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Genetic Engineering Misconceptions in High School Biology Textbooks

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Abstract

Background: In 12th-grade high school biology classes, genetic engineering is a complex subject that is prone to misconceptions. The molecular processes involved, along with the lack of practical experiments, are the primary factors contributing to this. Meanwhile, textbooks are the primary teaching materials used by teachers to instruct students on genetic engineering in class. This study aimed to analyze the existence of misconceptions about genetic engineering in 12th-grade high school biology textbooks in Yogyakarta, particularly in Sleman Regency.
Methods: This study was a qualitative content analysis. The research subjects consisted of 12th-grade high school biology textbooks. The textbooks were selected using purposive sampling, which involved choosing the 2 books most widely used by teachers in schools, based on the results of interviews. Data collection was conducted through content analysis using a misconception analysis sheet as an instrument. Data validity was tested through source triangulation. Data analysis techniques included unitizing, sampling, recording, reducing, inferring, and narrating.
Results: In Textbook A, 5 misconceptions were found, consisting of 3 misidentifications, 1 overgeneralization, and 1 oversimplification. In Textbook B, there were 3 misconceptions, namely 1 overgeneralization and 2 oversimplifications.
Conclusion: There were misconceptions in the textbooks, both regarding the principles of genetic engineering and their applications.

INTRODUCTION

Teaching materials play a vital role in achieving learning objectives by providing structured content and resources. They are adapted to the curriculum to meet predetermined competency standards and basic competencies (Irawan, 2025). According to Aisyah, Noviyanti, & Triyanto (2020), teaching materials are collections, either printed or electronic, used by teachers during instruction. Key benefits include supporting lesson delivery, aiding student comprehension, and ensuring consistency in learning experiences.

Textbooks are one type of teaching material used in school learning. According to Mithans & Grmek (2020), textbooks remain the primary teaching material used by teachers for primary and secondary school subjects more often than any other material. This is reinforced by research conducted by Li and Wang (2024), which suggests that textbooks are generally viewed as the primary teaching materials in schooling, used by teachers and students to achieve curriculum objectives. This may be because textbooks offer advantages for the teacher and student. Textbooks provide a sequenced syllabus/curriculum-aligned progression of topics, which helps ensure content is covered comprehensively and logically (Sutrimah et al., 2019). Textbooks already compile content, activities, exercises, visuals, and sometimes assessment tools; teachers don't need to create all materials from scratch, so this saves the teacher's time (Cadacio, 2024; Sutrimah et al., 2019). Textbooks are also often readily available and don't require special equipment, so they are usable even where resources are limited (Cadacio, 2024). Textbooks act as a comprehensive resource because it can contain explanations, examples, exercises, activities, and sometimes even teacher guidance; this makes it a complete package for teaching and learning (Cadacio, 2024; Sutrimah et al., 2019). Textbooks also support independent learning & review because students can revisit and review material on their own using textbooks (Cadacio, 2024).

The quality of textbooks can be assessed by various aspects, including the clarity of concepts (Pulungan, 2020). Therefore, textbooks must present clear and accurate material to support teachers and students in the learning process and prevent misconceptions. Misconceptions refer to concepts not in accordance with scientific understanding or expert consensus (Permadani et al., 2022). They are statements declared as errors or mistakes regarding concepts that are distinct and interact with one another.

Misconceptions not only occur due to ideas or notions based on irrelevant experiences, but can also occur due to textbooks that contain incorrect material descriptions, teachers who have misconceptions, language errors that arise due to a culture that has misunderstood scientific definitions, incorrect intuition, and inappropriate teaching methods (Fauziah & Darvina, 2019; Yuliati, 2017). Misconceptions in textbooks can be caused by several factors, such as incorrect explanations, writing errors, the use of language that is too advanced for the level of the intended students, the provision of illustrations taken from everyday life that are not in accordance with the true meaning of the concept, the use of cartoons, and the differences in presentation between textbooks from various publishers (Damanik et al., 2025; Mulia & Zulyusri, 2021; Syahyani, 2018).

One of the biology materials in high school is genetic engineering. Genetic engineering involves modifying the characteristics of organisms according to specific needs, usually by taking desirable traits from other organisms (Aslina et al., 2023). Genetic engineering material is expected to improve students' understanding of biotechnology because it is often the main topic of discussion in modern biotechnology. Several reports show that genetic engineering is considered a difficult subject. For example, research conducted by Zulpadly et al. (2016) revealed that the most difficult aspect of biotechnology was explaining the process of genetic engineering, with a percentage of 67.44%. In addition, genetic engineering material also raises socio-scientific issues. According to Wardani et al. (2023), cloning technology, which was one of the discoveries in genetic engineering, has become a hot issue because it has provoked both positive and negative reactions and perceptions in society.

Based on interviews conducted with 12th-grade biology teachers in Sleman Regency, it was found that genetic engineering is a difficult topic for students due to its high level of complexity. The abundance of theories about molecular processes and the lack of practical experiments are major factors contributing to this difficulty. Teachers also said that because this material is in the last chapter, it often does not receive full attention from students because they are busy preparing for school exams and college entrance exams. However, this material is one of the important materials that form the basis for students to determine their attitude towards one of the scientific advances in the field of biotechnology. Furthermore, based on interviews, it was also found that textbooks are the only teaching materials used by teachers to teach genetic engineering in class.

Yogyakarta has long been known as a city of education. Sleman is one of the regencies, which, according to the Ministry of Education, Culture, Research and Technology (2023), has the highest number of schools among other regencies in Yogyakarta. This condition provides an opportunity to analyze the most widely used textbooks in grade 12 high school learning. With the highest number of high schools in Yogyakarta, it is expected that the large number of students will provide a broader representation of students' understanding of genetic engineering material. In addition, based on interviews conducted with 12th-grade biology teachers in Sleman Regency, it was known that there has never been an analysis of misconceptions in the textbooks used there, especially on genetic engineering material.

METHODS

The research conducted was qualitative research. The type of qualitative research used was content/document analysis. According to Wahyuningrum (2022), content analysis aims to discuss the content of information in depth by recording information in a structured and systematic manner so as to provide an in-depth interpretation. This research was conducted by analyzing misconceptions about genetic engineering material in 12th-grade high school biology textbooks.

The research subjects were 12th-grade high school biology textbooks obtained using purposive sampling, namely the two textbooks most widely used by teachers at schools identified through interviews. Data collection through document analysis (Ary et al., 2015) used an instrument in the form of a misconception analysis sheet. Before use, the instrument was first validated using the expert judgment technique involving biology education experts. Data validity was tested through source triangulation involving the researcher, a genetics lecturer, and a 12th-grade high school biology teacher. The data analysis technique followed the qualitative content analysis technique by Krippendorff (2019). The process included unitizing, sampling, recording, reducing, inferring, and narrating.

(1) Unitizing was collecting the appropriate data for research. In this section, researchers determined the appropriate book unit as research data, namely the biology book most widely used by 12th-grade high school biology teachers in Sleman Regency. (2) Sampling was a method of analysis to limit observations or simplify research that summarizes existing unit types. At this stage, the researcher determined the text and pictures in the textbook that were included in the genetic engineering material. Because genetic engineering material was not a separate chapter in the textbook, but was included in the Biotechnology Chapter, the researcher must be careful in determining the material that was included in the object of this study. (3) Recording was the analysis stage. In this case, the researcher analyzed misconceptions of genetic engineering material in textbooks. The researcher used literature such as books and research articles to compare them with the concepts in textbooks, and was limited by the curriculum. (4) Reducing was the simplification of data. At this stage, the researcher simplified the data found from the analysis of misconceptions in the previous step. The researcher reduced concepts that were not the main topic of the research. (5) Inferring was drawing conclusions. At this stage, the researcher drew conclusions about the types/categories of misconceptions of genetic engineering material in textbooks. (6) Narrating was the presentation of the researcher's answers to the research questions. At this stage, the researcher presented the results of the analysis of misconceptions about genetic engineering in the form of an explanation of the analysis results (Pratiwi et al., 2024).

RESULT AND DISCUSSION

One of the subjects studied in high school biology is genetic engineering. Genetic engineering covers the principles of genetic engineering and its application in various fields. Based on a survey conducted in high schools in Sleman Regency, it was found that the biology textbooks were most widely used by teachers as teaching materials to explain genetic engineering in class. The analysis of misconceptions in this study was based on the criteria for conceptual errors according to Dikmenli (2009), there are misidentification, overgeneralization, oversimplification, obsolete concepts and terms, and undergeneralization.

Based on the analysis results, it was found that Textbook A contained 5 misconceptions out of a total of 16 concepts. The most dominant misconception was in the misidentification category, which contained 3 concepts. The Textbook B contained 3 misconceptions out of a total of 12 concepts. The most dominant misconception was in the oversimplification category, which contained 2 concepts. The complete data is presented in Table 1.

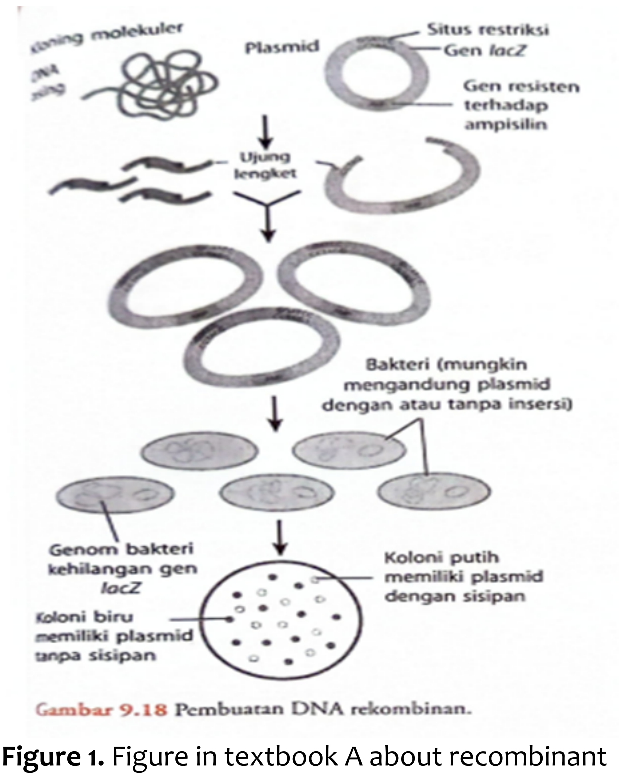
Table 1. Data tabulation of misconceptions analysis results from 12th-grade high school biology textbooks in each category

Book	Concept	Misconception Category					Total Misconception
		MI	OG	OS	OCT	UG	
A	16	3	1	1	0	0	5
B	12	0	1	2	0	0	3

MI: Misidentification
OG: Overgeneralization
OS: Oversimplification
OCT: Obsolete Concept and Terms
UG: Undergeneralization

The Textbook A defined genetic engineering as follows: Genetic engineering is the attempt to manipulate the traits of living organisms to produce desired traits. This definition contained a misconception in the form of misidentification because it met the indicator criteria, namely, an error in the use of terms in the concept. This misconception occurred particularly in the use of the term “traits” in the phrase “attempt to manipulate the traits of living things.” The correct concept is that what is manipulated in genetic engineering is not “traits” but genetic material, especially DNA. A trait is a specific characteristic of an organism that can be described or measured, such as fruit color, fruit shape, hair color, height, etc. A trait is determined by its genes and is expressed as part of an individual's phenotype. So, a trait is controlled by the gene. While many traits are purely genetic, some result from a combination of genetic and environmental factors (Hull, 2025; Moran et al., 2024). Meanwhile, what can be engineered in genetic engineering is genetic material. The DNA of a living organism is manipulated to express traits desired by the engineer. This is in line with the understanding conveyed by Bhat and Al-Khayri (2023), also Fan (2024), that genetic engineering refers to the manipulation of genetic material, primarily DNA, to create desired traits or outcomes. Chemical splicing, bacterial or viral recombination, and the design and engineering of novel life forms are among the approaches used. Techniques in genetic engineering are known to have undergone rapid progress. It began with DNA technology that combines DNA from two or more sources to create a new genetic sequence (Fan, 2024; Jena et al., 2024; Purkait & Yousuf, 2024). Currently, CRISPR-Cas9 is being developed, which is a revolutionary genome-editing technology that allows for precise, targeted changes to the DNA of an organism (Aljabali et al., 2024; Du et al., 2023; Y. Fan, 2024; Gan & Ling, 2022; Jiang & Doudna, 2017; T. Li et al., 2023; Liao et al., 2024; Nojadeh et al., 2023; Vaghari-Tabari et al., 2022; Wang et al., 2022; Yang et al., 2024; Zhu, 2022).

The next conceptual error in Textbook A occurred in the definition of chromosome mapping. This conceptual error also fell under the category of misidentification because it met the criteria of the indicator, namely, an error in the use of terms in the concept. The book stated that "Chromosome mapping is an effort to determine the location of chromosomes that contain genes carrying certain traits in a chromosome sequence in an organism's cells." This was incorrect. Chromosome mapping is not to determine the location of chromosomes, but to determine the location and sequence of genes within a chromosome. This is in accordance with the definitions provided by Salmon (2025) and Kubal (2025) that chromosome mapping refers to the process of locating genes and genetic markers on chromosomes. This can be achieved through genetic mapping, which relies on recombination frequencies during meiosis, and physical mapping that provides information about the location of genes and the distances between them (He, 2022; Salmon, 2025; Singh, 2023). Chromosome mapping offers a detailed picture of the structure, sequence of genes contained, and function of chromosomes (Salmon, 2025); therefore, it is useful for many applications. It supports carrier detection or identifying genes associated with genetic disorders, prenatal and newborn screening, and identification of disease predispositions. Chromosome mapping is also guiding personalized medicine, targeted therapies, and gene therapy approaches (Kuball, 2025; Salmon, 2025). In detecting and managing genetic conditions at an early stage, chromosome mapping plays a central role by helping identify variations responsible for diseases. For example, chromosomal mapping can identify people who have cystic fibrosis but do not exhibit symptoms. Furthermore, locating specific mutations allows for the development of targeted therapies (Salmon, 2025). In agriculture, chromosome mapping has become an essential tool in plant improvement. Chromosome mapping also facilitates the preservation of biodiversity by identifying genetic variation within and between species (Kuball, 2025).



Gambar 9.18 Pembuatan DNA rekombinan.

Figure 1. Figure in textbook A about recombinant DNA formation

The next misconception found in Textbook A was in the illustration of the process of recombinant DNA formation (Figure 1). The misconception in this picture was in the category of overgeneralization. The pictures in the textbook did not include several very important details that should be explained in the process of recombinant DNA production, namely, details of the gene that would be inserted into the plasmid, details of the cut plasmid, details of the recombinant DNA, and details of the recombinant plasmid being introduced into bacteria.

In recombinant DNA production using plasmids, the main components are the DNA to be inserted and the plasmid to be cut (Brown, 2025; Glick & Patten, 2022; Vioti, 2022). These fundamental components must be clearly shown in the picture so that students can easily understand them. Furthermore, the recombinant plasmid picture should also be labeled. Recombinant plasmids are formed from the combination of the desired DNA with a plasmid that has been cut using the same endonuclease restriction enzyme, resulting in complementary DNA ends (Glick & Patten, 2022; Vioti, 2022). This result is a fundamental part of recombinant DNA production. Therefore, the pictures in the textbook must be able to illustrate this well. Another limitation found in the pictures of recombinant DNA production in Textbook A was the absence of text explaining that the recombinant DNA that had been produced was then inserted into bacteria or host cells. This stage is the first step in multiplying recombinant DNA after the selection process of cells carrying recombinant DNA has taken place (Glick & Patten, 2022; Brown, 2025; Vioti, 2022). The lack of explanation in the illustration can cause confusion, a lack of understanding, and misconceptions among students.

There was another misconception in Textbook A, namely, in the definition of transgenic organisms. This misconception was in the category of oversimplification because the explanation was too simplistic. Textbook A stated that "transgenic organisms are organisms that obtain genes from other organisms." This overly simplified definition can lead to a misconception, namely, that when an organism obtains genes from another organism, either naturally or through human manipulation, it is still considered a transgenic organism. In fact, transgenic organisms are organisms that have been altered by the introduction of one or more foreign DNA sequences from another species by artificial means (Kaif, 2023; Liu, 2025). Transgenic organisms are generated in the laboratory through genetic engineering techniques. In this technique, scientists alter an organism's DNA by incorporating genes from another species, which facilitates the transfer of specific traits or characteristics (Kaif, 2023). Meanwhile, there are naturally occurring organisms that can incorporate DNA or genes from other organisms, such as bacteria. Bacteria take up exogenous DNA from the environment, and this process is called natural transformation (Debatisse et al., 2025; Domenech et al., 2020; Dubnau & Blokesch, 2019; Jin et al., 2020; Niu et al., 2025; Winter et al., 2021; Zhang et al., 2021). This ability can be performed by bacteria when they enter a transient physiological state known as competence (Domenech et al., 2020; Niu et al., 2025). Therefore, when a book defines a transgenic organism as an organism that obtains genes from other organisms without explaining that this was achieved through deliberate engineering or manipulation by humans, this definition cannot be categorized as a definition of a transgenic organism.

The next misconception found in textbook A was the picture of transgenic food crops (Figure 2). This misconception was a misidentification category because of the incorrect use of terms in the concept.

Figure 2. Examples of transgenic plants presented in textbook A

In Textbook A, the picture was titled “examples of transgenic food plants.” The picture shown was rice, bananas, tomatoes, and peppers. None of these were “crops.” A crop refers to a plant that can be grown and harvested extensively for profit or subsistence (Tikkanen, 2025; Aly & Borik, 2023). If the title of the picture in the textbook was transgenic food plants, then the picture could show a transgenic plant that was classified as a food crop, such as in Figure 3, which was taken from the research by Dale et al. (2017).

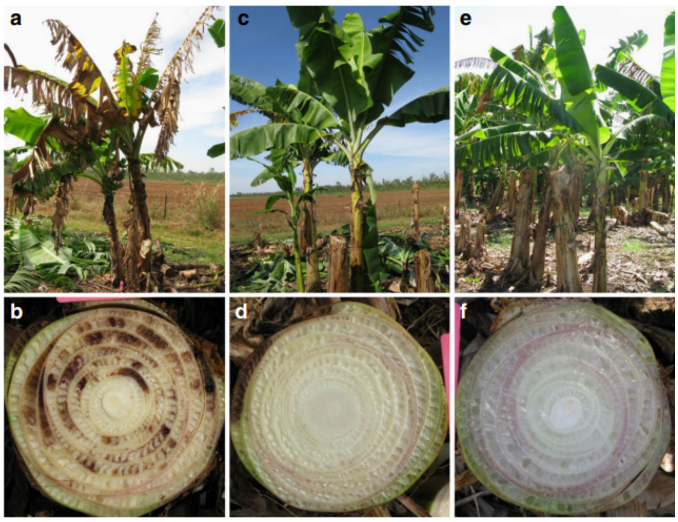


Figure 3. Cavendish banana plants (a-b. wild type, c-f. transgenic plants that were resistant to *Fusarium*) (Dale et al., 2017)

If the textbook wanted to retain the pictures of rice, bananas, tomatoes, and peppers, then the picture captions could be changed to be more accurate. Some appropriate terms to replace the picture captions were transgenic products, or transgenic products in agriculture, or genetically modified products, or genetically modified products in agriculture, or transgenic crops. In addition, among the pictures of rice, bananas, tomatoes, and peppers in the textbook, only the picture of rice showed the difference between transgenic and non-transgenic products. The pictures of bananas, tomatoes, and peppers should also be supplemented with comparisons between transgenic and non-transgenic products to reinforce students' understanding, as shown in Figure

4 (Dale et al., 2017). From the comparison shown in Figure 4, the difference between transgenic and non-transgenic bananas can be easily understood. In this case, transgenic bananas were genetically modified to accumulate elevated levels of provitamin A (PVA) in fruit. This process caused the bananas to have more orange or golden-yellow flesh, a significant color change from standard bananas (Dale et al., 2017).

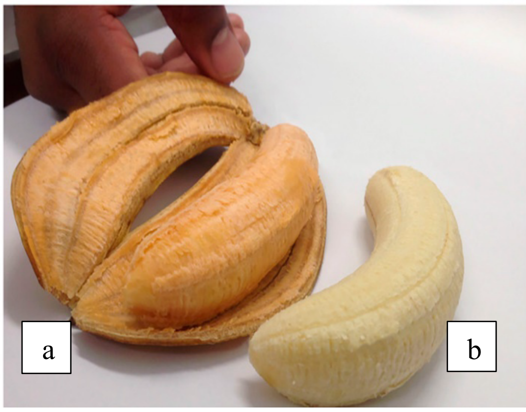


Figure 4. Bananas transgenic (a) and non-transgenic (b) (Dale et al., 2017)

Based on data analysis, it was known that Textbook B also contains misconceptions. The first misconception was found in the picture of genetic engineering to produce transgenic plants (Figure 5). The misconception in this image was in the category of oversimplification because it met the indicator, namely that the image/table/graph was too simple and did not describe the authenticity of the object.

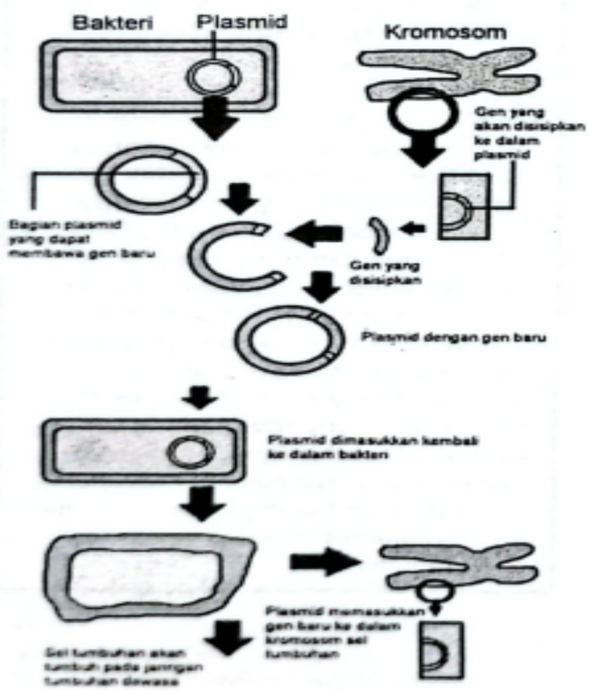


Figure 5. Picture in textbook B, entitled genetic engineering to produce transgenic plants

In the picture of the genetic engineering process for producing transgenic plants in Textbook B, there were key steps that were not presented. After the diagram and explanation showing that the plasmid (recombinant) was reinserted into the bacteria, textbook B did not include the step of infecting the bacteria into the plant, but instead went directly to the step "plant cells will grow in adult plant tissue." This was very likely to cause misconceptions among students. In the production of transgenic plants, *Agrobacterium tumefaciens* was usually used to carry recombinant DNA into the plant genome (Agrawal & Rami, 2022; Goralogia et al., 2025; Hwang et al., 2017; Ma et al., 2020; Niazian et al., 2017; Niedbała et al., 2021). This was based on its natural ability to infect plants and transfer any DNA sequence of interest to model plants and crops (Thomson et al., 2024). In the genetic engineering process involving *A. tumefaciens* to create transgenic plants, the stage of inserting recombinant DNA into plants (with the help of *A. tumefaciens*) was a key step that cannot be overlooked (Bélanger et al., 2024). If this step were not carried out, transgenic plants would not be formed. Therefore, the picture in the textbook should clearly show this step.

The next misconception found in Textbook B was related to the definition of plasmids. This misconception was categorized as an oversimplification because it did not explain the concept completely. In Textbook B, plasmids were defined as follows: "Plasmids are small DNA molecules found in bacteria or single-celled eukaryotes that can replicate." This definition only mentioned that plasmids were DNA molecules found in bacteria, even though bacteria contained chromosomal DNA and extra-chromosomal DNA. Meanwhile, plasmids are extra-chromosomal DNA molecules that are separate from chromosomal DNA (Dewan & Uecker, 2023; Helinski, 2022). The incomplete explanation in Textbook B led to a fatal misconception. More comprehensively, a plasmid can be defined as an extra-chromosomal, circular, double-stranded DNA genetic elements that replicate independently of genomic DNA (Atala, 2020; Castaneda-barba et al., 2025; Delafuente & Diaz-colunga, 2024). Plasmids are major vectors for horizontal gene transfer within bacterial populations (Castaneda-barba et al., 2025; Delafuente & Diaz-colunga, 2024; Helinski, 2022). Plasmids can carry accessory genes and move between hosts, acting as mobile genetic elements (Smyth et al., 2022).

The picture in Textbook B related to the insulin production process (Figure 6) also contained misconceptions. This misconception was in the category of overgeneralization and met the indicators, namely that the parts that make up the object were not mentioned in detail. This was because the picture of the insulin production process did not provide explanations or stage numbers for recombinant plasmids, which should be stage number 3.

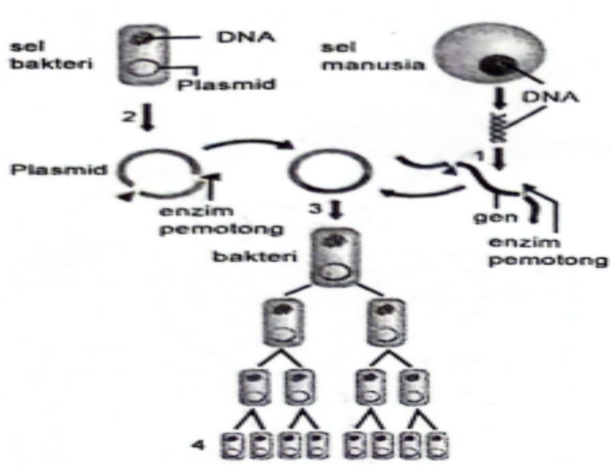


Figure 6. Insulin production process in textbook B

In the image, the first stage was visualized by the cutting of the gene by restriction enzymes. The second stage was the cutting of the plasmid by restriction enzymes. However, the third stage was visualized by the introduction of the plasmid into bacteria. Before this stage, the recombinant plasmid formed from the ligation of the gene and plasmid that have been cut using the same restriction enzymes should be named first. After that, the recombinant plasmid carrying the insulin gene was inserted into bacteria for selection and propagation (Riggs, 2021). In addition, the image of the insulin production process presented in Textbook B did not show the extraction and purification process of the insulin protein that was formed.

Misconceptions in textbooks can have a negative impact on students, teachers, and learning. Misconceptions in textbooks can significantly distort students' conceptual understanding, especially in science education (Fakhriyah et al., 2025). This is in line with the findings of Han and Heinze (2018) that misconceptions in textbooks can cause lower student achievement on conceptual assessments. Misconceptions in textbooks also contribute to the persistence of scientific misunderstandings across generations of learners (Guerra-Reyes et al, 2024). Guerra-Reyes et al. (2024) found that poorly conceptualized visuals and definitions, especially in natural sciences, lead to long-term cognitive barriers. Beside that, students exposed to inaccurate explanations from textbooks have weaker skills evaluating claims and evidence, harming scientific literacy more broadly. It can reduce critical thinking and scientific literacy (Chen et al., 2020). For teachers, misconceptions in textbooks can also have a negative impact, one of which is weakened teacher content knowledge and pedagogy. Textbook inaccuracies can misshape teachers' pedagogical content knowledge and reduce their ability to identify and remediate student misconceptions (Fan et al., 2021; Tore et al., 2023). In addition, misconceptions in textbooks can also lead to the propagation of errors through teaching and classes. When teachers rely on flawed textbooks, those errors get repeated in classroom instruction and assessments, spreading the misconceptions across cohorts (Fan et al., 2021; Tore et al., 2023). Furthermore, persistent textbook misconceptions slow curriculum updates and leave instructional materials out of step with current scientific consensus. Reviews of conceptual-change literature highlight this systemic problem.

Based on other studies, misconceptions in textbooks can actually be prevented, especially by authors and publishers. The first step that can be taken is to use rigorous expert peer review (content specialists + pedagogy experts). Subject experts catch factual errors, and pedagogy experts spot likely misinterpretations before publication (Fakhriyah et al., 2025; Zajkov et al., 2016). The next step is to write refutational/conceptual-change style explanations for topics known to provoke misconceptions. Research and meta-analysis show refutational texts and conceptual-change interventions are especially effective at replacing incorrect ideas (Prinz et al., 2022). Then, pilot textbooks with teachers and students (iterative classroom trials) and revise using feedback. Classroom piloting reveals ambiguous phrasing, inadequate examples, and teacher misreading that lead to downstream misconceptions (Fakhriyah et al., 2025; Soeharto, 2022). In addition, to avoid misconceptions in textbooks is essential to ensure alignment with current scientific consensus and make update cycles explicit. Outdated science or oversimplifications become entrenched; scheduled revision cycles and alignment checks keep textbooks current. Then, use interdisciplinary review panels to detect cultural/linguistic oversimplifications and ambiguous wording. Wording and cultural framing can foster misunderstandings; panels that include linguists/educational psychologists reduce this risk (Nketsiah & Motlhabane, 2025).

CONCLUSION

There were misconceptions in the textbooks regarding both the principles of genetic engineering and their applications. Misconceptions in Textbook A consisted of 3 categories of misidentification, 1 category of overgeneralization, and 1 category of oversimplification. There were misidentifications regarding the definition of genetic engineering, chromosome mapping, and transgenic organisms. The overgeneralization regarding the picture of the process of recombinant DNA formation. The oversimplification regarding the picture of GMO plants.

Misconceptions in Textbook B consisted of 1 category of overgeneralization, related to the picture of the insulin production process. Then, 2 categories of oversimplification regarding the picture of genetic engineering for producing transgenic plants and the definition of plasmids. Based on these findings, teachers must be more selective in selecting textbooks for use in learning. Furthermore, an independent review before using a textbook is also essential. Authors and publishers also have to be more thorough and responsible in presenting textbooks. This is because misconceptions in textbooks can negatively impact students, teachers, and learning. The results of this study also open up great opportunities for other researchers to analyze misconceptions in textbooks across various subjects and school levels, given that many textbooks are widely circulated in schools by various authors and publishers.

REFERENCES

Agrawal, S., & Rami, E. (2022). A Review: Agrobacterium-mediated Gene Transformation to Increase Plant Productivity. *The Journal of Phytopharmacology*, *11*(2), 111–117. https://doi.org/10.31254/phyto.2022.11211

Aisyah, S., Noviyanti, E., & Triyanto. (2020). Bahan Ajar sebagai Bagian dalam Kajian Problematika Pembelajaran Bahasa Indonesia. *Jurnal Salaka*, *2*(1), 62–65.

Aljabali, A. A. A., El-Tanani, M., & Tambuwala, M. M. (2024). Principles of CRISPR-Cas9 technology: Advancements in genome editing and emerging trends in drug delivery. In *Journal of Drug Delivery Science and Technology* (Vol. 92). Editions de Sante. https://doi.org/10.1016/j.jddst.2024.105338

Aly, A. A. & Borik, Z. M. (2023). Food crops, growth and productivity as an important focus for sustainable agriculture. In N. Guleria, P., Kumar, V., & Mo, B (Ed.), *Plant Small RNA in Food Crops.* Academic Press. https://doi.org/10.1016/B978-0-323-91722-3.00002-6

Ary, D., Jacobs, L. C., Sorensen, C., & Razavieh, A. (2015). *Introduction to Research in Education* (8th ed.). Cengange Learning.

Aslina, N., Azhari, M. I., Addieningrum, F. M., Mulyanto, & Sholeh, A. H. (2023). Analisis Kloning Dan Rekayasa Genetika Menurut Hukum Islam. *Jurnal Addayyan, XVIII* (II), 25-38. http://jurnalstaiibnusina.ac.id/index.php/AD

Atala, M. L. (2020). A Review Article: Bacterial Plasmids. *Novateur Publications*, 6(12), 8–12.

Bélanger, J. G., Copley, T. R., Hoyos-Villegas, V., Charron, J. B., & O'Donoughue, L. (2024). A comprehensive review of in planta stable transformation strategies. In *Plant Methods* (Vol. 20, Issue 1). BioMed Central Ltd. https://doi.org/10.1186/s13007-024-01200-8

Bhat, T.A. & Al-Khayri, J.M. (Eds.). (2023). *Genetic Engineering Volume 1: Principles Mechanism, and Expression*. Florida: Apple Academic Press.

Brown, T.A. (2025). *Gene cloning & DNA analysis: an introduction, ninth edition*. Manchester: John Wiley & Sons.

Cadacio, J. C. M. (2024). *The Utilization of the Instructional Materials in Science 7 in the Public Secondary Schools in the First Congressional District, Division of Camarines Sur*. *IX*(2454), 37–45. https://doi.org/10.51584/IJRIAS

Castaneda-barba, S., Top, E. M., & Stalder, T. (2025). Plasmids, a Molecular Cornerstone of Antimicrobial Resistance in the One Health Era. *Nat Rev Microbiol*, *22*(1), 18–32. https://doi.org/10.1038/s41579-023-00926-x.Plasmids

Chen, C., Sonnert, G., Sadler, P. M., & Fredericks, C. (2020). The impact of student misconceptions on student persistence in a MOOC. *J Res Sci Teach*, *57*, 879–910. https://doi.org/10.1002/tea.21616

Dale, J., James, A., Paul, J. Y., Khanna, H., Smith, M., Peraza-Echeverria, S., Garcia-Bastidas, F., Kema, G., Waterhouse, P., Mengersen, K., & Harding, R. (2017). Transgenic Cavendish bananas with resistance to Fusarium wilt tropical race 4. *Nature Communications*, *8*(1). https://doi.org/10.1038/s41467-017-01670-6

Dale, J., Paul, J. Y., Dugdale, B., & Harding, R. (2017). Modifying Bananas: From Transgenics to Organics? *Sustainability*, *9*(333), 1–13. https://doi.org/10.3390/su9030333

Damanik, C. A., Bayu, R., Simanullang, I. N. S., Sianipar, S. I., & Sihombing, W. L. (2025). Miskonsepsi Teorema Phytagoras pada Buku Ajar Siswa Sekolah Menegah Pertama dengan Perbandingan yang Benar. *Pendas, 10*(3), 250-254. https://doi.org/10.23969/jp.v10i03.33291

Debatisse, K., Brunie, M., Darracq, B., Bandini, E., Littner, E., Rocha, E. P. C., Mazel, D., & Loot, C. (2025). Bacterial natural transformation drives cassette shuffling and simplifies recombination in chromosomal integrons. *Nucleic Acids Research*, *53*(21). https://doi.org/10.1093/nar/gkaf1162

Delafuente, J., & Diaz-colunga, J. (2024). Global epistasis in plasmid-mediated antimicrobial resistance. *Mol Syst Biol*, *20*(4), 311–320. https://doi.org/10.1038/s44320-024-00012-1

Dewan, I., & Uecker, H. (2023). A mathematician's guide to plasmids: an introduction to plasmid biology for modellers. *Microbiology*, *169*(7), 1–23. https://doi.org/10.1099/mic.0.001362

Dikmenli, M., Çardak, O., & Öztaş, F. (2009). Conceptual Problems in Textbooks Conceptual Problems in Biology-Related Topics in Primary Science and Technology Textbooks in Turkey. *International Journal of Enviromental & Science Education, 4*(4), 429–440.

Domenech, A., Brochado, A. R., Sender, V., Hentrich, K., Henriques-Normark, B., Typas, A., & Veening, J. W. (2020). Proton Motive Force Disruptors Block Bacterial Competence and Horizontal Gene Transfer. *Cell Host and Microbe*, *27*(4), 544-555.e3. https://doi.org/10.1016/j.chom.2020.02.002

Du, Y., Liu, Y., Hu, J., Peng, X., & Liu, Z. (2023). CRISPR/Cas9 systems: Delivery technologies and biomedical applications. *Asian Journal of Pharmaceutical Sciences*, *18*(6), 1–31. https://doi.org/10.1016/j.ajps.2023.100854

Dubnau, D., & Blokesch, M. (2019). Mechanisms of DNA Uptake by Naturally Competent Bacteria. *Annual Review of Genetics*, *53*, 217–237. https://doi.org/10.1146/annurev-genet-112618

Fakhriyah, F., Syukur, A., Aminah, S. K., Ratnasari, Y., & Roslan, R. (2025). Analysis of Misconceptions in the 2023 Revised Edition of 4th Grade Elementary School Science Textbook. *JIPI (Jurnal IPA Dan Pembelajaran IPA)*, *9*(1), 276–292.

Fan, L., Cheng, J., Xie, S., Luo, J., Wang, Y., & Sun, Y. (2021). Are textbooks facilitators or barriers for teachers' teaching and instructional change? An investigation of secondary mathematics teachers in Shanghai, China. *ZDM – Mathematics Education*, *53*(6), 1313–1330. https://doi.org/10.1007/s11858-021-01306-6

Fan, Y. (2024). Citation Fan Y (2024) Genetic Manipulation: Techniques and Applications. *J Curr Neur Biol*, *4*, 20. https://doi.org/10.21767/JCNB-24.2.20

Fauziah, A., & Darvina, Y. (2019). Analisis Miskonsepsi Peserta Didik dalam Memahami Materi Gerak Lurus dan Gerak Parabola pada Kelas X SMAN 1 Padang. *Pillar of Physics Education*, *12*(1), 73–80.

Gan, W. C., & Ling, A. P. K. (2022). CRISPR/Cas9 in plant biotechnology: applications and challenges. *Biotechnologia*, *103*(1), 81–93. https://doi.org/10.5114/bta.2022.113919

Glick, B.R. & Patten, C.L. (2022). *Molecular Biotechnology: Principles and Applications of Recombinant DNA Sixth Edition*. Hokoben USA: John Wiley & Sons.

Goralogia, G. S., Willig, C., & Strauss, S. H. (2025). Engineering Agrobacterium for improved plant transformation. *Plant Journal*, *121*(5), 1–16. https://doi.org/10.1111/tpj.70015

Guerra-Reyes, F., Guerra-Dávila, E., Naranjo-Toro, M., Basantes-Andrade, A., & Guevara-betancourt, S. (2024). Misconceptions in the Learning of Natural Sciences: A Systematic Review. *Education Sciences*, *14*(497), 1–17.

Guleria, V. Kumar, & B. Mo. (Eds.), *Plant Small RNA in Food Crops*. India: Academic Press Elsevier.

Ham, A. Van Den, & Heinze, A. (2018). Studies in Educational Evaluation Does the textbook matter? Longitudinal effects of textbook choice on primary school students' achievement in mathematics. *Studies in Educational Evaluation*, *59*(July), 133–140. https://doi.org/10.1016/j.stueduc.2018.07.005

He, Y. (2022). Genetic Mapping usage in Better Diagnosis of Diseases. *Advanced Techniques in Biology & Medicine*, *10*(11).

Helinski, D. R. (2022). A Brief History of Plasmids. *EcoSal Plus*, *10*(1). https://doi.org/10.1128/ecosalplus.esp-0028-2021

Hull, S.C. (2025). *Trait*. Retrieved from https://www.genome.gov/genetics-glossary/Trait

Hwang, H.-H., Yu, M., & Lai, E.-M. (2017). Agrobacterium -Mediated Plant Transformation: Biology and Applications. *The Arabidopsis Book*, *15*, e0186. https://doi.org/10.1199/tab.0186

Irawan, A. (2025). Basic Concepts and Importance of Educational Materials Development for Teachers and Students: General Theoretical Ideas. *Al-Ahnaf: Journal of Islamic Education, Learning and …* , *2*(1), 167–177.

Jena, A. K., Pradhan, S., & Pradhan, P. (2024). Recombinant DNA Technology & Its Importance in Agriculture. *Futuristic Trends in Biotechnology*, *3*(17), 978–993.

Jiang, F., & Doudna, J. A. (2017). CRISPR–Cas9 Structures and Mechanisms. *Annu. Rev. Biophys.*, *46*, 505–529. https://doi.org/10.1146/annurev-biophys

Jin, M., Liu, L., Wang, D. N., Yang, D., Liu, W. L., Yin, J., Yang, Z. W., Wang, H. R., Qiu, Z. G., Shen, Z. Q., Shi, D. Y., Li, H. B., Guo, J. H., & Li, J. W. (2020). Chlorine disinfection promotes the exchange of antibiotic resistance genes across bacterial genera by natural transformation. *ISME Journal*, *14*(7), 1847–1856. https://doi.org/10.1038/s41396-020-0656-9

Kaif, A. (2023). Transgenic Organisms: Exploring the Promise and Controversies of Genetic Engineering. *International Research Journal of Biotechnology*, *14*(3), 1–4. https://doi.org/10.14303/2141-5153.2023.51

Krippendorff, K. (2019). *Content Analysis: An Introduction to Its Methodology* (Fourth). SAGE Publications, Inc.

Kuball, J. (2025). *Advancements in Genome Mapping for Genetic Research*. *14*(1000312), 1000312. https://doi.org/10.35248/2329-6682.25.14.312

Lewis, J., & Kattmann, U. (2004). Traits, genes, particles and information: Re-visiting students' understandings of genetics. *International Journal of Science Education*, *26*(2), 195–206. https://doi.org/10.1080/0950069032000072782

Li, F., & Wang, L. (2024). A study on textbook use and its effects on students' academic performance. *Disciplinary and Interdisciplinary Science Education Research*, *6*(4), 1–20. https://doi.org/10.1186/s43031-023-00094-1

Li, T., Yang, Y., Qi, H., Cui, W., Zhang, L., Fu, X., He, X., Liu, M., Li, P. feng, & Yu, T. (2023). CRISPR/Cas9 therapeutics: progress and prospects. *Signal Transduction and Targeted Therapy*, *8*(1), 1–23. https://doi.org/10.1038/s41392-023-01309-7

Liao, H., Wu, J., VanDusen, N. J., Li, Y., & Zheng, Y. (2024). CRISPR-Cas9-mediated homology-directed repair for precise gene editing. *Molecular Therapy Nucleic Acids*, *35*(4), 1–20. https://doi.org/10.1016/j.omtn.2024.102344

Liu, P.P. (2025). *Transgenic*. Retrieved from https://www.genome.gov/genetics-glossary/Transgenic

Ma, R., Yu, Z., Cai, Q., Li, H., Dong, Y., Oksman-Caldentey, K. M., & Rischer, H. (2020). Agrobacterium-mediated genetic transformation of the medicinal plant veratrum dahuricum. *Plants*, *9*(2). https://doi.org/10.3390/plants9020191

Ministry of Education, Culture, Research and Technology. (2023). *Data Pokok Pendidikan*. Retrieved from https://dapo.kemdikbud.go.id/

Mithans, M., & Grmek, M. I. (2020). *The Use of Textbooks in The Teaching Learning Process* (A. Lipovec, J. Batic, & E. Kranjec (eds.)). University Press.

Mulia, N. & Zulyusri. (2021). Meta-Analisis Miskonsepsi Buku Teks Biologi SMA. *Biodik, 7*(1), 102-111. https://doi.org/10.22437/bio.v7i01.12220

Moran, M. N., Jones, D. B., Jensen, S. A., Marcoli, R., & Jerry, D. R. (2024). Optimising commercial traits through gene editing in aquaculture: Strategies for accelerating genetic improvement. *Reviews in Aquaculture*, *16*(3), 1127–1159. https://doi.org/10.1111/raq.12889

Niazian, M., Sadatnoori, S. A., Galuszka, P., & Mortazavian, S. M. M. (2017). Tissue culture-based Agrobacterium-mediated and in Planta transformation methods. *Czech Journal of Genetics and Plant Breeding*, *53*(4), 133–143. https://doi.org/10.17221/177/2016-CJGPB

Niedbała, G., Niazian, M., & Sabbatini, P. (2021). Modeling Agrobacterium-Mediated Gene Transformation of Tobacco (Nicotiana tabacum)—A Model Plant for Gene Transformation Studies. *Frontiers in Plant Science*, *12*. https://doi.org/10.3389/fpls.2021.695110

Niu, C., Wu, H., Wang, X., Hu, L., Han, Y., & Qiao, J. (2025). Molecular mechanisms and applications of natural transformation in bacteria. *Frontiers in Microbiology*, *16*, 1–17. https://doi.org/10.3389/fmicb.2025.1578813

Nketsiah, J., & Motlhabane, A. (2025). Evaluating Chemistry Textbooks in Ghanaian Senior High Schools: A Focus on The Presentation of Qualitative Analysis and Perspectives of Teachers and Learners. *UNESA Journal of Chemical Education*, *14*(1), 8–21.

Nojadeh, J. N., Eryılmaz, N. S. B., & Ergüder, B. İ. (2023). CRISPR/CAS9 GENOME EDITING FOR NEURODEGENERATIVE DISEASES. In *EXCLI Journal* (Vol. 22, pp. 567–582). Leibniz Research Centre for Working Environment and Human Factors. https://doi.org/10.17179/excli2023-6155

Permadani, S. P., Aini, J. D. N., & Thohir, M. A. (2022). Identifikasi Miskonsepsi Materi Upaya Pelestarian dan Keseimbangan Alam Kelas V SDN Bendogerit 1. *Jurnal Pembelajaran, Bimbingan, Dan Pengelolaan Pendidikan*, *2*(10), 916–924. https://doi.org/10.17977/um065v2i102022p916-924

Pratiwi, S., Purbosari, P. P., Aji, O. R., & Putra, R. R. (2024). Analysis of Genetic Engineering Material Misconceptions in Biology Textbooks for Ninth-Grade in Yogyakarta. *Jurnal Pendidikan Sains*, *12*(2).

Prinz, A., Kollmer, J., Flick, L., Renkl, A., & Eitel, A. (2022). Refuting student teachers' misconceptions about multimedia learning. *Instructional Science*, *50*(1), 89–110. https://doi.org/10.1007/s11251-021-09568-z

Purkait, S., & Yousuf, P. (2024). Recombinant DNA Technology and Its Applications. *Futuristic Trends in Biotechnology*, *3*(5), 219–236.

Riggs, A. D. (2021). Making, Cloning, and the Expression of Human Insulin Genes in Bacteria: The Path to Humulin. *Endocrine Reviews*, *42*(3), 374–380. https://doi.org/10.1210/endrev/bnaa029

Salmon, B. (2025). The Role of Chromosome Mapping in Detecting and Managing Genetic Conditions Early. *Journal of Down Syndrome & Chromosome Abnormalities*, *11*(278). https://doi.org/10.35248/2472-1115.25.11.278

Singh, N.R. (2023). *Introduction to genetics*. British Columbia: Thompson Rivers University.

Smyth, C., Leigh, R. J., Delaney, S., Murphy, R. A., & Walsh, F. (2022). Shooting hoops: globetrotting plasmids spreading more than just antimicrobial resistance genes across One Health. *Microb. Genom.*, *8*(8). https://doi.org/10.1099/mgen.0.000858

Soeharto, S., & Csap, B. (2022). Exploring Indonesian student misconceptions in science concepts. *Heliyon*, *8*(May), 1–10. https://doi.org/10.1016/j.heliyon.2022.e10720

Sutrimah, Winarni, R., Wardani, N. E., & Ngadino. (2019). Evaluating the Use of Modern Indonesian Literary History Textbook (Poetry in East Java) in Teaching Literary History Course. *International Journal of Instruction*, *12*(3), 1–16.

Syahyani, I. (2018). Analisis Miskonsepsi Materi Buku Pelajaran Biologi Kelas XII untuk Sekolah Menengah Atas. *Inovasi Pendidikan*, *5*(2), 72–78.

Thomson, G., Dickinson, L., & Jacob, Y. (2024). Genomic consequences associated with Agrobacterium-mediated transformation of plants. *Plant Journal*, *117*(2), 342–363.

Tikkanen, A. (2025). *Crop agriculture*. Retrieved from https://www.britannica.com/topic/crop-agriculture

Tore, O., Maria, K., & Andreas, L. (2023). Teachers' Error - handling Practices Within and Across Lesson Phases in the Mathematics Classroom. *International Journal of Science and Mathematics Education*, 1289–1314. https://doi.org/10.1007/s10763-022-10294-2

Vaghari-Tabari, M., Hassanpour, P., Sadeghsoltani, F., Malakoti, F., Alemi, F., Qujeq, D., Asemi, Z., & Yousefi, B. (2022). CRISPR/Cas9 gene editing: a new approach for overcoming drug resistance in cancer. *Cellular and Molecular Biology Letters*, 27(49), 1–29. https://doi.org/10.1186/s11658-022-00348-2

Vioti, A. (2022). Procedure Involved in Recombinant DNA Technology Advancements in Genetic Engineering. *Advan Genet Eng*, *11*(2), 1000193–1000194. https://doi.org/10.35248/2169-0111.22.11:193

Wang, S. W., Gao, C., Zheng, Y. M., Yi, L., Lu, J. C., Huang, X. Y., Cai, J. Bin, Zhang, P. F., Cui, Y. H., & Ke, A. W. (2022). Current applications and future perspective of CRISPR/Cas9 gene editing in cancer. *Molecular Cancer*, *21*(57), 1–27. https://doi.org/10.1186/s12943-022-01518-8

Wardani, F., Khairuddin, & Rasyidah. (2023). Analisis Isu Sosio-Saintifik pada Buku Teks Biologi SMA Kelas XII Materi Bioteknologi. *Bioedukasi*, *14*(1), 38–48.

Winter, M., Buckling, A., Harms, K., Johnsen, P. J., & Vos, M. (2021). Antimicrobial resistance acquisition via natural transformation: context is everything. *Current Opinion in Microbiology*, *64*, 133–138. https://doi.org/10.1016/j.mib.2021.09.009

Yang, P., Zhang, S., Hu, D., Li, X., Guo, Y., Guo, H., Zhang, L., & Ding, X. (2024). Research Progress on the Mechanism and Application of the Type I CRISPR-Cas System. *International Journal of Molecular Sciences*, *25*(23), 1–24. https://doi.org/10.3390/ijms252312544

Yuliati, Y. (2017). Miskonsepsi Siswa pada Pembelajaran IPA serta Remidiasinya. *Bio Educatio*, *2*(2), 50–58.

Zajkov, O., Gegovska-zajkova, S., & Mitrevski, B. (2016). Textbook-Caused Misconceptions, Inconsistencies, and Experimental Safety Risks of a Grade 8 Physics Textbook. *International Journal of Science and Mathematics Education*, *14*(1). https://doi.org/10.1007/s10763-016-9715-0

Zhang, S., Wang, Y., Lu, J., Yu, Z., Song, H., Bond, P. L., & Guo, J. (2021). Chlorine disinfection facilitates natural transformation through ROS-mediated oxidative stress. *ISME Journal*, *15*(10), 2969–2985. https://doi.org/10.1038/s41396-021-00980-4

Zhu, Y. (2022). Advances in CRISPR/Cas9. *BioMed Research International*, *2022*, 1–13. https://doi.org/10.1155/2022/9978571