https://doi.org/10.1080/02635143.2021.1894113.

Taslidere, E. (2016). Development and use of a three-tier diagnostic test to assess high school students' misconceptions about the photoelectric effect. *Research in Science and Technological Education*, *34*(2), 164–186. https://doi.org/10.1080/02635143.2015.1124409.

Triman, Mursalin, & Odja, A. H. (2021). Misconception Analysis to Know the Understanding Static Electrical Concept at SMK Bina Taruna Gorontalo by Using the Certainty of Response Index (CRI). *7th International Conference on Research, Implementation, and Education of Mathematics and Sciences (ICRIEMS 2020)*, *528*, 608–611. https://doi.org/10.2991/assehr.k.210305.088.

Widiyanto, A., Sujarwanto, E., & Prihaningtiyas, S. (2018). Analisis pemahaman konsep peserta didik

dengan instrumen. *Prosiding Seminar Nasional Multidisiplin*, 138–146. http://ejournal.unwaha.ac.id/index.php/snami/article/view/279.

Widyaningsih, S. W., Yusuf, I., Prasetyo, Z. K., & Istiyono, E. (2020). Online Interactive Multimedia Oriented to HOTS through E-Learning on Physics Material about Electrical Circuit. *JPI (Jurnal Pendidikan Indonesia)*, *9*(1), 1. https://doi.org/10.23887/jpi-undiksha.v9i1.17667.

Wuryanti, S., Yennitta, & Fakhruddin. (2017). Analysis of Students' Misconception on Dinamic Motion Using Three-Tier Multiple Choice Diagnostic Test. *Jurnal Geliga Sains: Jurnal Pendidikan Fisika*, *5*(2), 110–118. https://doi.org/10.31258/jgs.5.2.110-118.

Yusrizal, & Halim, A. (2017). the Effect of the One-Tier, Two-Tier, and Three-Tier Diagnostic Test Toward the Students ' Confidence and. *Unnes Science Educational Journal*, *6*(2), 1583–1590. https://journal.unnes.ac.id/sju/index.php/usej/article/view/15856.

Zain, A. R., & Jumadi. (2018). Effectiveness of guided inquiry based on blended learning in physics instruction to improve critical thinking skills of the senior high school student Effectiveness of guided inquiry based on blended learning in physics instruction to improve critical thi. *Journal of Physics: Conference Series*, 1–7. https://doi.org/10.1088/1742-6596/1097/1/012015.

Živkovi, S. (2016). A Model of Critical Thinking as an Important Attribute to Success in the 21st Century. *Procedia - Social and Behavioral Sciences*, *232*, 102–108. https://doi.org/10.1016/j.sbspro.2016.10.034.