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ANALYSIS OF GENETIC ENGINEERING MATERIAL MISCONCEPTIONS IN BIOLOGY TEXTBOOKS FOR NINTH-GRADE IN YOGYAKARTA

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ABSTRACT

Textbooks play a pivotal role in the pedagogical landscape, serving as indispensable aids for learning, founts of knowledge, and platforms for practical application. This study endeavors to scrutinize the content of textbooks, specifically focusing on ninth-grade biology textbooks within the educational milieu of Yogyakarta City, and to juxtapose these contents with existing literature to discern potential misconceptions. Employing a descriptive qualitative approach, the investigation centers on printed biology textbooks utilized in ninth-grade curricula across junior high schools in Yogyakarta. The selection of textbooks for analysis was based on their prevalence as instructional materials, as determined through survey data. Genetic engineering emerged as the focal point for identifying misconceptions within the chosen textbooks. The tool employed for this purpose was a meticulously crafted misconception analysis sheet, utilized alongside textual scrutiny. Analysis revealed the presence of misconceptions within both Textbooks A and B. Textbook A exhibited one instance of misidentification and one of oversimplification, while Textbook B featured two instances of oversimplification. The prevalence of misconception categories in Textbook A was calculated at 5.88% for misidentification and an equal percentage for oversimplification. In Textbook B, the percentage rose to 15.38%, exclusively attributed to oversimplification. Despite the relatively low incidence of misconceptions in both textbooks, these findings underscore the imperative of mitigating such inaccuracies in future editions.

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INTRODUCTION

Textbooks serve as foundational references in various academic disciplines, characterized by their systematic arrangement, simplicity, and accompanied learning instructions (Akbar, 2013). They are pivotal tools in the educational landscape, functioning as reservoirs of knowledge, instructional materials, and platforms for practice (Kosasih, 2021). Traditionally, textbooks exist in two forms: printed and non-printed. Printed textbooks, conveyed through paper sheets, remain the predominant choice in educational institutions, offering tangible learning resources (Susilawati et al., 2021). Given their centrality, textbooks assume a crucial role as the primary informational conduit for students (Arlitasari et al., 2013). Consequently, ensuring the quality of textbooks becomes paramount to meet the dynamic needs of both teachers and students in the teaching-learning process. This necessitates meticulous adherence to specific criteria during textbook preparation, encompassing clarity of concepts, comprehensible language, appropriate illustrations, and a discerning perspective, aimed at mitigating the proliferation of misconceptions (Muslich, 2010).

Misconceptions found within textbooks arise from disparities between the concepts presented and those supported by scientific consensus or expert understanding. Suparno (2013) explicates misconceptions as divergences from the established understanding put forth by experts. Dikmenli et al. (2009) outlines five categories of textbook misconceptions. Firstly, undergeneralizations (UG) involve a narrowed application of a concept, resulting in a scope narrower than justified. Secondly, obsolete concepts and terms (OCT) refer to ideas and terminology no longer relevant due to contemporary research findings. Thirdly, oversimplifications (OC) manifest as excessively simplified representations of concepts, leading to incompleteness or inaccuracy. Fourthly, overgeneralizations (OG) occur when concepts are overly broad in scope. Lastly, misidentification (MI) arises from misinterpreting the conditions associated with a concept.

According to Suparno (2013), misconceptions in textbooks often arise from complexities in language, incorrect explanations, or materials that surpass the students' current comprehension level. Errors in textual content or theoretical explanations can lead to misguided understandings, while inappropriate diagrams and illustrations may exacerbate misconceptions. Regrettably, the ramifications of misconceptions in textbooks extend to students, potentially leading to enduring misconceptions, as corroborated by Suhermiati et al. (2015), who suggests that misconceptions are notoriously resistant to change.

Tekkaya (2003) underscores that misconceptions within textbooks impede the comprehension of biological material. Given the interconnected nature of many biological concepts, misconceptions regarding one concept can cascade, affecting understanding across multiple domains (Samiha et al., 2017). Genetic engineering, a fundamental concept introduced to students at ninth-grade level, particularly in the context of biotechnology chapters within biology subjects, frequently encounters misconceptions (Agustina et al., 2016). In alignment with the 2013 curriculum, genetic engineering material falls under basic competency 3.7, "Applying biotechnology concepts and their role in human life" (Sutarno, 2016). It is intended that students grasp the principles and applications of genetic engineering as a cornerstone of modern biotechnology, fostering an understanding of its implications and benefits.

The finding of Suryanda et al. (2020) indicate that biotechnology material, particularly genetic engineering, poses significant challenges for student comprehension. The inherent complexity and abstract nature of genetic engineering render it difficult for students to grasp, thereby fostering misconceptions surrounding this material. Zulpadly et al. (2016) delves further into students' learning difficulties in biotechnology, identifying the explanation of the genetic engineering process as the most challenging among nine indicators of biotechnology material. This heightened difficulty arises from students' lack of direct experience with the genetic engineering process. Hence, there exists a critical imperative to investigate and analyze misconceptions pertaining to genetic engineering material within ninth-grade junior high school biology textbooks.

METHOD

The conducted research adopts a qualitative descriptive approach, aimed at elucidating the landscape of printed biology textbooks for ninth-grade junior high schools in Yogyakarta. Spanning from February to August 2023, this study meticulously scrutinizes prevalent misconceptions pertaining to genetic engineering embedded within these educational resources. To ensure representation, textbook selections derive from a comprehensive survey encompassing the most commonly utilized editions, denoted as A and B, across junior high schools in Yogyakarta. Through this methodological, the research endeavors to furnish a nuanced understanding of the prevailing discourse surrounding genetic engineering misconceptions in the educational materials designed for ninth-grade junior high schools.

This investigation into biology textbooks was conducted through a comprehensive analysis of genetic engineering concepts therein. Employing the conceptual error analysis sheet as the primary instrument, the study aimed to pinpoint and elucidate misconceptions embedded within the educational materials. Data collection was facilitated through a meticulous document study approach. A triangulation strategy that encompasses both time and sources is employed to ensure data credibility. Time triangulation was executed through three distinct review phases conducted at different intervals. Meanwhile, source triangulation involved the scrutiny of misconceptions by varied entities, including researchers and subject matter experts. Data analysis adhered to Krippendorff's theoretical framework, leveraging qualitative content analysis methodology. This entailed sequential stages of data procurement, categorization, data reduction, concluding insights, and comprehensive description, as delineated by Meilani (2020). Furthermore, to gauge the prevalence of misconceptions across textbooks, conceptual error percentages were calculated using Equation 1, as delineated by Utami (2013), where K represents is conceptual error, Nks is number of incorrect concepts, and Nk is total number of concepts.

$$K = \frac{Nks}{Nk} \times 100\% \quad (1)$$

RESULTS

The preliminary study of printed biology textbooks intended for ninth-grade junior high schools in Yogyakarta, focusing on genetic engineering material, has revealed the presence of persistent misconceptions. Textbook A exhibited misconceptions in both the misidentification and oversimplification categories, at percentages of 5.88% each, resulting in a total misconception rate of 11.76%. Conversely, in Textbook B, the oversimplification category accounted for 15.38% of identified misconceptions. Overall, the data from both textbooks identified four misconceptions, as detailed in Table 1. Meanwhile, Table 2 highlights one misidentification and one oversimplification in Textbook A, along with two oversimplification-related misconceptions in Textbook B.

Table 1. Total of misconception in Textbook A and Textbook B.

Textbook	Number of Misconceptions in Each Category					Total
	MI	OG	OS	OCT	UG	
A	1	0	1	0	0	2
B	0	0	2	0	0	2
Total	1	0	3	0	0	4

Table 2. Misconceptions in Textbook A and Textbook B.

Textbook	Misconception	Topic	Comparative Reference
A	MI (misidentification)	Transgenic animal	Forabosco et al., 2013; Mora et al., 2012; Pandey et al., 2016; Sulabh & Kumar, 2018; Van Der Berg et al., 2020; Vàzquez-Salat et al., 2012; Wu et al., 2012
	OS (oversimplification)	Sheep cloning process	Campbell et al., 2010
B	OS (oversimplification)	Transgenic animal	Sundström et al., 2014
	OS (oversimplification)	Genetic engineering of animal growth hormone	Kotijah & Ventyrina, 2018

DISCUSSION

Misconceptions pertain to erroneous perceptions or interpretations of a concept that deviate from the consensus among experts. These misconceptions possess distinct attributes: they represent incorrect perspectives, exhibit resistance to change, and often endure over time (Suhermiati et al., 2015). Within educational contexts, misconceptions present in teaching materials, such as textbooks, significantly impact students' understanding. Dwilestari and Desstya (2022) revealed that 46.46% of student misconceptions stemmed from inaccuracies in textbooks. Consequently, it becomes imperative to identify and mitigate misconceptions within educational resources to promote accurate comprehension among students.

The analysis of misconceptions in this study was conducted based on the criteria outlined by Dikmenli et al. (2009), which categorize conceptual errors into five distinct criteria, i.e. misidentification (MI), overgeneralization (OG), oversimplification (OS), obsolete concepts and terms (OCT), and undergeneralization (UG). In Textbook A, two misconceptions were identified, comprising one instance of misidentification and one of oversimplification. Meanwhile, Textbook B exhibited two misconceptions, both falling under the category of oversimplification.

Analysis of Misconceptions in Textbook A

Within Textbook A, the misidentification was characterized by ambiguous descriptions leading to novel and uncertain interpretations. This misconception was observed in a depiction of transgenic cattle (Figure 1). Figure 1b presented an image of transgenic cattle. This depiction was characterized by misidentification due to its potential to foster new or ambiguous interpretations. The misidentification stemmed from the inaccuracies in the shape and color of the depicted cow, compounded by the absence of explanatory information regarding the engineered aspects. It is important to note that transgenic cattle do not consistently exhibit distinct physical features, such as a stockier build or altered coloration, compared to non-transgenic counterparts. Instead, genetic modifications in transgenic cattle can target specific traits, such as enhancing meat quality or promoting rapid growth (Forabosco et al., 2013; Mora et al., 2012; Pandey et al., 2016; Sulabh & Kumar, 2018; Van Der Berg et al., 2020; Vàzquez-Salat et al., 2012). Moreover, transgenic modifications may introduce new elements into cattle, such as omega-3 fatty acids, as demonstrated by Wu et al. (2012). Importantly, these modifications typically do not alter the animal's body shape or coloration but rather affect specific biochemical compositions, such as meat and milk content.

In addition to the aforementioned misidentification, Textbook A also featured an instance of oversimplification. This oversimplification was evident in the depiction of the sheep cloning process, where the image presented was overly simplistic. Figure 2 illustrated the process of egg cell culture and body cell culture in a manner that omitted crucial steps necessary for students' comprehensive understanding. Specifically, the critical treatments of nucleus removal in egg cells and the induction of differentiation in body cells were not depicted. Moreover, the process failed to emphasize that only the nucleus of the body cell needs to be inserted into the enucleated egg cell to initiate cloning. Consequently, Figure 2 did not accurately portray the formation of genetically identical clones. Furthermore, the stages depicted in Figure 2 did not illustrate the growth of fusion cells in the culture medium before implantation into the surrogate mother's uterus. Additionally, the roles of sheep as egg donors, body cell donors, and surrogate mothers were not explicitly labeled in Figure 2. Thus, Figure 2 lacked the clarity necessary for a thorough understanding of the cloning process, unlike Figure 3, extracted from Campbell et al. (2010), which provides a more detailed and comprehensive representation of the cloning process.

(a) (b)

Figure 1. Examples of (a) non-transgenic and (b) transgenic cattle were presented in Textbook A.

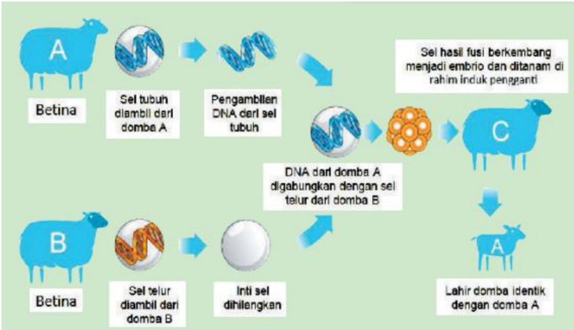

Figure 2. Sheep cloning process in Textbook A.

Figure 3. Sheep cloning process in Campbell et al. (2010) book.

Analysis of Misconceptions in Textbook B

In Textbook B, two instances of misconception were identified within the oversimplification category. The first instance involved a picture of transgenic cattle, depicted in Figure 4, which exhibited oversimplification due to its lack of complexity. This image failed to meet the necessary criteria by omitting a comparative analysis between non-transgenic and transgenic cattle, accompanied by explanatory details elucidating the engineered differences. For instance, the absence of textual annotations explaining the specific genetic modifications in transgenic cattle contributed to the oversimplification of the concept.

Textbook B presenting images that juxtapose examples of transgenic animals alongside their non-transgenic counterparts, accompanied by detailed explanatory information regarding the specific genetic modifications. Such visual aids would elucidate the deliberate changes introduced through genetic engineering in the creation of transgenic animals, fostering clearer comprehension among students. An exemplary reference for such an image could be sourced from Sundström et al. (2014), as presented in Figure 5. This image effectively illustrates the contrast between transgenic and non-transgenic animals, enhancing understanding by visually highlighting the engineered alterations.

In another instance of oversimplification within Textbook B, the concept of transgenic cattle producing the hormone bovine somatotropin (bST) exemplified incomplete explanation. The textbook merely stated the function of bST in stimulating milk production, positing transgenic cattle as advantageous due to their increased milk yield compared to non-transgenic counterparts. However, this portrayal lacked comprehensive coverage as it failed to elucidate the general technique involved in producing bST through genetic engineering, a requirement outlined in the curriculum's material standards (basic competencies 3.7). A more thorough understanding of the genetic engineering process for bST production, as delineated in Kotijah and Ventyrina (2018), entails the following steps: Cleaving the E. coli bacterial plasmid with the endonuclease enzyme, isolating the bovine somatotropin gene from bovine cells, inserting the somatotropin gene into a bacterial plasmid, cultivating bacteria capable of producing bovine somatotropin in fermentation tanks, and extracting and purifying bovine somatotropin from bacteria. This hormone, when administered, can stimulate growth and augment milk production in cattle by increasing the number of mammary gland cells. Injection of bST produced through genetic engineering has been shown to boost milk production by up to 20 percent. Thus, a more comprehensive depiction of the genetic engineering process would enhance students' understanding of the concept.

Figure 4. An example of transgenic cattle was presented in Textbook B.

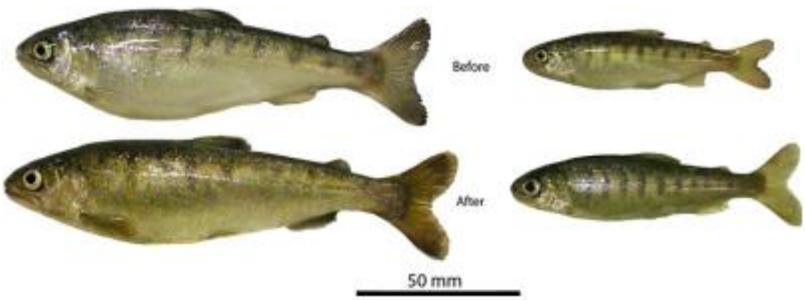

Figure 5. Growth-engineered transgenic and non-transgenic salmon (Sundström et al., 2014).

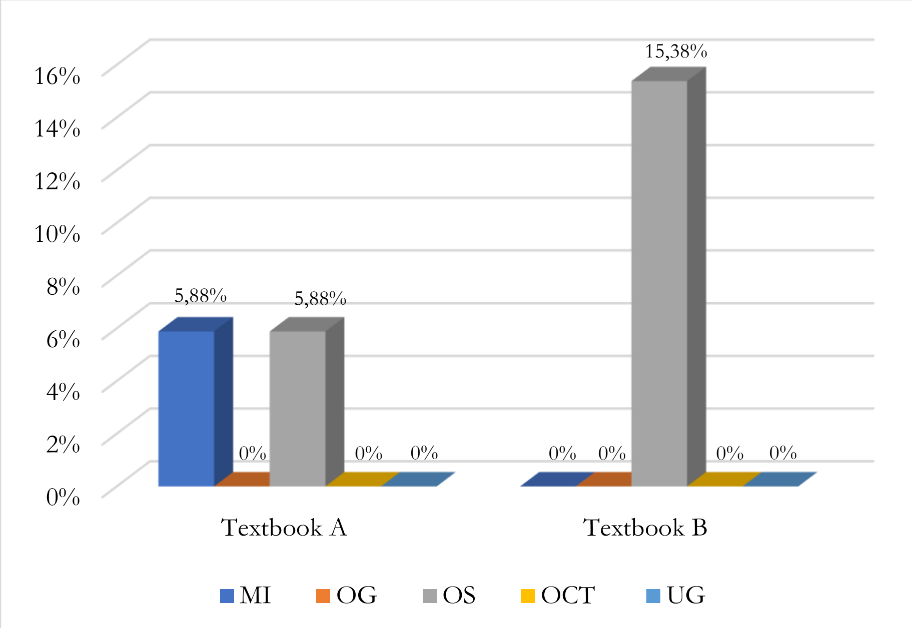

Figure 6. Percentage of misconception for each category.

Percentage of Misconceptions in Textbooks A and B

The recapitulatory findings derived from the analysis of misconceptions within textbook A revealed that two erroneous concepts out of a total of 17 were identified. Similarly, in textbook B, two misconceptions were discerned among a pool of 13 concepts. The computation of the recapitulation outcome for the percentage of misconceptions was conducted by dividing the number of incorrect concepts by the total number of concepts, followed by multiplication by 100%, as described by Utami (2013). To facilitate comprehension of the misconceptions across each textbook based on specific criteria, a graphical representation of the percentage of misconceptions was generated, as depicted in Figure 6.

Based on the data presented in Figure 6, an examination of dominant and less prevalent misconceptions within the textbooks can be conducted. For textbook A, the misidentification category accounted for 5.88% of the total, while the overgeneralization category had no instances recorded. Additionally, the oversimplification category was observed at 5.88%, with no occurrences noted for the obsolete concept and term, as well as the undergeneralization categories. In contrast, for textbook B, no instances were found in the misidentification and overgeneralization categories. However, the oversimplification category exhibited a higher percentage, standing at 15.38%, with no recorded instances for obsolete concepts and terms or undergeneralization. Through these calculations, the total percentage of misconceptions for textbook A amounted to 11.76%, while textbook B yielded a slightly higher figure at 15.38%. Consequently, it can be inferred that both textbooks exhibit a very low level of conceptual errors, as indicated by Riduwan (2009).

Although the incidence of misconceptions in the aforementioned textbooks was notably low, it remains imperative for authors and publishers to endeavor towards minimizing such inaccuracies in future publications. Furthermore, the analysis conducted by previous researchers underscores the prevalence of misconceptions within various textbooks utilized across junior and senior high school curricula. This observation is substantiated by the findings of Elnissa and Jayanti (2023), Afifah and Isnawati (2023), Waoma (2023), Lestari and Zulyusri (2021), Novitasari et al. (2019), Mitha et al. (2018), Pribadi et al. (2018), and Syahyani (2018). Thus, it is evident that concerted efforts are requisite to rectify and mitigate misconceptions across educational materials.

CONCLUSION

The examination of genetic engineering material within ninth-grade junior high school biology textbooks unveiled the presence of misconceptions within textbooks A and B. In textbook A, two misconceptions were identified, distributed across the categories of misidentification (5.88%) and oversimplification (5.88%). Conversely, textbook B exhibited two misconceptions solely within the oversimplification category, accounting for 15.38% of the total content. Notably, the incidence of misconceptions in both textbooks fell within the very low category. Despite this, it remains imperative to mitigate these misconceptions in forthcoming publications.

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AUTHOR CONTRIBUTIONS

All authors contributed to the conception and design of the study, data collection, analysis, interpretation, writing, and revision of the manuscript. The final version of the manuscript was approved by all authors.

CONFLICT OF INTEREST STATEMENT

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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