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**Students' Knowledge and Attitude toward Genetic Engineering**

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**Abstract:** Students are the people who will be consumers, producers, and policymakers about the genetic engineering application product in the future. This paper reviewed research exploring the students' knowledge and attitude toward genetic engineering through a narrative literature review of articles published between 2012 and 2022. After applying criteria of inclusion, exclusion, and thematic belonging in google scholar databases, the sample was constituted of 20 studies. The results showed that most secondary school students needed more knowledge of genetic engineering, even in countries that produce genetically modified organisms through genetic engineering nationally. Most studies also revealed that most students expressed a negative attitude toward genetic engineering and its products. Besides that, students with a positive attitude toward genetic engineering often showed multiple attitudes, depending on which aspects they focus on.

**Keywords:** Attitude; Genetic engineering; Knowledge; Students

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**Introduction**

Genetic engineering is an essential field of biotechnology and is very close to human life. In the United States, genetic engineering in agriculture was applied in 1996 to pest-resistant corn, soybeans, and cotton (Fernandez-Cornejo et al., 2014). Engineering using more sophisticated technology has even been carried out to increase the production of rice, tobacco, soyghum, wheat, corn, soybeans, tomatoes, and potatoes (Jaganathan et al., 2018; Osakabe & Osakabe, 2015; Wada et al., 2020) as well as coffee breeding (Casarin et al., 2022).

In animal husbandry, genetic engineering started in 1985 and experienced rapid development. Genetically engineered products in the livestock sector include accelerating the growth of salmon, pigs that are resistant to respiratory viruses (Van Eenennaam et al., 2021), and sheep with better meat and wool quality (Niu et al., 2017). The application of genetic engineering in the field of medicine, for example, the treatment of  $\beta$ -thalassaemia and Sickle Cell Disease (SCD) (Hu, 2016), pathogen control, applications in clinical diagnostics and treatment of human genetic diseases, whether caused by somatic diseases (e.g., cancer) or genetic mutations (mendelian disorder) (Piergentili et al., 2021). In addition, modern genetic engineering also plays a role in treating infectious viral infections. For example the Human Immunodeficiency Virus (HIV), Hepatitis B Virus (HBV), Human papillomavirus (HPV) (Lin et al., 2021), and other viruses that are still a global threat with potential causes of pandemics such as Covid-19 resulting from the coronavirus (SARS-CoV-2) that causing severe acute respiratory syndrome (SARS-CoV-2) (Shademan et al., 2022).

The society's view and opinion towards genetic engineering and genetically modified products need to be taken into account. It is because the society's

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perception, knowledge and acceptance of genetic engineering and its products determines if the commercializing process and its usage can be done (Meerah et al., 2012). Moreover, genetic engineering is often associated with social and ethical issues that cause debate in society.

Therefore, genetic engineering has to be discussed at different levels in society. Not only among adults, but also schoolchildren. In this context, the role of school education is clear. Students expected understand genetic engineering as a biotechnology at an appropriate level and also know the possible applications of it; economic, social and moral impacts (Vera & Vera, 2014). Students should have an unbiased attitude towards biotechnology based on a factual understanding of the issues, given that they will be consumers, producers, and policymakers in the future (Alanaazi, 2021). Several countries have included the topic of genetic engineering as a subject matter in their curricula. In Indonesia, the topic of genetic engineering is often used as a prime example of the application of modern biotechnology taught in grade 12 through biology subjects (Indonesian Ministry of Education and Culture, 2018).

Previous studies reveal students' knowledge and attitudes towards genetic engineering only in one particular region or country. Nevertheless, the topic of genetic engineering has become a global issue not only in producing countries but also in importing countries of genetically engineered products. Therefore, this study on genetic engineering associated with students could be found. The inclusion of these two words in search terms would further limit the search. After applying criteria of inclusion, exclusion, and thematic belonging, the sample was constituted of 20 studies. A thorough review was carried out on that 20 articles to answer the objectives of this study.

### Result and Discussion

Genetic engineering has long been a social issue that continues to be debated. The various benefits that can be obtained from genetic engineering are often limited by the issue of its potential risks and possible negative effects, such as genetically modified organisms are a threat to biodiversity, farmer autonomy, and food safety (Lucht, 2015). Not only the general public but the knowledge and attitude of students towards genetic engineering are also important. Students are the people who will influence the sustainability of this innovation in the future.

Several studies have attempted to measure the knowledge and attitudes of students in secondary schools toward genetic engineering and its products. The research comes from various countries in the world.

**Student's knowledge of Genetic Engineering**  
As example of modern biotechnology, genetic engineering is often included as one of the materials in

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of genetically engineered products. Therefore, this study attempts to review students' knowledge and attitudes toward genetic engineering more broadly by reviewing previous studies.

### Method

This paper reviewed research exploring the knowledge and attitude of secondary school students towards genetic engineering and its applications through a narrative literature review of articles published between 2012 and 2022. The search was limited to peer-reviewed journal articles and was conducted utilizing google scholar as science databases. The terms used were "student genetic engineering", "student GMO", "student genetically modified", "student transgenic", "student gene technology", "student gene modification", "student biotechnology". The term "student biotechnology" was also used as a search term because people often associate genetic engineering with biotechnology (Alanaazi, 2021; Meerah et al., 2012; Vera & Vera, 2014). Meanwhile, the words "attitude" and "knowledge" were not used because only a few articles engineering is often included as one of the materials in school. It is done by countries that produce genetic engineering products and those that are not producers. Even in several countries, news about genetic engineering is carried out massively in the mass media.

Several researchers have explored students' knowledge related to engineering genetics. From 2012 to 2022, students from at least 15 countries have their knowledge measured. Even though the instrument items were not exactly the same, based on the results of the review, it could be seen that the focus of the items asked for were mostly related to the concepts, processes, benefits, and risks of genetic engineering. In addition, most researchers used not only one grade students from secondary school as respondents in their research. However, in Indonesia, research had yet to be found that explored knowledge or attitudes toward genetic engineering at the school student level. Research had been done only at the university student level (Ma'rifah & Purbosari, 2021; Purbosari & Ma'rifah, 2021). Data regarding students' knowledge related to genetic engineering is presented in Table 1.

**Table 1: Students' Knowledge of Genetic Engineering**

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However, other results shown by (Meerah et al., 2012) that no significant difference between the score of male and female students' knowledge of genetic engineering.

The review results regarding students' attitudes toward genetic engineering are presented in Table 2.

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**Students' Attitude towards Genetic Engineering**

Table 2: Students' Attitudes toward Genetic Engineering

Year	Authors	Students	Country	Measured aspect	Result
2012	Meerah et al.	Secondary school students (16 years old)	Malaysia	<ul style="list-style-type: none"> <li>- Consumption of GM products</li> <li>- GM in agroindustry</li> <li>- Shopping of GM products</li> <li>- Ethics of genetic modifications</li> <li>- Ecological impact of genetic engineering</li> <li>- Use of genetic engineering in human medicine</li> </ul>	Overall, the students showed neutral attitude towards the consumption of genetically modified products, shopping of GM products, and the ethic of genetic modifications. Besides that, students showed a positive attitude towards genetically modification in agroindustry and the use of genetic engineering in human medicine. But as whole students showed negative attitude towards ecological impact of genetic engineering
2012	Fonseca et al.	High school students (17-18 years old)	Portugal	<ul style="list-style-type: none"> <li>- Application of genetic engineering products in waste treatment, gene alteration, treatment of genetic disorders, medicine, pesticide resistant plants, insulin production, organ transplant, human cloning.</li> <li>- Labels of transgenic foods</li> </ul>	Mean scores for the whole sample indicate that students were optimistic about gene therapy, but did not approve of applications mentioning animal manipulation

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Year	Authors	Students	Country	Measured aspect	Result
2014	Věra & Vera	Secondary school students	Czech Republic	<ul style="list-style-type: none"> <li>- use of genetically modified animals to produce drugs, the use of human embryonic cells for therapeutic reasons and the modification of human genes to treat certain diseases, the consumption of GMF, the consumption of medicine issued from GMO, and the participation in protests against certain biotechnological applications)</li> <li>- Traditional biotechnology (using organisms) versus modern biotechnology (genetic engineering)</li> <li>- genetic engineering in plants and animals (including humans)</li> <li>- genetic modifications of plants those leading to a greater resistance to pests</li> <li>- genetic modifications of plants those leading to a greater resistance to an increase of yields</li> <li>- inserting gene of microorganisms and animals into the genome of plants</li> <li>- inserting genes of plants into the genome of animals</li> <li>- Genetically modified foods</li> <li>- Gene therapy</li> </ul>	Students had more conservative attitude to genetic engineering (modern biotechnological technological technique) plants than animals including humans, unless the emphasis was laid on treatment of human diseases. Genetic modifications of microorganisms to enhance their ability to degrade waste was evaluated very positively. The better accepted genetic modifications of plants were those leading to a greater resistance to pests than to an increase of yields. genetic modifications of plants those leading to a greater resistance to an increase of yields was better than inserting gene of microorganisms.
2016	van Lieshout &	Year 10 High	Australia		Students showed no clear opposition to genetically modified food, and

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manipulation (Fonseca et al., 2012). Besides that, students with a positive attitude toward genetic engineering often showed multiple attitudes, depending on which aspects they focus on.

Besides being related to the curriculum, correct and scientifically solid information delivered through the newspaper, internet, and other multimedia exposures should be of great concern. That is important to re-educate the students and society with correct attitudes towards genetic engineering and other biotechnology applications. It is because the relationship between knowledge and attitudes toward genetic engineering or other biotechnology applications is complex. Developments in genetic engineering and other biotechnology applications received coverage not only in textbooks but also in the newspaper, social media, the internet, and films with varying degrees of reliability (Chen et al., 2016). Not only for students but for adults, the media also has a significant role as a provider of information about the products of genetic engineering. As in Turkey, 74.3% of nursing students received genetic engineering product information from television or radio (Turker et al., 2013), while 77.3% of Latvian consumers received genetic engineering product information from the Internet (Aleksejeva, 2014).

Based on the study results, it was also known that attitudes toward genetic engineering were found to be different in male and female students. Males showed

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