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Knowledge and attitudes of high school students toward genetically modified foods

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Abstract

This study aims to assess the knowledge and perception variation among high school students regarding genetically modified organisms (GMOs) from year to year. A comprehensive analysis was conducted through surveys and interviews to evaluate the depth of understanding and their attitudes toward GMOs. Due to the utilization of GMOs in different fields, such as food industry, medicine and pharmacy, students were asked to express their opinion about GMOs usage in these fields as well. A survey comprising 10 questions was administered to 249 high school students from 2018 to 2023 (7% of them were in ninth grade, 29% tenth grade, 31% eleventh grade and 30% Twelfth grade, last year students). Among the surveyed students, 81.7% demonstrated a strong understanding of GMOs, while 18.3% reported having no knowledge about them. In terms of information sources, 55.42% acquired their knowledge from books and scientific articles, predominantly during classes. Additionally, 27.71% gathered information from television or the internet, while 12.05% encountered the concept of GMOs for the first time through this questionnaire. A smaller percentage, 2.4%, received information from newspapers and magazines and 2.41% from various organizations involved in environmental education and awareness. 81.7 % of the students had good knowledge about GMOs, while 18.3 % of them had no knowledge at all about GMOs. Regarding the consumption of GMO versus BIO products, 80% of students expressed a preference for BIO products, 8.33% chose GMO products, and 11.66% were uncertain about their choice. The results indicate a strong preference for BIO products among students, with a significant majority (80%) choosing them. The findings suggest varying levels of knowledge among high school students. Several factors appear to influence their perceptions, including educational exposure, media coverage, cultural backgrounds, and personal beliefs. These factors likely shape students' attitudes toward GMOs and BIO products, influencing their choices.

Keywords: GMO, knowledge, high school students, awareness

1. Introduction

Genetically modified foods (GMFs) have increasingly emerged as a central subject of both scientific research and public debate, captivating the attention of experts, policymakers, and

consumers alike. Surveys of undergraduate students have shown that their understanding about GMOs, like that of the general population, is incomplete or inaccurate (Chrispeels et al., 2016). As the conversation, surrounding GMOs continues to grow, it becomes increasingly important to examine and understand the implications of this technology. The widespread use and potential benefits of GMFs, such as enhanced nutritional value and increased agricultural productivity, are often weighed against concerns over safety, environmental impact, and ethical considerations. Therefore, raising awareness and promoting comprehensive education about GMOs are crucial in ensuring that individuals, particularly younger generations, are equipped with the knowledge necessary to make informed decisions and contribute meaningfully to the ongoing discussions about the future of food production. Studying the perceptions and understanding of genetically modified foods, especially among high school students, is essential for fostering a society that can navigate the complexities of biotechnology and its role in shaping our food systems. Modern biotechnology and associated genetic modification techniques can help tackle several global challenges such as rising pollution levels, biodiversity loss, water and land scarcity, climate change (Dupont-Inglis & Borg, 2018; Khalid et al., 2024), and food security (Georges & Ray, 2017; Khalid et al., 2024).

Different studies point to the fact that the general public's perception of genetically modified (GM) foods is often shaped by the level of knowledge and understanding they have about these products. Research shows that misinformation or lack of education can lead to fear, skepticism, and negative attitudes toward GMOs. Thus, correct information and education play a crucial role in creating an informed and positive perception of GM foods (Rathod & Hedaoo, 2022). Other studies also (Chen et al., 2016) suggest that this enables consumers to make an informed choice about their intake and consumption of these processed foods. Critical thinking is a key condition to be able to select, judge, analyze and evaluate information to develop a balanced understanding of the topic (Akyüz & Samsa, 2009; Saadé et al., 2012; Maes et al., 2016). One of the major steps in developing an attitude towards GMO is linked to balancing the risks and benefits associated with GMOs (Frewer et al., 2013; Rollin et al., 2011; Maes et al., 2016).

Studies on consumers' knowledge and attitudes toward GM crops and foods have highlighted that, due to insufficient information and education, the general public tends to have a negative perception of genetic technology. These studies primarily focused on the broader population, revealing that a lack of awareness contributes to the widespread skepticism surrounding GMOs (Rathod & Hedaoo, 2022; Deodhar S.Y., Sankar, 2022). Therefore, providing accurate information and education is crucial in shaping an informed and positive perception of GM foods. Other studies also emphasize that this empowers consumers to make well-informed decisions regarding their choice and consumption of these genetically modified products (Rathod & Hedaoo, 2022; Chen et al., 2016).

The objective of our study was to thoroughly evaluate high school students' understanding and perspectives on genetically modified organisms (GMOs), with a particular focus on their knowledge of the technology and the significance of its application in various fields. By investigating the level of awareness and the attitudes students hold toward GMOs, we aimed to assess how well-informed they are about the scientific, environmental, and societal implications of using genetically modified organisms. Additionally, the study sought to explore the importance that students attribute to the role of GMOs in addressing challenges such as food security, sustainability, and agricultural innovation. Through this research, we aimed to contribute to the growing body of knowledge on the educational needs regarding biotechnology and its potential impact on future generations.

2. Materials and Methods

This study was conducted as part of the diploma project undertaken by students enrolled in the Master's program in Science Education, with a specific focus on Biology (future Biology teachers). The research involved a total of 249 high school students, ranging in age from 14 to 18 years old, and was carried out over a period spanning from 2018 to 2023. The student participants were drawn from several high schools in Tirana, including 80 students from "Arben Broci" High School, 92 students from "Ismail Qemali" High School, and 60 students from "Sinan Tafaj" High School. In addition to these students, 17 students from various other schools, all in the ninth grade, were also included in the study. This diverse sample was selected to provide a comprehensive representation of student knowledge and attitudes across different educational settings.

After carefully examining the biology curriculum, a comprehensive set of questions was developed to evaluate the students' general knowledge of the subject matter. These questions were designed to assess their understanding of genetically modified organisms (GMOs) and their grasp of the scientific principles behind this technology. In addition to testing their knowledge, the questions also aimed to measure students' critical thinking skills by encouraging them to analyze, evaluate, and apply the information related to GMOs in a meaningful way.

Furthermore, the questions sought to explore students' attitudes, beliefs, and opinions regarding the use of GMOs, offering valuable insights into how they perceive the potential benefits and risks associated with this technology. By including both factual knowledge and personal perspectives, this approach ensured that the study addressed not only what students know about GMOs but also how they feel about their impact on society, the environment, and human health.

With the students' consent, a Google Form was provided for them to complete online. The data gathered from their responses was then systematically organized and analyzed. The findings were presented in tables and graphs to facilitate clearer visualization and interpretation of the results.

3. Results

Participants of this study were high school students from different schools in Tirana. The study included 249 high school students, aged 14 to 18, who all shared similar backgrounds. High school students showed strong interest in participating in the survey on genetically modified organisms (GMOs), driven by factors such as curiosity, relevance to their daily lives, and opportunities to learn about topics like food production, health, environmental sustainability, climate change, and biotechnology. Many students were particularly eager to engage with the survey as it offered a chance to deepen their understanding of a topic that has significant implications for the future.

Students who had been introduced to GMOs through their biology curriculum were especially motivated to participate, as they were already familiar with the subject matter and were interested in expressing their opinions. Students with a solid understanding of GMOs' science, benefits, and potential risks were more likely to share their views and contribute meaningfully to the research. On the other hand, students with limited knowledge on the

topic were also keen to participate when provided with clear, accessible information that sparked their interest. Overall, the students' enthusiasm was largely influenced by how the survey connected GMOs to real-world issues, highlighted the importance of the topic, and offered them a platform to share their perspectives. The educational value of the survey, and how it contributed to enhancing their understanding of GMOs, further encouraged high school students to take part.

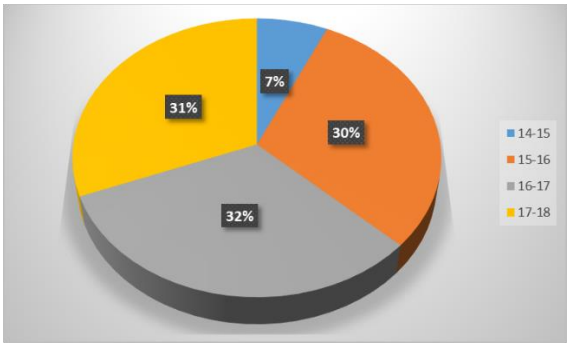

Figure 1. Distribution in percentage of different age groups of students included in the study

The distribution of students who participated in the questionnaire (Figure 1), based on their age groups, was as follows: 7% of the participants were in the 13-14 years age group, 30% belonged to the 15-16 years age group, 32% were in the 16-17 years age group, and 31% fell within the 17-18 years age group. This distribution provides a diverse range of age groups, allowing for a comprehensive understanding of students' knowledge and attitudes toward GMOs across different stages of high school.

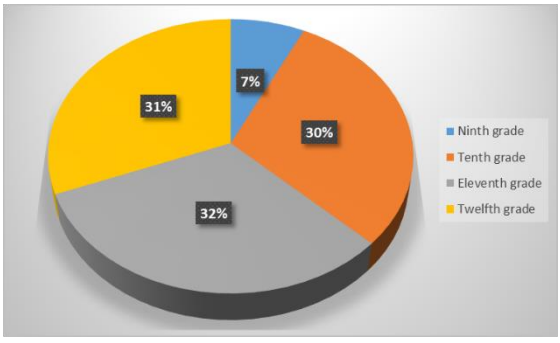

Figure 2. Distribution of students by year of study (Percentage Breakdown)

Based on the percentage distribution of age groups (Graph 1) and as illustrated in Graph 2, it is evident that only 7% of the participants are in the ninth grade, while the tenth, eleventh, and twelfth grades have a nearly equal distribution of students, with similar numbers of participants from each grade level.

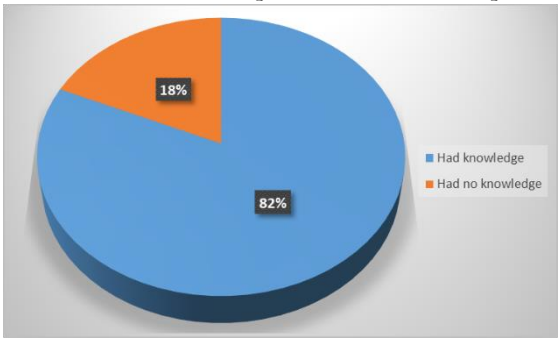

Figure 3. Students' knowledge about GMOs

The students were surveyed regarding their knowledge of genetically modified organisms (GMOs), and the results revealed that 18.3%, reported having no knowledge of GMOs. In contrast, a significant majority, accounting for 81.7% of the students, demonstrated some level of knowledge or familiarity with the subject. This indicates a general awareness of GMOs among the students, although the depth of their understanding may vary. Although the students shared similar backgrounds, their preferences for further studies varied, which influenced their areas of focus. As a result, these differences in academic interests may have contributed to varying levels of knowledge among them.

After reviewing the biology curriculum, it was found that GMOs are primarily studied in the 11th and 12th grades under several key topics. These include Biotechnology in Agriculture, Gene Technology in Animals, Bioethics, and Biotechnology of Transgenic Plants. Specific areas of focus include Transgenic Plants, where students explore the benefits and risks associated with them, and Transgenic Animals, which covers cloning in the animal world. Other relevant topics are Environmental Biotechnology, Genetic Engineering, and Molecular and Environmental Biology in Daily Life. Additionally, students are introduced to the practical applications of biotechnology, such as the use of enzymes, penicillin production and other biotechnological processes, often supported by visual aids to enhance understanding.

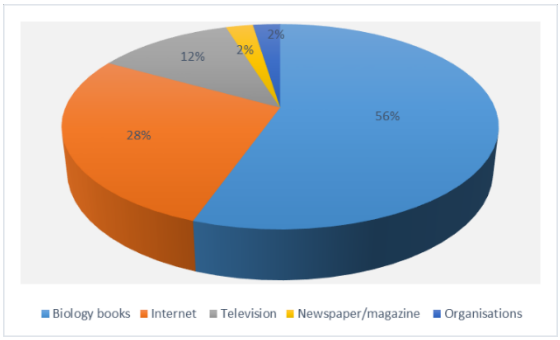

Figure 4. Sources of information for students

After being asked about the sources of information regarding GMOs, 55.42% of students reported obtaining their knowledge from biology textbooks, 27.71% indicated the internet as

their primary source, 12.05% cited television, 2.4% referred to newspapers and magazines, and 2.41% mentioned various organizations involved in environmental work.
Biology textbooks (55.42%) are the first and more common source of information regarding GMO-s, which suggests that formal education remains the most trusted and prominent avenue through which students learn about biology related topics. This underscores the critical role of traditional educational resources in shaping students' understanding of scientific topics. The internet was the second most common source of information (27.71%), reflecting the growing role of digital platforms in education. While the internet provides easy access to vast content, it also raises concerns about the quality and reliability of information. With the prevalence of unverified sources and misinformation, it is essential for students to critically evaluate online content. In this process, the role of teachers is crucial in guiding students to analyze and assess the credibility of information, ensuring they obtain accurate and appropriate knowledge.

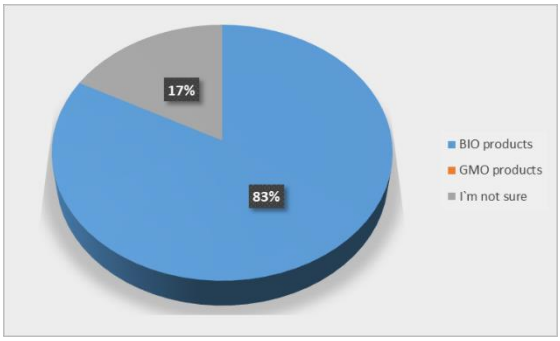

Figure 5. Students' preference for BIO vs. GMO products when priced equally

When asked about their preference between GMO and BIO products priced equally, 82.86% of students preferred BIO products, 17.14% were uncertain, and none chose GMO products. This suggests a strong inclination towards BIO products among students, with a notable lack of support for GMO options when there is no price difference. The high percentage of uncertainty also indicates a need for further education or information on the differences between these product types.

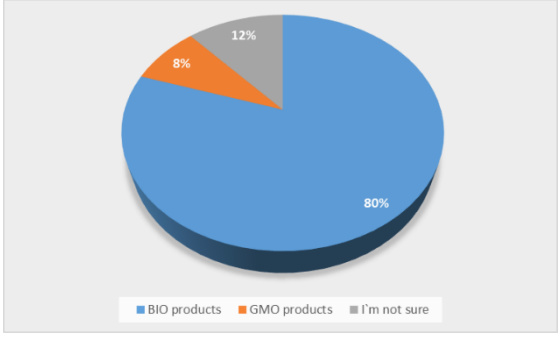

Figure 6. Students' preference for BIO vs. GMO products when priced differently

When asked about their preference between GMO and BIO products, priced differently, where GMO products were cheaper and BIO products were more expensive, 80% of students

still expressed a preference for BIO products, 8.33% chose GMO products, and 11.66% were uncertain about their choice. These results provide valuable insights into the students' attitudes toward BIO and GMO products, even when the price disparity is a factor. The results indicate a strong preference for BIO products among students, with a significant majority (80%) choose them. This preference, according to student's statements is influenced by factors such as perceptions of health mainly, environmental concerns, and a general preference for natural or organic options, which are free of chemicals and more secure to use.

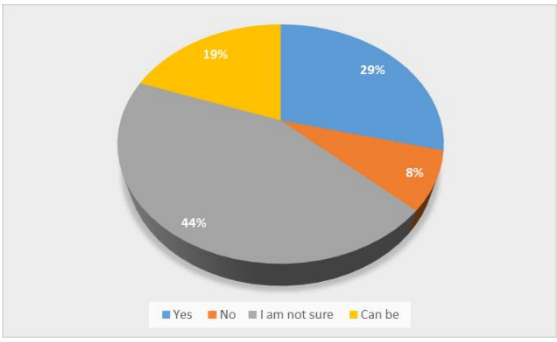

Figure 7. Students' perceptions of the effect of GMOs on consumer health

Students were asked whether they consider GMOs harmful or dangerous to human health. The results show a significant divide in students' perceptions of GMOs' potential health risks. With 29% affirming that GMOs are harmful or dangerous, nearly a third of the respondents hold strong concerns about the safety of GMOs. On the other hand, only 7.9% outright denied any health risks, indicating that a small minority does not perceive any danger associated with GMOs. The largest group, 43.7%, expressed uncertainty, suggesting that many students may lack sufficient knowledge or are undecided about the risks of GMOs. The 19.4% who believe GMOs "can be dangerous" reflect a more cautious stance, acknowledging potential risks without firmly asserting that GMOs are essential harmful. These results highlight a need for clearer, more accessible information on GMOs to help students make informed opinions about their health risks. It also points to the importance of addressing the knowledge gap and reducing uncertainty through education and balanced discussions.

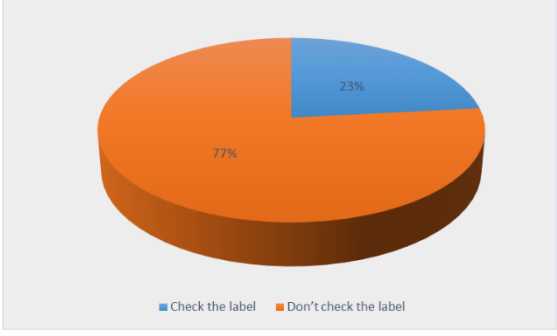

Figure 8. Students' responses on product label control

Students were asked whether they check product labels to determine if a product is BIO. Despite 80% of students expressing a preference for BIO products over GMO products, only 23.33% actually check the product labels to verify if the product is BIO.

The results show a disconnect between students' preferences and behaviors (while 80% prefer BIO products, only 23.33% check labels to verify if products meet this preference). This suggests that convenience, lack of awareness, or other priorities may influence purchasing decisions. It highlights the need for clearer labeling and stronger awareness campaigns to help students align their choices with their preferences. The low label-checking rate indicates a need for better education on label reading and the importance of verifying product claims.

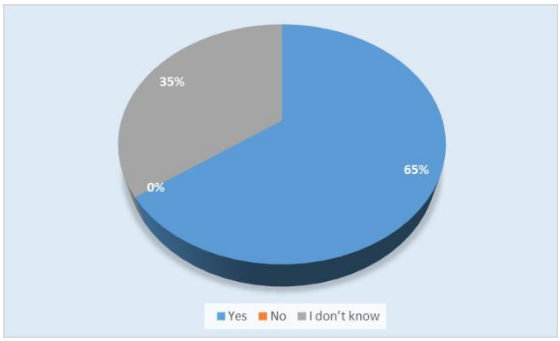

Figure 9. Students' responses regarding the presence of GMO products in the market

Students were asked about their opinion about the presence of GMO products in the market in our country. 65% of students responded affirmatively, indicating that they believe GMO products are available, while 35% were uncertain about their presence in the market. The fact that no student denied the presence of GMOs suggests that they generally recognize GMOs are in the market, even if some are unsure of the details. This shows the need for better education on GMOs to clear up any confusion and improve understanding.

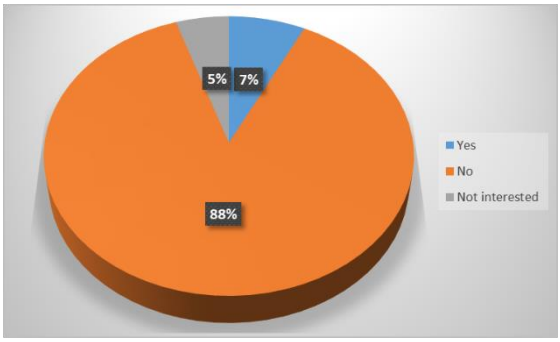

Figure 10. Students' knowledge of GMO-related legislation

Students were asked about their knowledge of existing legislation regarding GMOs in Albania. The results showed that 87.58% of students were unaware of whether any legal framework exists for GMO products, which suggests that there is a substantial lack of knowledge about the legal regulation of GMOs among the student population. This could indicate that

education on this specific aspect of GMOs, particularly the legal and regulatory side, is insufficient or not emphasized in the academic curricula. The 5.08% of students who expressed no interest in the topic may reflect a lack of perceived relevance, suggesting they don't see the connection between GMO legislation and broader environmental, health, or ethical concerns. Only a small percentage, 7.34% were informed about this issue, which suggests that while some students may be aware of the issue, this knowledge is limited to a minority. This highlights the need for more targeted educational efforts that focus not only on the science and impacts of GMOs but also on the legal regulations governing their use in the country. The low level of awareness overall suggests that increasing education on this topic could play a key role in helping students better understand the broader implications of GMOs.

4. Discussion

GM products have been in the food system for decades and are becoming even more present, yet consumer knowledge and awareness are not improving accordingly (Shahla & Kelsey, 2015). From the results of this study, we notice that only 81.7% of the students were aware of the concept of GMOs. From the literature review, we notice similar results recorded by Rathod & Hedaoo, 2022, who assessed the knowledge and attitudes on GMOs among students studying life sciences, Wnuk and Kozak, 2011, who assessed the knowledge and attitudes about GMOs of Polish students of life-sciences faculty, and also by Folkerth, 2022, where the knowledge and opinions of the students regarding GMOs were examined. The results show that 55.42% of students rely on biology textbooks as their main source of information about GMOs, highlighting the continued importance of formal education in shaping scientific understanding. The internet follows as the second most common source (27.71%), reflecting its growing influence on students' learning, though it also raises concerns about information reliability. This underscores the need for critical thinking skills and the role of educators in guiding students to evaluate digital content. Other sources, such as television, newspapers, and environmental organizations, contribute less to students' knowledge, emphasizing the importance of balancing both traditional and modern resources in educating about GMOs. According to other studies from Uszczki et al., 2016, the greatest majority (70.9%) of adolescents completing secondary schools are not interested at all in the problems related with GMO. The level of adolescents' interest in the application of genetic engineering in agriculture is rather low and does not considerably differ from that possessed by the rest of society (Uszczki et al., 2016). Other surveys of undergraduate students have shown that their understanding about GMOs, like that of the general population, is incomplete or inaccurate (Chrispeels et al., 2019).

Several studies of undergraduates have found that students who teach achieve higher test scores than students who learn material with no expectation of teaching or only for the purpose of taking a test (Chrispeels, 2019; Bargh & Schul, 1980; Annis, 1983; Benware & Deci, 1984; Fiorella and Mayer, 2013). Undergraduates enrolled in an introductory nonmajors biology course participated in a service-learning program (SLP) in which they acted as cross-age peer teachers to high school students, teaching about the role of genetics in crop improvement through traditional breeding and GM approaches. This peer-teaching approach can effectively enhance learning and foster critical thinking. It allows students to deepen their understanding not just through reading and studying, but by engaging in interactions with their more knowledgeable peers, gaining insights from their greater expertise and comprehension of the topic.

Biology teachers can employ various strategies to effectively teach high school students about GMOs. Hands-on experiments and simulations can help students experience the process of genetic modification, deepening their understanding of its impacts on agriculture, health, and the environment. Utilizing multimedia resources like videos, animations, and interactive websites can visually explain complex concepts and make the material more engaging. Encouraging critical thinking through debates and group discussions allows students to consider both the benefits and risks of GMOs from various perspectives, including scientific, ethical, environmental, and cultural angles. Simplifying technical jargon and providing relatable examples ensures that students can grasp challenging topics. Connecting the material to current events, such as new GMO crops or legislation, makes the subject more relevant and timely. Peer teaching also reinforces learning, as older students explain concepts to their peers. Addressing common misconceptions with evidence-based explanations can help clarify misunderstandings, while fostering inquiry-based learning encourages students to explore GMO-related topics that interest them. Finally, using real-life examples, such as genetically modified foods or medicines, demonstrates the practical applications of GMOs, making the subject more relatable and tangible. These strategies together can enhance student engagement, understanding, and critical thinking regarding GMOs.

5. Conclusions

This study reveals that 81.7% of high school students have a strong understanding of genetically modified organisms (GMOs), while 18.3% report having no prior knowledge. Students primarily acquire information from formal educational sources, such as books and scientific articles, though media platforms like the internet and television also influence their understanding. Despite this knowledge, 80% of students prefer BIO products over GMO products, suggesting that personal values, media influences, and cultural backgrounds play a significant role in shaping their preferences. The study highlights the importance of education in shaping attitudes towards GMOs. While most students grasp the concept, there remains a gap in understanding, as evidenced by the 11.66% who were uncertain about their product choices. This points to the need for clearer, more comprehensive information on GMOs, particularly regarding their benefits and risks, to help reduce uncertainty and aid informed decision-making. The findings emphasize the need for ongoing, balanced education about GMOs to address knowledge gaps and foster more informed opinions. Educators should consider the various factors influencing students' perceptions to better guide their understanding and choices regarding biotechnology and food products, by incorporating a variety of teaching strategies.

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Conflict of interests

The authors affirm that they have no competing interests to disclose.

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