

## Misconception Analysis of Biology Education Students Using Diagnostic Three Tier Test on Genetics Material

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### ABSTRACT

*Genetics is a branch of Biology that becomes the basic building blocks of Biology, because almost none of the development of biological science is based on the concept of genetics. However, until now Genetics is still considered difficult for students so that the opportunity for the emergence of an understanding of the concept of genetics that is different from the understanding put forward by experts. The difference in understanding can trigger misconceptions especially in Biology Education students as future teachers who need to master Genetics content. Therefore, efforts are needed to identify students' conceptions with diagnostic three tier test which is considered capable of providing information about misconceptions. This study aims to identify and analyze the misconceptions of Biology Education students on Genetics material. The sample used is a saturated sample, namely all Biology Education Semester 2 students of FKIP UHAMKA. The research method used is descriptive quantitative, which plays a role in data collection in the form of a percentage of student conceptions to be compared with predetermined criteria. The results of this study concluded that there were misconceptions from the 18th diagnostic three tier test of Genetics material by 50%. Of the four sub-materials, respectively, the highest misconceptions occurred in the substance of genetics by 54%, cell division by 51%, patterns of inheritance of traits by 49%, and mutations by 43%.*

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## 1. INTRODUCTION

Misconceptions are defined as cognitive structures that are strongly embedded in individuals, but are inconsistent with the concept. Not only inconsistent, misconceptions are strongly supported by the individual which will be more difficult to correct than with individuals who have not or do not understand the concept at all, because the person concerned has not realized the error of his concept (Mukhlisa, 2021). Misconceptions can be obtained from various conditions, such as inappropriate preconceptions, learning methods obtained from previous levels of education, or from the source of teaching materials used. This has the opportunity to hinder success in the learning process of students, especially in understanding science events and providing interrelated scientific science arguments (Putri, et al., 2020).

Misconceptions in Biology Education students are still often found, especially in abstract science concepts that are difficult to understand with the naked eye (Alonemarera, 2020). In fact, according to (Safitri, 2019), one of the current professional standards of teachers is to be able to master teaching materials based on a close understanding of concepts. One of the Biology concepts that often experience misconceptions to date occurs in the concept of genetics, because genetics is a broad, complex and abstract material to understand (Hidayat,

2020). The difficulty of genetics material can trigger the emergence of misconceptions, especially in fundamental concepts such as genes, chromosomes, alleles, meiosis, mitosis, and concepts regarding gene expression (Machová et al., 2021). Prospective biology teachers whose cognitive abilities are much more developed are required to master content and pedagogy in order to be able to connect between concepts regarding genetics (Elvianasti, 2019). This is because, according to (Nusantari, 2014), not only studying the science of trait inheritance, but almost or none of the biological sciences have developed without being based on the concept of genetics. Therefore, this paper will introduce a new concept of entrepreneurial education framework that will expose young children to entrepreneurship thinking.

In order to realize the performance of professional prospective teachers, before the Genetics lecture takes place, in order to introduce the correct concept, it is necessary to identify and analyze which part of the misconception needs to be addressed, and to find out, misconception detection research is needed so that further learning designs can be evaluated to minimize sustainable misconceptions (Alonemarera, 2020). Based on this, the use of diagnostic tests can be applied as an identification effort in diagnosing misconceptions and analyzing student difficulties in understanding the concept of Genetics material (Kurniawati et al., 2019). Diagnostic test is an assessment technique that is carried out specifically to identify the competencies, strengths, weaknesses of students, so that further learning can be designed according to the competencies and conditions of students (Kemdikbud, 2020). One form of diagnostic test that can be used to identify misconceptions is a reasoned multiple choice question.

The design of the questions presented in the form of a Diagnostic Three Tier Test is certainly able to show and inform how much misconception is obtained from the results of students' answers (Nur et al., 2023). In several related studies, the use of the Diagnostic Three Tier Test as an assessment to diagnose misconceptions has advantages and effectiveness. Among them are being able to provide information about student conceptions, easier to use than other diagnostic tests, using simple work instructions, and suitable for use at every level, especially in Genetics material which has material complexity that will be more easily identified using this question design (Rizki et al., 2022).

## **2. BIOLOGY CONCEPT, MISCONCEPTION OF GENETIC MATERIAL, DIAGNOSTIC THREE TIER TEST**

### **2.1 Biology Concept**

The nature of Biology provides consequences on how a person can respond and appreciate a problem about living things. Biology as a science that studies living things has scientific truth and can be accounted for. Biology as a science that has proven its scientificity will continue to apply until there is new evidence that can abort it. Below are things that need to be learned to help our understanding of the nature of biology according to (Darmawan et al., 2021). Biology as a collection of knowledge, it makes biology as a science of living things related to the universe. Knowledge is defined as a fact, concept, theory or generalization of something that can explain phenomena in life. Biology as an investigative process, it shows that biology as a process of search or investigation activities, because since ancient times, scientists provide a variety of ideas or ideas involving the scientific method process. Biology is a collection of values. It can be interpreted that in biology inherent values that are scientific in nature. Values such as curiosity, honesty, thoroughness, cooperation, respect for fellow opinions, and openness to various new phenomena. Therefore, in developing biology learning should be able to consider the values of humanity. Biology as part of everyday life - day, Biology is referred to as a science that has contributed a lot in meeting the needs of everyday life. For example, such as health problems, hygiene, improved nutrition, to the findings of genetic engineering that is useful for social life.

Understanding of concepts in Biology broadly consists of three objects, namely facts, operations and principles. In addition, according to Sudajdi (1985) in general, concepts in Biology consist of previous understandings that are accompanied by facts. Meanwhile, to show a certain understanding, a limitation or definition is used. Thus it can be obtained that in Biology, an understanding is used continuously to explain other understandings. This is because the hierarchical nature of Biology will allow the emergence of misunderstandings that are fatal, making it difficult to learn the next understandings related to the following understandings (Nurmala, 2021).

The fascinating and amazing concept of Biology lies in the statement of unity within great diversity. Diversity is a focus of biological research that explains some structure by classifying organisms according to certain dimensions. Botanists study plants, zoologists study animals, and microbiologists study bacteria and viruses. Some biologists focus on the study of shape and structure, a field of study known as morphology. Then those who concentrate on tissues and organs are anatomy, understanding the processes and mechanisms in living organisms are physiology, those who study the relationship between organisms and their environment are ecology, and those who study survival, transmission of traits from generation to generation are genetics (Henuhili, 2008).

## 2.2 Misconceptions in Genetics Learning

Misconceptions in the learning process are defined as misunderstandings before or during teaching activities that are contrary to scientific concepts (Hajiriah et al., 2019). During the teaching and learning process, it is possible that misconceptions will occur in various contexts which, if they continue to persist, are not realized, and are not immediately identified, confusion will occur in the students themselves, which hinders their cognitive development (Mukhlisa, 2021). Below are other common factors that cause other misconceptions in the teaching and learning process.

**Table 1. Common causes of misconceptions in the learning process**

Primary Cause	Specific Cause
Student	Preconception, associative thinking, humanistic thinking, incomplete reasoning, wrong intuition, learners' cognitive development stage, learners' ability, learners' interest in learning
Teacher / Lectures	Teachers/lecturers who do not master the material or do not understand the concept will cause students to experience misconceptions because the teacher does not pass on the correct concept to students.
Book	Textbooks can cause misconceptions due to language that is difficult to understand or explanations that are not correct so that misconceptions will be passed on.
Context	Learners' experiences, different everyday language, wrong discussion partner, wrong explanation of others
Teaching Methods	Teachers only use lecture and writing methods, do not reveal misconceptions, do not correct assignments, models and approaches are still conventional.

Biology learning is closely related to practicum activities and experiments, because in learning it upholds the truth of a theory or creates a new theory through an experimental activity. Experimentation characterizes biology learning as a skill to test ideas derived from facts, concepts, and principles of science. Practical activities as a very important part serves to connect theories or concepts, increase the attractiveness of students, to correct misconceptions. However, it cannot be denied that in every biology learning activity it is found that it is not followed by practicum activities due to various factors that cause misunderstanding of concepts or misconceptions (Ziraluo, 2021).

Genetics is a branch of biology that analyzes hereditary units and regulatory changes in various physiological functions that shape the character of organisms. The concept of genetics develops from a science that discusses how a trait can be inherited to a broader one. Genetics does not only study the inheritance of traits, but almost or none of the biological sciences can develop without knowing the concept of genetics (Rahmadina, 2019). The position of genetics in Biology according to some previous scientists states that genetics is known as the main core of modern biology, as well as one of the key fields in biology. No other field has played a greater role in shaping our knowledge of life than Genetics. Corebima (2010) states that the relationship between genetics and physiology shows that the main substance of biochemical reactions in organism cells (plants, animals, humans) requires enzymes as biocatalysts. Biosynthesis of proteins that make up enzymes is the process of translating genetic codes on mRNA. Another example of the relationship between genetics and taxonomy is related to the grouping of diversity based on the process of recombination, mutation, and sexual reproduction (Nusantari, 2014).

The contret concept that has been explained previously needs to be based on the cultivation of basic concepts before entering concrete concepts that require strong reasoning. Among the basic concepts that need to be understood to be a provision in understanding more complex concepts in genetics material can be shown in the table below.

**Table 2. Important concepts in Genetics**

No.	The Important Concept of Genetics Material
1.	Relationship between genes, DNA, and Chromosomes
2.	Mitosis and Meiosis that play a role in the inheritance of traits
3.	Mendel's Law
4.	Mutation

One of the sub-genetics that often experience misconceptions is in the material of protein synthesis and DNA replication (Permata et al., 2017). This is still often found in students which may be caused by explanations from teachers that are still difficult to understand, such as when analyzing the relationship between the structure and function of Deoxyribonucleic Acid (DNA), an explanation of chromosomes, so that the application of the principle of inheritance of traits in living things. In addition, in formulating the sequence of protein synthesis processes in relation to the delivery of the DNA - RNA genetic code. In research conducted by (Permata et al., 2017) students generally said that the work of DNA and RNA functions is still confused, namely from the process of replication, transcription, to translation.

Cell division is also a part of genetics that is classified as difficult because it tends not to be seen directly by the senses (Azizah, 2021). The information that can be absorbed by students is only understanding the material from what is read along with pictures or illustrations in the form of information that is certainly conveyed by the teacher so that it is prone to misconceptions. Identified misconceptions occur at the stages of spermatogenesis, oogenesis, as well as the stages of mitotic and meiotic division. Misconceptions can occur due to not understanding the terms diploid and haploid which are represented in the process of spermatogenesis, oogenesis, and mitosis and meiosis division. In addition, in terms of stage by stage and differences from each division process, it is sometimes difficult to identify the differences (Azizah, 2021).

The coverage of genetics material is very complex, mutation sub-material is also part of the topic of genetics where many misconceptions are still found (Wolly et al., 2021) The concept of mutation that often experiences misconceptions starts with the difference between body cells and sex cells and the types of mutations that cause syndromes. In a study conducted by (Wolly et al., 2021), it was found that the cause of misconceptions was incomplete reasoning regarding the process of how mutations can occur, both mutations in chromosomes, and mutations in nitrogenous base genetic material, this shows that there is a close relationship in the genetics sub-material.

### 2.3 Diagnostic Three Tier Test

Diagnostic tests in their implementation in learning aim to see the learning progress of students related to the process of finding the weaknesses of these students in certain materials using valid and reliable test content so as to be able to measure students' conceptions of circumstances and materials. In relation to misconceptions, the diagnostic test can be said to be a tool that can reveal the misunderstanding of concepts experienced (Jubaedah, 2017). With the use of diagnostic tests, it can detect and reveal the weaknesses experienced by students based on their knowledge. According to Mehrens & Lehmann, 1984 in (Prihatni et al., 2016), the Diagnostic Test must meet two criteria. The test is able to identify problems or difficulties experienced by students, and then the test is able to provide information for the next step in fixing certain problems found from the results obtained.

The Three Tier Test Diagnostic Problem Design is the method that is most capable of providing an overview of misconceptions (Putra et al., 2019). The Three Tier Test is a three-tier multiple choice test developed from the Two Tier Test by Treagust (Treagust, 1988). The first tier is a multiple-choice HOTS question with one answer questioning the truth or untruth of a question, the second tier is the reason for choosing the answer with one answer key and four error answers, the third tier questions the belief in both the first and second tier questions developed by Hasan, Bagayoko & Kelley (1999) in (Nur et al., 2023). This test facilitates a good examination of misconception scores, because the correlation between the scores of the first two tiers and the level of confidence will provide accurate information about misconceptions, can determine the parts of the material that require more emphasis during future learning, The diversity of the results of the diagnostic three tier test answers is shown in the table below

**Table 3. Categories of Diagnostic Three Tier Test Answer**

Answer Combination			Category
Level 1 (Answer)	Level 2 (Reason)	Level 3 (Confidence Level)	
Correct	Correct	Sure	Concept Understanding
Correct	Correct	Sure	False Misconception (+)
Incorrect	Correct	Sure	False Misconception (-)
Incorrect	Correct	Sure	Full misconception
Correct	Correct	Not sure	Understand the concept, but not sure
Correct	Incorrect	Not sure	Not Understanding the Concept
Incorrect	Correct	Not sure	Not Understanding the Concept
Incorrect	Incorrect	Not sure	Not Understanding the Concept

### 3. DISCUSSION AND CONCLUSION

A total of 18 diagnostic three tier test questions on Genetics material that have been done by students as a whole show a high percentage of misconception criteria in each sub and overall. Students as research samples who have worked on diagnostic three tier test questions show quite high misconception results which may be caused by internal and external factors (Rahayu, 2021) including the learners themselves (students), facilitators or teachers, teaching methods, learning contexts, and learning textbooks.

The results of interviews conducted with Semester 2 Biology Education students at FKIP UHAMKA stated that Genetics material is abstract, widespread, contains foreign terms, and is difficult to understand. In addition, Genetics learning generally tends to be skipped and not delivered as a whole, even though the students themselves realize that Genetics material is important to learn. This is in line with the opinion (Alonemara, 2020) that Genetics material is important to learn as a basis for understanding other interrelated biological concepts. So that this misconception can be an obstacle in the next learning process.

The lack of interest of students to learn this material is one of the factors that cause this misconception to occur, because the material is considered difficult, teaching methods are less varied, and students' readiness to develop their understanding is still minimal. In addition, the conditions experienced by Biology Education 2nd semester students when they were in high school, to be precise, during the Covid-19 pandemic, which was dominated by online teaching and learning activities. There are factors that cause high misconceptions, including learning that is not comprehensive, passive, minimal question and answer discussions, and even not carrying out teaching and learning activities. This is in line with the opinion (Rizki et al., 2022) that the influence of students' misconceptions is caused by the lack of effective online learning. The teacher only explains the material through learning media in the form of video explanations which are not necessarily students can focus on observing and listening well to the explanation, then during online learning the learning process is carried out using devices to support the learning process such as cellphones, computers, laptops which of course require other support such as certain educational platforms which are also supported by an adequate internet connection, even though not all students are guaranteed to have these needs met. Then, the next factor causing misconceptions put forward by students is about the content of textbooks available at educational institutions and related textbooks. The content of the concept of Genetics material specifically and in depth is still considered incomplete and includes basic material that only focuses on certain material, this is in line with what was revealed by (Wulandari et al., 2021) that Biology books circulating to date still contain content that contains old genetic concepts, while the nature of the genetic material itself is to study living things in a sustainable manner.

In depth, the misconceptions identified by students come from the answers put forward by students from each question. In the genetics sub-substance, the highest misconception occurs in question number 3 with the question indicator "Students are able to understand the ability of replication in DNA and RNA". From the results of the interview, one of the students with the initials N. K. that every RNA can carry out the reverse transcription process, without giving a full explanation that the RNA in question is RNA in prokaryotic or RNA in eukaryotic. The statement was supported by the student. Furthermore, in the interview results, one of the other students with the initials F. N. provided information on the reason that DNA and RNA have the same position as nucleic acids that are able to carry genetic information, so the roles and functions of DNA and RNA are considered the same by the student. The correct concept is that eukaryotic RNA does not replicate like DNA, but replication only occurs through the stages of the transcription process (mRNA synthesis) from template DNA by RNA polymerase (Latunra et al., 2017), 2017), besides that reverse transcription will be experienced by viruses that have genetic material in the form of RNA, because RNA in viruses has a reverse transcriptase enzyme to synthesize complementary or complementary chains (negative chains) using the parent chain (positive chain) (Syukur, M.,

& Sastrosumarjo, 2018). Then, RNA polymerase only plays a role to accelerate the process of RNA formation, the enzyme adds nucleotides to the 3' end along the DNA double chain in the transcription process (Gabrys et al., 2008). The most correct answer to the question above is that RNA in eukaryotic does not have the ability to replicate, because RNA in eukaryotic does not have enzymes that support the replication process like DNA. The presentation of question number 3 which discusses replication in DNA and RNA has the highest misconception in line with research (Permata et al., 2017) that students are still unable to distinguish the work of DNA and RNA functions. The presentation of questions in number 3 which discusses replication in DNA and RNA has the highest misconceptions in line with research (Permata et al., 2017) that students are still unable to distinguish the work of DNA and RNA functions.

In the second sub, namely Cell Division, the highest misconception occurs in question number 8 with the indicator "Students are able to understand the equations that occur in mitotic and meiotic cell division". The results of an interview with one of the students with the initials B. D. who answered "no" there are similarities in the stages of mitosis and meiosis on the grounds that there are different specific phases provides information that the student's understanding is that the process of mitosis and meiosis occurs under different conditions, resulting in different chromosome products, so it is conveyed that this is influenced by the phases and stages between the two different processes. Students are convinced that the process of interphase - prophase - metaphase - anaphase - telophase only applies in the process of meiosis alone whose stages are quite complex, while the stages of mitosis are believed to be based only on the cell cycle process, namely Phase Gap 1 - Synthesis - Gap 2 - Mitosis. The actual concept is that there are similarities between the stages of mitosis and meiosis which lie in the continuity of the DNA replication process before division. In mitotic division, DNA replication occurs during the interphase stage, which is the stage before the mitotic process begins, while DNA replication in meiotic division occurs during interphase before meiosis I begins (Dinanti et al., 2014). In the specific phases of the process of mitosis and meiosis are the same, namely passing through the stages of interphase, prophase, metaphase, anaphase and telophase but the difference is in the interaction of homologous chromosomes. Meiosis division produces chromosomes half of the parent, while mitosis does not. (Effendi, 2020). Then mitosis only occurs once the division includes the process of interphase, prophase, metaphase, anaphase, and telophase. Meanwhile, meiosis division occurs twice, namely meiosis I and meiosis II whose specific phases are the same as mitosis. The finding of misconceptions in the presentation of question number 8 which questions the differences and similarities of the stages of mitosis and meiosis is in line with research (Azizah, 2021) that in terms of stage by stage and differences from each division process it was found that it was still difficult to identify the differences.

In the Trait Inheritance Pattern sub, the highest misconceptions occur in numbers 11 and 12 with indicators "Students are able to understand the degree of dominance of an organism cross" and "Students are able to analyze the link between genes that affect the inheritance of two different characters". The results of interviews conducted with students with the initials R. S. who answered that this condition was not a perfect dominance phenomenon, and gave the reason that this was because there was a dominant gene that was hidden when paired with its allele, namely heterozygous flowers have less red pigment than red homozygotes, providing information on the dominant gene in dominant homozygous red flowers when crossed with recessive homozygous white flowers, then the gene in red flowers becomes hidden when paired with its allele. The allele referred to here according to the student is the recessive homozygous white flower. The real concept is that the picture presented in the question that shows the crossing of a red snapdragon flower plant with a white snapdragon plant producing a pink snapdragon plant is not a perfect dominance phenomenon. The segregation of red flower and white flower alleles in gametes produced by pink flowers confirms that the flower color alleles in the parent are inherited factors that maintain their respective identities so that it can be mentioned that the dominant allele in homozygous red flowers cannot cover the recessive allele in white flowers completely, which causes heterozygous individuals to have half dominant and half recessive traits. Based on this, the above cross is called an imperfect dominance cross, (Campbell Neil A, 2010). Misconceptions in the inheritance pattern of Mendel's law of genetics are still often found on how to distinguish the phenomenon of crosses, this is in line with research (Fajri et al., 2022). That misconceptions are still found in representing a phenomenon that occurs in crosses - crosses of Mendel's law and deviations from Mendel's law.

In the fourth sub-material, namely the Mutation sub-material, the highest misconception of the mutation sub-material occurs in question number 15 with the question indicator "Students are able to apply an example of point mutation that can cause frame shifts,". The results of the interview with one of the students with the initials B. H. who mentioned that the condition of the frame shift can occur because the insertion is a reduction of three nucleotides at the end of the encoding sequence provides information that as far as the student understands the insertion is one form of point mutation, namely the reduction of nitrogenous bases. In addition, in the reason option, the next statement states that the reduction of three nucleotides at the end of the coding sequence can change the order shift massively, moreover there are three reduced nucleotides that will cause errors in the fatal amino acid translation process. The actual concept is that an Insertion is the insertion of one or more nucleotides in a gene which is a point mutation (Warmadewi, 2017). This will result in a shift in the reading frame that affects

the structure and function of the protein. During protein synthesis, the reading of the genetic code will start from one end of the protein reference, namely mRNA, and will be read as a unit of three bases in sequence. So that it will cause a shift in the nitrogen base frame with the impact of the formation of proteins that do not function as a result of the synthesized amino acid sequence (Campbell Neil A, 2010). The finding of misconceptions in this mutase material is in line with one of the studies (Wolly et al., 2021) which states that in the mutation sub, misconceptions occur due to the delivery of incomplete reasons regarding the mechanism of mutation in chromosomes and point mutations in nitrogenous bases which are closely related to the substance of genetics.

## REFERENCES

- Abdul, M. (2021). Metodologi Penelitian Bisni Dengan Pendekatan Kuantitatif. In W. Sri (Ed.), *Syria Studies* (Vol. 7, Issue 1). Jakad Media Publishing.
- Campbell Neil A. (2010). *Biologi* (H. W. Hardani, Ed.; Edisi 8). Penerbit Erlangga.
- Cetin-Dindar, A., & Geban, O. (2018). Development of a three-tier test to assess high school students' understanding of acids and bases. *Procedia-Social and Behavioral Sciences*, *15*, 600–604. <https://doi.org/10.1016/j.sbspro.2011.03.147>
- Chairunnisa ... Khairil. (2016). Rekonstruksi Miskonsepsi Siswa Pada Konsep Materi Genetik Melalui Penerapan Model Learning Cycle 7E. *Jurnal EduBio Tropika*, *4*(1), 15–18.
- Darmawan, E. ... Rizhal, R. (2021). *Strategi Belajar Mengajar Biologi*. Pustaka Rumah Cinta.
- Elvianasti, M. (2019). Content Representation (CoRe) Calon Guru Biologi pada Konsep Genetika. *Bioeduscience*, *3*(1), 33–40.
- Fadhilla, R., Tp, S., & Si, M. (2019). *Kimia Organik Dasar* (Vol. 253, pp. 0–17).
- Halim, A., Farada, S., Hamid, A., Mustafa, Nurulwati, Mahzum, E., & Irwandi, I. (2021). Effect of concept attainment model on student's science process skills. *Journal of Physics: Conference Series*, *1882*(1), 1–7. <https://doi.org/10.1088/1742-6596/1882/1/012157>
- Hamid, H. (2015). ANALISIS MISKONSEPSI MAHASISWA CALON GURU BIOLOGI PADA KONSEP MORFOLOGI DAUN. In *Jurnal Pendidikan Biologi* (Vol. 2, Issue 2).
- Istiyani, R., Muchyidin, A., & Rahardjo, H. (2018). Analisis Miskonsepsi Siswa pada Konsep Geometri Menggunakan Three-Tier Diagnostic Test. *Cakrawala Pendidikan*, *2*, 223–236.
- Jubaedah. (2017). Pengembangan Tes Diagnostik Berformat Four-Tier Untuk Mengidentifikasi. *Prosiding Seminar Nasional Fisika (E-Journal) SNF 2017*, *VI*(October), 35–40.
- Kemdikbud. (2020). Kepmendikbud Nomor 719/P/2020 tentang Pedoman Pelaksanaan Kurikulum pada Satuan Pendidikan dalam Kondisi Khusus. *Www.Kemdikbud.Go.Id*, *022651*, 9.
- Machová, M., & Ehler, E. (2021). Secondary school students' misconceptions in genetics: origins and solutions. *Journal of Biological Education*, *00*(00), 1–14. <https://doi.org/10.1080/00219266.2021.1933136>
- Mehmetlioglu, D. (2014). Misconceptions of Elementary School Students about Comparing Decimal Numbers. *Procedia - Social and Behavioral Sciences*, *152*, 569–574. <https://doi.org/10.1016/j.sbspro.2014.09.245>
- Nabilah, L. Y., Ruslan, R., & Rusli, R. (2020). Pengembangan Instrumen Diagnostik Three Tier Test pada Materi Pecahan Kelas VII. *Issues in Mathematics Education (IMED)*, *3*(2), 184. <https://doi.org/10.35580/imed12421>
- Nadelson, L. S., Heddy, B. C., Jones, S., Taasobshirazi, G., & Johnson, M. (2018). Conceptual change in science teaching and learning: Introducing the dynamic model of conceptual change. *International Journal of Educational Psychology*, *7*(2), 151–195. <https://doi.org/10.17583/ijep.2018.3349>
- Permata, S. I. (2018). Profil Miskonsepsi Siswa SMA pada Materi Sintesis Protein Menggunakan Three Tier Test. *BioEdu*, *7* No. 3, 490–495.
- Rahmat, F. L. A., Suwatno, S., & Rasto, R. (2018). Meningkatkan Pemahaman Konsep Siswa Melalui Teams Games Tournament (Tgt): Meta Analisis. *Jurnal MANAJERIAL*, *17*(2), 239. <https://doi.org/10.17509/manajerial.v17i2.11783>
- Soeharto, S., & Csapó, B. (2022a). Exploring Indonesian student misconceptions in science concepts. *Heliyon*, *8*(9), e10720. <https://doi.org/10.1016/j.heliyon.2022.e10720>

- Uriel, C., Sergio, S., Carolina, G., Mariano, G., Paola, D., & Martín, A. (2020). Improving the understanding of Basic Sciences concepts by using Virtual and Augmented Reality. *Procedia Computer Science*, 172, 389–392. <https://doi.org/10.1016/j.procs.2020.05.165>
- Versteeg, M., Hafkemeijer, A., de Beaufort, A. J., & Steendijk, P. (2021). An Understanding of (Mis)Understanders: Exploring the Underlying Mechanisms of Concept Learning Using Functional Magnetic Resonance Imaging. *Mind, Brain, and Education*, 15(1), 129–138. <https://doi.org/10.1111/mbe.12273>
- Wahyuni, S., Awal, R., & Martala, S. (2019). Identifikasi Miskonsepsi Mahasiswa Pendidikan Biologi pada Matakuliah Zoologi Invertebrata di FKIP Universitas Lancang Kuning Pekanbaru. *Jurnal Pendidikan Biologi*, 6(1), 87–98.
- Warmadewi, D. A. (2017). Buku Ajar Mutasi Genetik. *Mutasi Genetik*, 15–16(Mutasi), 1–53.
- Wolly, C., & Waskito, P. (2021). Miskonsepsi Siswa Sekolah Menengah Atas Tentang Mutasi Dalam Materi Genetika. *Jurnal Bioeducation*, 8(1), 1–7.
- Wulandari, S., Gusmalini\*, A., & Zulfarina, Z. (2021a). Analisis Miskonsepsi Mahasiswa Pada Konsep Genetika Menggunakan Instrumen Four Tier Diagnostic Test. *Jurnal Pendidikan Sains Indonesia*, 9(4), 642–654. <https://doi.org/10.24815/jpsi.v9i4.21153>
- Ziraluo, Y. P. B. (2021). *Pembelajaran Biologi: Implementasi dan Pengembangan* (S. Lita (ed.); Cetakan Ke, Vol. 1). Forum Pemuda Aswaja.