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Knowledge and Attitude of Biology Teacher Candidate Students towards Genetically Modified Organisms (GMOs)

Purwanti Pratiwi Purbosari*, Destri Ratna Ma'rifah

Department of Biology Education, Faculty of Teacher Training and Education, Universitas Ahmad Dahlan, Yogyakarta, Indonesia

*Corresponding author: Jl. Ahmad Yani (Ringroad Selatan) Tamanan Banguntapan Bantul Yogyakarta 55166, Indonesia. E-mail addresses: purwanti.purbosari@pbio.uad.ac.id

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abstract

Genetically Modified Organisms (GMOs) provide many benefits and promote public debate regarding their safety and risks. Currently, there is a lack of research that specifically focuses on biology teacher candidates' knowledge and attitude towards GMOs. This study aimed to explore the knowledge and attitude of biology teacher candidate students towards GMOs. The data was collected through an online questionnaire distributed. The data scores of knowledge and attitude were analyzed using an independent sample t-test to analyze the effect of the genetic course on the knowledge and attitude of biology teacher candidate students towards GMOs. A Pearson correlation was used to determine the correlation between teacher candidates' knowledge and attitudes towards GMOs. As a result, genetic courses do not significantly affect the knowledge or attitude of biology teacher candidate students towards GMOs. There was a positive correlation between knowledge and attitude of biology teacher candidate students towards GMOs.

1. Introduction

Genetic research studies have undergone rapid development, especially in the genetic engineering applied to plants, animals, and microorganisms. Scientists have developed the highest amount of genetically engineered products produced by many countries for public consumption. The first commercialization of genetically modified crops occurred in 1994 (FlavrSavr tomato). In 2011, 59 countries already used genetically modified organisms (GMOs) (Zhang & Guo, 2011). It is widely acknowledged that genetic engineering can improve agricultural productivity and food production, reduce the use of pesticides, and yield specific desired products (Du & Rachul, 2012) (Hansson & Joelsson, 2013) (Pamfilie & Cristescu, 2011) (Mishra et al., 2020) (Schutte et al., 2017) (Bawa & Anilakuma, 2013) (Mishra & Singh, 2013). Even genetically modified organisms play an essential role in bioremediation, such as remediating industrial waste, reducing the toxicity of some harmful compounds, and helping eliminate pollution from hydrocarbons and fuel oils used (Kumar et al., 2018). However, the use of GMOs would involve considerable risks to health and the environment, as well as ethical violations (Du & Rachul, 2012). Therefore, GMOs still have pros and cons in society.

Several studies have discussed people's knowledge, perceptions, and attitudes towards GMOs, such as The general public's knowledge about genetic engineering in America (Hallman et al., 2013) and Latvia (Aleksejeva, 2014); The general public's knowledge, attitudes, and perceptions about GMOs in Zimbabwe (Chagwena et al., 2019); Attitudes of young people completing secondary school in Poland towards GMOs and genetically modified foods (Jurkiewicz et al., 2014); The knowledge and acceptance of GMFs in South Africa (Luntulwandile, 2014); Knowledge, perception, and attitudes of Mexican urban population towards GMO (Montesinos et al., 2016); Knowledge, attitudes, and behavior of nursing students in Turkey about GMO (Turker et al., 2013); Knowledge and attitudes of teachers and students in India towards GMF (Mohapatra et al., 2010).

Meanwhile, in Indonesia, some research studies have also been investigated, including a study of biology students' knowledge of genetic engineering in the perspective of Islam (Hadi, 2021) and the attitude of agricultural scientists to GMOs, especially applicated in food (Judhiastuty et al., 2007). However, no research has empirically examined the knowledge and attitudes of biology education students as biology teacher candidates towards GMOs, including the same topic as in Indonesia. Biology education students study genetics, and they have opportunities to study the development of genetics, especially genetic engineering whereby the world community utilizes it. The students' basic knowledge about genes and genetics generally may affect students' knowledge and attitudes towards genetically engineered products. Moreover, GMOs are an example of a biotechnology product that should be understood by biology teacher candidates because there are basic competencies (KD 3.10, 12^{th} grade) consisting of biotechnology based on the 2013 Curriculum in biology subjects at the senior high school level.

Therefore, this study aimed to investigate the knowledge and attitude of biology teacher candidate students towards GMOs. As they become teachers later, those teachers have to teach biotechnology materials to their students. Therefore, they hopefully will teach an illustration of conventional biotechnology examples to students and those of modern biotechnology. GMO is one example of modern biotechnology that greatly affects people's lives.

2. Method

This research was conducted with a sample involving 63 biology education students as biology teacher candidates. The data was collected in September 2021. The questionnaire exploring students' knowledge and attitude from Prokop et al. (2007) collected data. These questionnaire questions were imported into an online questionnaire using the Google Form platform.

This study involved data checking before the analysis process. The data was analyzed using Microsoft Excel and SPSS software. The data of students' knowledge were converted into 0 and 1 scores, where 0 represented the wrong answer and 1 represented the correct answer. If respondents chose "I don't know," it was recognized as the wrong answer because it indicated that they lacked knowledge about the stated information. The data of student attitude from strongly disagree to strongly agree were converted into 1, 2, 3, 4, and 5 scores. In terms of statements consisting of negative attitudes, the score was reversed.

The Chi-square analysis was carried out to ensure the significant association between the differences of genetic course background variable and students' response towards the asked information. The Fisher-Freeman-Halton exact test was used when the cell with the total number of the data was less than five for a 2x2 contingency table, and Kolmogorov Smirnov test for more than 2x2 contingency table. The score of 14 items in the knowledge questionnaire was summed as the knowledge score of each student. The knowledge level of students was grouped based on Bloom's cut-off point as "good," "moderate," or "low ."The score of 14 items in the attitude questionnaire was summed as the attitude score of each student. The attitude level of students

was also grouped based on Bloom's cut-off point with "negative," "neutral," or "positive" attitudes (Seid & Hussen, 2018). The frequency of knowledge and attitude levels of each students' group based on the genetic course were then displayed in a pie chart. Each students' knowledge and attitude scores were analyzed using an independent sample t-test to analyze the genetic courses' effect on knowledge and attitude of biology teacher candidate students towards GMOs. Furthermore, Pearson correlation was utilized to establish the correlation between students' knowledge and their attitudes towards GMOs.

3. Result and Discussion

After conducting the research, data scores of the knowledge and attitude of biology education students towards Genetically Modified Organisms (GMOs) were obtained. Most biology education students knew that genetically modified organisms are used in medicine (e.g., insulin production with GM microorganisms). This item is the question whereby biology education teacher candidates mostly respond with the correct answer (92,1%). The students also knew the effect of DNA manipulation on organism genes (90.5%), the advantages of Practical application of GM on plant nutrition, flavor of fruits, and developing traits to withstand the shipping process (87.3%), as well as increase productivity and resistance of plants against diseases (85.7%). Table 1 summarizes biology teacher candidate students' knowledge about GMOs. Based on the Chi-Square test and Fisher-Freeman-Halton exact test, only knowledge about the effect of GM food on human genes and the advantages of GM plants on nutritional quality, flavor, and traits to withstand the shipping process were significantly associated with the genetics course ($P < 0.05$).

Table 1. The knowledge of biology teacher candidate students about GMOs

Item	Genetic Course		Total n (%)	P-value
	Have not taken n (%)	Have taken n (%)		
1. Effect of DNA manipulation on organism genes				0,387*
Improper	1 (3,8%)	5 (13,5%)	6 (9,5%)	
Proper	25 (96,2%)	(86,5%)	57 (90,5%)	
2. *Material genetic transfer between different species organism*				0,306
Improper	16 (61,5%)	17 (45,9%)	33 (52,4%)	
Proper	10 (38,5%)	20 (54,1%)	30 (47,6%)	
3. Size of GMOs				0,406
Improper	20 (76,9%)	24 (64,9%)	44 (69,8%)	
Proper	6 (23,1%)	13 (35,1%)	19 (30,2%)	
4. Dangerous chemicals on GMOs				0,296
Improper	19 (73,1%)	22 (59,5%)	41 (65,5%)	
Proper	7 (26,9%)	15 (40,5%)	22 (34,9%)	
5. GMOs in madicine				0,394*
Improper	1 (3,8%)	4 (10,8%)	5 (7,9%)	
Proper	25 (96,2%)	33 (89,2%)	58 (92,1%)	
6. Genetic engineering for microbes				1,000
Improper	16 (61,5%)	23 (62,2%)	39 (61,9%)	
Proper	10 (38,5%)	14 (37,8%)	24 (38,1%)	
7. Application of Genetic manipulation in food				0,353
Improper	7 (26,9%)	6 (16,2%)	13 (20,6%)	

Item	Genetic Course		Total n (%)	P-value
	Have not taken n (%)	Have taken n (%)		
Proper	19 (73,1%)	31 (83,8%)	50 (79,4%)	
8. Effect of GM food on human genes				0,041
Improper	19 (73,1%)	17 (45,9%)	38 (57,1%)	
Proper	7 (26,9%)	20 (54,1%)	27 (42,9%)	
9. The advantages of GM plants on productivity and diseases resistance				0,725
Improper	3 (11,5%)	6 (16,2%)	9 (14,3%)	
Proper	23 (88,5%)	31 (83,8%)	54 (85,7%)	
10. The advantages of GM plants on nutritional quality, flavor, and traits to withstand the shipping process				0,007
Improper	7 (26,9%)	1 (2,7%)	8 (12,7%)	
Proper	19 (73,1%)	36 (97,3%)	55 (87,3%)	
11. Characteristic of GM crop				0,179
Improper	14 (53,8%)	27 (73,0%)	41 (65,1%)	
Proper	12 (46,2%)	10 (27,0%)	22 (34,9%)	
12. The advantages of the application of GM methods on animals resistance				1,000
Improper	7 (26,9%)	10 (27,00%)	17 (27,0%)	
Proper	19 (73,1%)	27 (73,0%)	46 (73,0%)	
13. The advantages of application of GM methods on animals' lean				1,000
Improper	8 (30,8%)	12 (32,4%)	20 (31,7%)	
Proper	18 (69,2%)	25 (67,6%)	43 (68,3%)	
14. Effect of genetic modification for animals				0,188
Improper	19 (73,1%)	20 (54,1%)	39 (61,9%)	
Proper	7 (26,9%)	17 (45,9%)	24 (38,1%)	

All P-values were based on Chi-square analysis except those with the asterisk mark (*), based on Fisher-Freeman-Halton exact test.

Figure 1 depicts the knowledge level of biology teacher candidate students about GMOs. The majority of students who have not taken genetic courses possess a low knowledge about GMOs. Meanwhile, in groups who have taken genetics courses, the total number of students with a low level of knowledge about GMOs is the same as candidates with a moderate level of knowledge.

This low level of knowledge related to GMOs can be caused by students' lack of exploration of knowledge about the development and application of biotechnology. In addition, the biological material presented in the educational study program is not as deep as in the biology study program because, primarily, they are prepared to become a teacher, not a biology scientist. However, this is not in line with previous research, which revealed that students studying biological or physical materials should have more knowledge related to biotechnology, including GMOs (Tegegne et al., 2013). Therefore, the level of knowledge of biology education students related to GMOs, which are mostly at a low level, should be used as a reminder. Biology education students can be encouraged again to update their knowledge more regarding biotechnology, whose products are widely used for society.

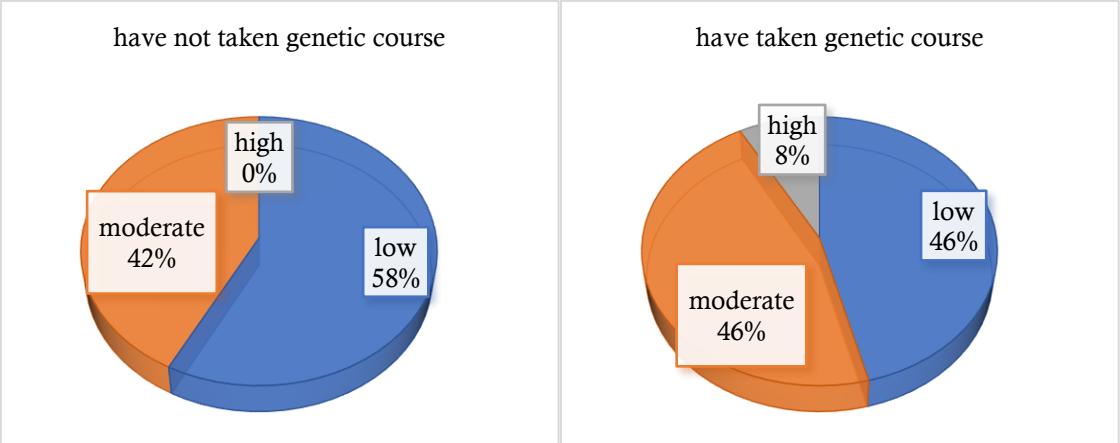

Figure 1. The different profile of knowledge level of biology teacher candidate students based on a genetic course group

On top of that, biology education students are prospective teachers who will be required to teach the topics about biotechnology in schools. They hopefully share teaching materials on either conventional or modern biotechnology, which covers its application used widely for society. Similar results were also found in India regarding teachers' and students' knowledge of GMOs. There are still misconceptions among teachers and students regarding these GMOs, especially the topic of genetically modified food (Mohapatra et al., 2010).

Based on attitude data collected, most biology education students agreed that the public should be informed about the risks associated with GMOs (58,7%), and the food industry should take the necessary measures to provide completely safe GM food (58,7%). Test of Kolmogorov Smirnov showed that for each statement submitted, and there was no significant association with genetics course ($p > 0.05$).

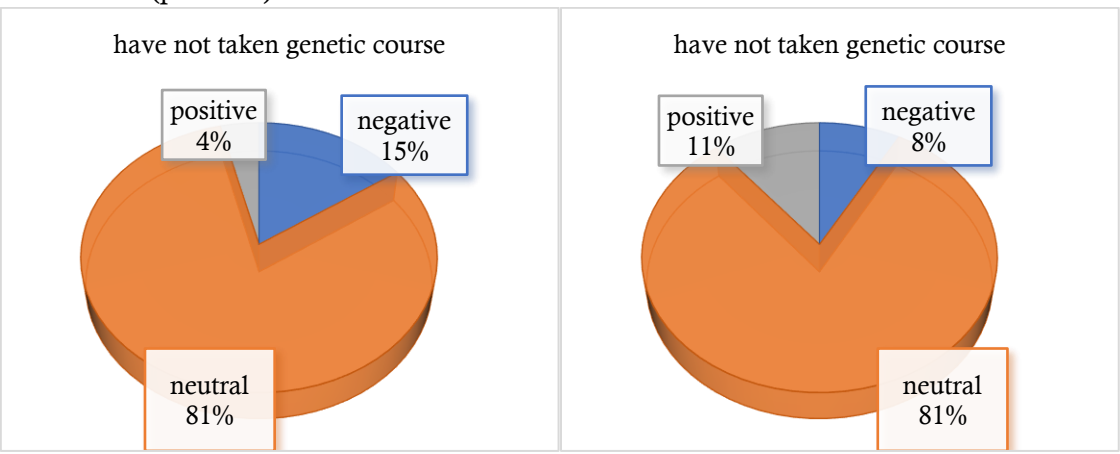

Figure 2. The different profile of attitude level of biology teacher candidate students based on a genetic course group

The attitude level of biology teacher candidate students towards GMOs is shown in Figure 2. Most students who have taken genetic courses or not own a neutral attitude towards GMOs. The total biology education students with a positive attitude towards GMOs only account for 7,94%. This is not in line with previous research, which stated that students studying biological material should have a more positive attitude towards biotechnology, including GMOs (Tegegne et al., 2013).

Table 2. The results of the independent sample t-test

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Student Knowledge	Equal variances assumed	-1.548	61	.127	-.79522	.51367	-1.822	.232
	Equal variances not assumed	-1.538	52.748	.130	-.79522	.51691	-1.832	.242
Student Attitude	Equal variances assumed	-1.462	61	.149	-2.14865	1.46932	-5.086	.789
	Equal variances not assumed	-1.450	52.259	.153	-2.14865	1.48222	-5.122	.825

Based on the independent sample t-test, it is known that genetic courses have no significant effect on students' knowledge ($t = -1.548$, $p=0.127>0.05$) or attitudes ($t = -1.462$, $p=0.149>0.05$) towards GMOs. This result indicates that there may be a need for unique methods in genetic courses to improve students' understanding and attitudes towards GMOs, such as several studies succeeded to improve students' knowledge and attitudes towards GMOs through direct practicum activities (Klop et al., 2010) (Witzig et al., 2013), the use of rebuttal texts (Heddy et al., 2016), or case studies (Dori et al., 2003). Table 2 presents the results of the independent sample t-test.

Table 3. The results of Pearson correlation analysis

		Knowledge	Attitude
Knowledge	Pearson Correlation	1	.359**
	Sig. (2-tailed)		.004
	N	63	63
Attitude	Pearson Correlation	.359**	1
	Sig. (2-tailed)	.004	
	N	63	63

**. Correlation is significant at the 0.01 level (2-tailed).

Pearson Correlation analysis was used to analyze the correlation between students' knowledge and attitudes towards GMOs. Based on the results of that analysis (Table 3), it is known that there is a positive correlation between student's knowledge and their attitudes towards GMOs, although the correlation is relatively weak ($r=0.359$, $p<0.05$). This is in line with previous research showing a positive correlation between students' knowledge of genetically modified foods and their attitudes towards them (Heddy et al., 2016), as well as the knowledge and attitudes of high school students related to biotechnology which also discussed genetically modified products (Klop et al., 2010).

This result happens since knowledge has a big influence over students' attitudes through their impact on benefit perceptions (Zhu & Xie, 2015). When individuals have more knowledge about the potential benefits of GMOs, they naturally perceive more benefits leading to a positive attitude and greater acceptance toward GMOs (Chen & Li, 2007). Besides that, improvement in the level of knowledge may result in higher familiarity, fewer misconceptions, and fewer uncertainties regarding GMOs (Qin & Brown, 2006), which reduces risk perception so that the attitude towards GMOs will be positive (Siegrist et al., 2006). Therefore, a positive attitude about biotechnology (including GMOs) is generally correlated with correct knowledge about biotechnology. The prevalence of positive attitudes can also increase as knowledge increases (Heddy et al., 2016).

This is both a challenge and an opportunity. Students' attitudes towards GMOs can depend on their knowledge of GMOs, and this attitude can be changed to a more positive direction by increasing student knowledge (Zhu & Xie, 2015). To generate a more positive attitude towards GMOs can be done in various ways, such as through education in the classroom. Alternatively, as Linnoff et al. (2017) stated, factual information can be presented effectively through news releases to the media, websites, and other places, so that negative attitudes towards GMOs can be reduced.

4. Conclusion

This research has explored the level of knowledge and attitude towards GMOs among biology teacher candidate students. Based on data collected, most biology teacher candidates students who have not taken genetic courses possess a low level of knowledge about GMOs. Meanwhile, in the group that has taken genetics courses, students with a low level of knowledge about GMOs are the same as students with a moderate level of knowledge. In terms of their attitude towards GMOs, most biology teacher candidates students have neutral attitude levels. Genetic courses do not significantly affect the knowledge or attitude of biology teacher candidate students towards GMOs. However, a positive correlation existed between knowledge and attitude of biology teacher candidate students towards GMOs.

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