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Perceptions of genetically modified and bioengineered organisms and corresponding food labels among undergraduate students at Binghamton University

Rachel D. Marcus[1] and Sara H. Velardi[1,2]

[1]Sustainable Communities Program, Binghamton University, M.S. in Sustainable Communities, Binghamton University, USA and [2]Environmental Studies Program, Binghamton University, Ph.D. in Environmental and Natural Resource Policy, SUNY College of Environmental Science and Forestry, USA

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Author for correspondence:
Rachel D. Marcus,
E-mail: rmarcus3@binghamton.edu

Abstract

In January 2020, the United States implemented a federal bioengineered labeling standard for food products that contain genetically modified material set to go into effect in January 2022. This bioengineered label indicates which products contain detectable levels of genetic material that have been modified through lab techniques that cannot be achieved in nature. An already existing alternative to the bioengineered label is the Non-GMO Project verified label which has been on the market since 2007, and indicates products free of genetically modified material through lab techniques. As consumers are now confronted with multiple labels pertaining to information related to genetic engineering, it is important to understand how people interpret these labels as it can lead to a greater understanding of how they inform consumer choice. We conducted a survey with 153 biology and environmental studies undergraduate students at Binghamton University in Binghamton, New York, asking questions about participants' views on genetically modified organisms (GMOs) and related terminology, corresponding food labels and how these labels influence their purchasing decisions. Results demonstrated a lack of awareness of the bioengineered label compared to the Non-GMO Project verified label. Additionally, individuals associated 'bioengineered' and 'genetically modified' with differing themes, where 'bioengineered' was more often associated with a scientific theme and 'genetically modified' was more often associated with an agricultural theme. There was also a discrepancy in how individuals said these labels influenced their purchases *vs* how the labels actually influenced purchasing decisions when participating in choice experiments. While the majority of participants reported that neither the Non-GMO Project verified label nor the bioengineered label influenced their purchasing decisions, in choice experiments, the majority of respondents chose products with the Non-GMO Project verified label. This study can give insight into overall perceptions of different terminologies associated with genetic engineering, in addition to how these labels are interpreted by consumers, and how they could affect purchasing decisions with the implementation of the new bioengineered label.

Introduction

In 2016, Congress passed The National Bioengineered Food Disclosure Law, which directed the United States Department of Agriculture (USDA) to establish a national standard for bioengineered foods. This mandatory national standard, which went into effect in January 2022, discloses all foods that are bioengineered through a variety of labeling options which can include written text, USDA symbol, electronic or digital link or a text message. Bioengineered foods are defined as those which contain detectable genetic material that has been modified with particular lab techniques that cannot be created through conventional breeding, and cannot be found in nature. This in particular includes foods created through the process of transgenesis or *in vitro* recombinant DNA techniques where foreign DNA is inserted into an organism to express a particular trait, but does not include processes like mutagenesis where organisms are exposed to high levels of radiation to alter an organism's DNA. This policy also sets the threshold of genetically modified organism (GMO) DNA for this bioengineered label as any amount above 0.9%, which is the same as the European Union (EU) and the Non-GMO Project (USDA, 2018). This standard requires regulated entities—including food manufacturers, importers and certain retailers—to ensure appropriate disclosure of bioengineered foods. The Agricultural Marketing Service (AMS) developed the list of bioengineered foods to identify the crops and foods available in a bioengineered form for which these regulated entities must maintain records. Any food included on this list or food item with ingredients on this list must be disclosed as a bioengineered food. Even if a food is not included in this list, regulated entities whose records indicate a food being sold

is bioengineered must make the appropriate disclosure of that food. This Bioengineered Disclosure Law had an initial implementation date of January 1, 2020, except for small food manufacturers which had the initial implementation date of January 1, 2021. Regulated entities could voluntarily comply through December 31, 2021, and mandatory compliance came into effect on January 1, 2022 (USDA, n.d.).

The passage of this law can be attributed to a culmination of grassroots mandatory GMO labeling movements that occurred across the US beginning in the early 2010s. Around 2012, multiple states including California, Washington, Connecticut and Vermont began to introduce ballot initiatives and legislation to require labeling of GMOs (Bain and Dandachi, 2014; Velardi and Selfa, 2021). Labeling proponents contended that due to increased social, environmental and human health risks with the consumption of GMOs, GMOs should be labeled. A prominent message that emerged from these labeling movements was the consumers' 'right to know' what they were eating when it came to the consumption of genetically modified foods (Velardi and Selfa, 2021). Most ballot initiatives and legislation failed to pass with the exception of Vermont's labeling law which passed in 2014 and went into effect in 2016. The federal labeling law, which passed just a few weeks after Vermont's state law went into effect, preempting any state labeling laws, outlined a national mandatory standard for foods made with genetic engineering, now using the term 'bioengineered' (Weiss-Tisman, 2018).

The National Bioengineered Food Disclosure Law has been met with mixed reviews. Certain groups that support the law, such as the American Soybean Association and the National Corn Growers Association, believe that it will create more transparency in the food industry and more consistency under a uniform standard (Hernandez, 2022). However, this new standard has also been met with a great deal of criticism, especially during the COVID-19 pandemic. Many critics feel the law is confusing and places an undue burden on consumers to interpret these labels. Some contend that a mandatory label related to genetic engineering will do little to advance consumers' right to know if consumers do not understand the information or terms used in the label in the first place (Crawford, 2017; Westerman, 2018) and others note that the multiple options to label (i.e., written text, symbol or digital link) mislead and deceive consumers (Spector, 2018; Wolkowitz, 2021). Groups such as the Center for Science in the Public Interest find that the use of 'bioengineered' over 'GMO' is unfair to consumers as 'GMO' is the one they are familiar with. Additional advocacy groups such as the Center for Food Safety believe the new labeling is discriminatory against groups that do not have access to smartphones or cell service—such as the elderly, poor or those in rural communities—who cannot scan QR codes or visit digital links to access information (Reiley, 2022). Spector (2018) notes that the QR code options can make this label inaccessible to many and in fact 'disguises' the label as consumers trying to avoid bioengineered products may not know to look for this specific electronic disclosure (469). The Center for Food Safety has sued the USDA in an attempt to block this new labeling standard as they find the confusing and discriminatory labeling is designed for corporations to hide their use of bioengineered foods, rather than to inform the public (Hernandez, 2022). Additionally, many companies argued that enacting this mandatory standard during the COVID-19 pandemic and the current supply-chain crisis puts an excessive burden on the companies themselves. As such, some trade groups like the Consumer Brands Association are advocating for a temporary pause on the labeling rules (Reiley, 2022). Despite concerns, the labeling regulation went into effect in January 2022.

In response to consumer interest in labeling related to GMOs and an absence of mandatory labeling standards, food companies and private third-party certification companies have begun to implement voluntary non-GMO labeling. Found most prominently on consumer products is the Non-GMO Project label. Established in 2007, the Non-GMO Project nonprofit organization states that its mission is to build and preserve sources of non-GMO products, educate consumers and to provide reliably verified non-GMO options (The Non-GMO Project, 2016). The Non-GMO Project defines a GMO as an organism in which the genetic material has been altered through biotechnology that would not occur naturally. The standard specifically notes that this includes where only the genetic material of an organism is altered or artificially merging DNA of different species that would not naturally reproduce on their own (The Non-GMO Project, 2019). The Non-GMO Project has specifically stated that gene editing techniques fall under their standard of a GMO (The Non-GMO Project, 2021).

For a product to become non-GMO verified, the Non-GMO Project requires ongoing testing of any ingredients deemed at-risk for GMO contamination, and requires companies to adhere to practices to keep GMO DNA out of the product and ensure that it is entirely GMO-free. This process must be completed annually for certification renewal. For a product to be verified it must meet or be below the threshold of acceptable traces of genetically modified DNA. This threshold varies based on the type of product—for seed and plant products the threshold is 0.25%, for wholesale or retail goods that are either ingested or applied topically the threshold is 0.9%, for animal feed and supplements the threshold is 5.0%, and for wholesale or retail goods that are not ingested or topically applied the threshold is 1.5%. To become verified a statistically valid sampling and testing plan is created for each product based on a risk assessment of the production and handling system. The testing must be carried out at a laboratory approved by the Non-GMO Project where they will employ polymerase chain reaction tests. Animal feed is the only category of certified products in which immunological testing methods may be used in place of molecular testing (The Non-GMO Project, 2020).

As this mandatory labeling policy has gone into effect in January 2022, American consumers are confronted with two types of informational labels related to genetically modified foods, containing different information from differing sources. How will these labels be perceived by the public? How will they impact purchasing decisions? Our exploratory survey with university students in New York State intends to help answer these questions as the new bioengineered labels hit shelves across the US. Our research is considered exploratory and therefore not meant to be representative of the university population in the US. Following methods of similar university-based studies, we attempt to understand perceptions of novel phenomena in the food system and suggest that future research expand upon our research by way of a larger sample size with wider demographics. While past research has studied labeling, value-based attributes of food and preferences among university students (Silva *et al.*, 2019; Hillmire and Schnitker, 2020), including specifically GMO and GMO-free labels (Oselinsky *et al.*, 2021), and others have assessed students' knowledge and attitudes of GMOs (Hekmat and Dawson, 2019), our research will look at perceptions and consumer preferences related to the new bioengineered label and associated terminology.

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Literature review

Opposition to biotechnology dates back to 1970s when activists, many from academia, began to highlight potential societal risks and dangers with the use of the technology. However, while grassroots organizing against biotechnology was continuing to form, the introduction of biotechnology into the food system in the 1990s received relatively minimal public pushback due to a lack of public knowledge and understanding surrounding the technology (Schurman and Munro, 2010; Bain and Dandachi, 2014). Proponents touted the agricultural, human health and environmental benefits of agricultural biotechnology with rising global populations to feed and the world food crisis of 2007 added relevancy to proponents' arguments that biotechnology could help address global food insecurity (Bain and Dandachi, 2014). However beginning in the 2010s, small, grassroots movements calling for the labeling of GMOs across the US gained significant traction thus leading to many state-wide labeling initiatives and placing GMOs at the center of public policy debates. As many of these early state-wide labeling bills did not pass, the public turned to the market to encourage companies and private third party certifications (such as the Non-GMO Project) to voluntarily label their products as *not* containing GMOs (Bain and Dandachi, 2014).

The advent of quality assurance and process labels developed under a neoliberal paradigm where heightened hostility toward state intervention and regulation opened spaces for non-state actors (such as civil society and corporations) to participate in policy arenas (Rodrick, 2011; Clapp, 2012). A new role emerged for consumers to participate in the production side of economic systems through their 'conscientious consumerism' by way of knowledge about a product through quality assurance labels such as fair trade certified, non-GMO or environmentally friendly 'green' (Bain and Dandachi, 2014; Bartley *et al.*, 2015), with some now having a greater emphasis on 'sustainable production' (Autzen and Hegland, 2021; Burrows *et al.*, 2022; Siraj *et al.*, 2022). By emphasizing a products' quality attributes through labels, consumers can influence the demand (and thus the production) of products focused on social and environmental welfare by 'voting with their dollars'. These types of labels have been viewed as an effective way to communicate information to consumers (Schiano *et al.*, 2020), thus benefitting the greater public, especially when these certifications have government oversight (Messer *et al.*, 2017). However, some scholars note that conscientious consumerism driven by quality assurance labels has a negligible effect on the social and political spheres pertaining to factors such as labor rights and environmental degradation (Guthman, 2007; Szasz, 2007; Bartley *et al.*, 2015). While many promote the benefits of eco- and sustainable labeling in consumption practices, they also note the risks of excessive consumption and waste on sustainability (Siraj *et al.*, 2021; Burrows *et al.*, 2022). Lastly, some scholars have critiqued the standards of some certifications as not neutral, objective measurements, but rather influenced by who developed the standards and could be co-opted by larger companies in their attempts to gain certification (Bostrom and Klintman, 2008; Jaffee, 2012). In the case of the National Bioengineered Disclosure Law, as previously stated, concerns have arisen related to the true transparency of the law and the ability to fully inform consumer choices based on the information given.

While the general consensus from the scientific community is that genetically modified foods are safe to eat and do not negatively impact human health, it is important to understand how consumers feel (Key *et al.*, 2008). In 2016, the National Academies of Sciences (NAS) produced an extensive report on GMOs or genetically engineered (GE) crops. They found no evidence of adverse health effects caused by the consumption of foods derived from GE crops or animals, and instead found evidence of several GE crops that can be beneficial to human health such as insect-resistant crops that can reduce insecticide poisonings and biofortified crops such as rice with increased beta-carotene to help combat complications from vitamin A deficiencies (NAS, 2016).

The public holds varied beliefs about GMOs. Several studies have assessed the public's knowledge and attitudes surrounding GMOs and found that many individuals are unaware or uninformed about GMOs. Vecchione *et al.* (2015) found in their survey of grocery store customers in Northern New Jersey that increased knowledge of GMOs (based on questions asking if they had heard of the term and to give a definition) was tied to a preference for non-GMO products and a higher willingness to pay for those products. Other studies have attempted to understand if greater knowledge of GMOs leads to higher acceptance, usually finding weak correlations between knowledge and acceptance that could vary based on the specific application or method (Christoph *et al.*, 2008; Sorgo and Ambrozic-Dolinsek, 2010; Mielby *et al.*, 2012). Wunderlich and Gatto (2015) found large percentages of consumers are unaware of GMOs or do not fully understand GM products, their traits and their effects. Additionally, sources of consumer information were examined, finding that while consumers trust expert opinions most, they end up relying more on internet and media sources which often consist of inaccurate, incomplete or misleading information. Thus, the authors note there should be a distinction between familiarity with GMOs (i.e., self-reported familiarity with the term and ability to define it) and scientific understanding of GMOs.

Knowledge background has led to differing perceptions and attitudes toward GMOs. A 2019 study with first-year students at Western University in Ontario, Canada compared knowledge and attitudes of GMOs among students studying nutrition to those who were not. Researchers found that GMO knowledge was strong for both populations of students, but nutrition students were found to have a stronger knowledge of GMOs grown in Canada. The questions regarding attitudes toward GMOs showed that overall both populations either felt unsure or held negative attitudes about GMOs. However, theme analysis of open-ended responses showed that the students studying nutrition were less apprehensive of GMOs in general (Hekmat and Dawson, 2019). Therefore, educational background in terms of college majors and classes taken can lead to differing perceptions related to biotechnology.

Some economics literature has suggested that adopting mandatory GMO labeling could signal to consumers that food produced with biotechnology is unsafe or should be avoided (Lusk and Rozan, 2008; Liaukonyte *et al.*, 2013). The signaling effect resulting from mandatory 'contains GMOs' labels generated significantly higher willingness-to-pay to avoid GMOs than the voluntary 'does not contain GMO' labels (Costanigro and Lusk, 2014). In regards to different types of value-added labels, Kanter *et al.* concluded in their study on consumer choice and production labeling surrounding milk, that consumers may decrease their willingness to pay for conventional (non-labeled) products when confronted with value-added labels (such

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as recombinant bovine somatotropin (rBST)-free and organic) (2009). Others note that based on the way GE foods are marketed to the public, and thus perceived as risky, mandatory labels could create a 'health halo effect' where consumers use a favorable piece of information about a product to overgeneralize ideal features of the product that it may in reality not hold, thus only leading to further consumer confusion about the product and the label (Crawford, 2017). However, other studies found that mandatory labeling that provides a simple disclosure of GE foods actually leads to a reduction in the opposition to them (Kolodinsky and Lusk, 2018). Additionally, Kolodinksy (2008) found that when unbiased information is available, such as 'contains' and 'does not contain' food labels, consumers will not rely on their attitudes while choosing products and instead will rely on informational signals. Kolodinsky *et al.*'s (2018) study on Vermont residents' perceptions of genetic engineering labels found that the majority of respondents view 'contains GMO' labels and 'does not contain GMO' labels as an informational cue that reveals already-established consumer preferences, while few demonstrated the label influenced their preferences and behavior. Oselinksy *et al.*'s (2021) study of attitudes and food selection with 'GMO-free' labels, 'contains GMOs' labels or no GMO labels among university students found that neither the 'GMO-free' nor the 'contains GMOs' labels had a significant impact on participants' self-reported food choice even when they had believed GMOs to be dangerous. Thus, the authors note that in their study there was an attitude–behavior gap when it came to GMOs and food choices.

This previous research informs our research into understanding perceptions and purchasing decisions surrounding labeling and GMOs. We build upon the existing literature to understand perceptions of GMOs by additionally seeking to understand the perceptions of the term 'bioengineered' with the implementation of the new labels. We also build on the literature investigating perceptions of biotechnology based on education by comparing college students majoring in environmental studies *vs* biology.

Materials and methods

A survey was distributed via email to the listserv of the environmental studies students ($n = 251$) and biology students ($n = 2053$) at Binghamton University located in Binghamton, New York. Binghamton University is a public university in New York State, hosting around 14,000 undergraduate students and 3800 graduate students enrolled in over 130 academic programs. Programs are housed in different schools across the University including Harpur College of Arts and Sciences which is home to popular majors such biology and environmental studies (Binghamton University, 2022). The environmental studies and biology majors were purposively selected based on the fact that students in these majors would have likely been introduced to the concept of genetic engineering through their coursework, but in differing contexts—where biology students may learn it in more of a cellular/molecular context whereas environmental studies students learn it in a broader environmental context, which creates an interesting comparative opportunity in evaluating the perceptions of different terminologies associated with genetic engineering and corresponding labels. Recruitment materials specified that only current undergraduate students should participate. A modified version of Dillman's Tailored Design Method (Dillman *et al.*, 2014) was employed with an initial email with a survey link sent in early February 2020 followed by two reminders with the survey open for a total of 10 days. The survey received a total of 153 responses, with ten as partial responses. Total response rate was 7% with completed response rate at 6% ($n = 143$). However, our response rate can be interpreted as slightly higher as double-majors appear on both listservs and both listservs also contained students minoring in those respective disciplines. Of the total respondents, 34% ($n = 52$) of them were environmental studies majors, 62% ($n = 95$) were biology majors and 4% ($n = 6$) were dual majors in both biology and environmental studies.

The survey, created with Qualtrics, contained questions pertaining to familiarity, perceptions, behavior and choice experiment questions about GMOs, bioengineered foods and the corresponding labels, as well as demographic questions (see supplemental information for list of questions). Familiarity-related questions had participants rate statements such as 'I have heard of the term "Genetically modified food"' or 'I have seen this label on food products at the grocery store' with either 'agree', 'disagree' or 'unsure'. Perception-related questions included free-text responses to questions such as 'What are 1–3 words that come to mind when you hear "Genetically Modified Food/Bioengineered Food?"'. Questions on behavior directly asked participants how seeing either the bioengineered label or the Non-GMO Project label impacted their purchasing decisions, having them rate if they were more or less likely to purchase items with the labels or if the labels had no impact on their purchasing decisions. The choice experiment questions provided participants with a number of grocery products—milk, apples, eggs, cereal, ground beef, salmon, corn and salt—with four options for each food product to select from asking which they would purchase if all other attributes were equal including brand and price. Grocery products were chosen to include a variety of food options, some that are currently produced through genetic engineering, and some that are not (or not able to be; i.e., salt) to better understand how the information on the label and thus interpretation of the label impact food choice. Options for grocery products were a Non-GMO Project verified label, the USDA bioengineered label, no label or no preference. Data were analyzed using Qualtrics and Google Sheets. Response percentages were calculated for closed-end responses and open-ended responses were coded through the process of open coding to identify the most emergent categories and overarching themes within the data (Corbin and Strauss, 2015). Following the open coding process, response percentages were calculated for each of the emergent thematic categories.

Results

In order to assess familiarity of terminology and labeling, participants were asked if they had heard of the term 'genetically modified food' with all participants agreeing they had heard the term. In terms of labeling, nearly all participants agreed that they had seen the Non-GMO Project verified label at the store while very few were unsure or disagreed that they had seen the Non-GMO Project label at the store. When asked if they had heard of the term 'bioengineered food', just over half of respondents agreed they had heard the term, while nearly a third were unsure, and the minority disagreed that they had heard the term. However, when it came to labeling, only a minority of participants agreed that they had seen the bioengineered label and just over half of respondents stated they have not seen the label before, with nearly a third remaining unsure (Table 1). When comparing awareness

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Table 1. Terminology and labeling familiarity

'I have heard of the term…/I have seen the following label…'	Agree	Disagree	Unsure
'Genetically modified food'	100% ($n = 153$)	0% ($n = 0$)	0% ($n = 0$)
'Bioengineered food'	55% ($n = 81$)	18% ($n = 27$)	27% ($n = 39$)
Non-GMO Project verified label	97% ($n = 149$)	1% ($n = 2$)	1% ($n = 2$)
USDA bioengineered label	17% ($n = 25$)	55% ($n = 81$)	28% ($n = 41$)

Table 2. Word association thematic sorting

Thematic category	Associated words
Science	Genetics, chemicals, labs, research
Agriculture	Monoculture, specific foods (e.g., corn, tomatoes, soy)
Unnatural	Unnatural, artificial, processed, altered, inorganic
Uncertain attitude	Unknown, controversial, confusing, questionable, misunderstood
Negative attitude	Bad, unhealthy, scary, toxic, dangerous
Enhancement	Growth, bigger, increased, progress, enhanced technology
Positive attitude	Good, efficient, sustainable, safe, innovative
Corporate	Monsanto, industrial, corporate, economics, big business
GMO synonym	GMO, genetically modified organism, same as GMO, genetically modified food

between terminologies, approximately half the number of participants had heard of the term 'bioengineered food' compared to those who had heard of 'genetically modified food'. In addition, participants were more familiar with the Non-GMO Project verified label than the USDA bioengineered label.

To assess perceptions, participants were asked to free-associate words with the terms 'genetically modified food' and 'bioengineered food'. The words reported were sorted into thematic categories. The main thematic categories that emerged were: (1) science, (2) agriculture, (3) unnatural, (4) uncertain attitude, (5) negative attitude, (6) enhancement, (7) positive attitude and (8) corporate. Specifically for categorizing words for 'bioengineered food' a distinct thematic category 'GMO synonym' emerged. Words such as 'monoculture' and 'corn' were put into an agriculture thematic category, while words such as 'biology' and 'lab' were placed in a science thematic category. A listing of thematic categories with examples of most prominent associated words found in each category can be found in Table 2. The most common thematic category found among the words associated with 'genetically modified food' was agriculture making up 24% ($n = 73$) of responses. The most common thematic category found among the words associated with 'bioengineered food' was science, making up 33% ($n = 60$) of responses. Comparing across disciplines, for 'genetically modified food' words reported by environmental studies students ($n = 105$) most commonly fell into the agriculture thematic category followed by the science thematic category. Similarly, the words associated by biology students ($n = 191$) most commonly fell into the agriculture thematic category followed by the science thematic category (Fig. 1). For 'bioengineered food', the biology students' associated words ($n = 102$) most commonly fell into the science thematic category closely followed by the unnatural thematic category, and then the agriculture thematic category. The words associated by the environmental studies students ($n = 73$) followed a similar pattern where most words fell in the science thematic category followed by unnatural, and then agriculture (Fig. 2).

Participants were asked how the Non-GMO Project verified label influences their purchasing decisions. Of the total responses, the majority reported that the label has no impact on their purchasing decisions, approximately one-third claimed that they were more likely to purchase items with the Non-GMO Project verified label, and one respondent claimed they were less likely to purchase items with that label. Participants were also asked how the bioengineered label influences their purchasing decisions. Of the total responses, the majority reported the label has no impact on their purchasing decisions, just under a third said they were less likely to purchase items with the label, and the minority of respondents claimed they were more likely to purchase items with the bioengineered label (Table 3).

Comparing across disciplines, discounting those double majoring, approximately half of the environmental studies students reported that the Non-GMO Project verified label had no impact on their purchasing decisions while the other half reported that they were more likely to purchase products with the label. The biology students had a greater disparity in their responses with the majority reporting the label had no impact on their decisions, nearly a quarter reporting they were more likely to purchase items with that label, and one respondent reporting they were less likely to purchase products with the label. When it came to the bioengineered label, the majority of both environmental studies students and biology students reported the label had no impact on their purchasing behaviors; 4% ($n = 2$) of environmental studies students and 4% ($n = 4$) of biology students reported they were more likely to purchase items with the label; 27% ($n = 13$) of environmental studies students and 15% ($n = 14$) of biology students reported they were less likely to purchase products that had the bioengineered label (Table 4).

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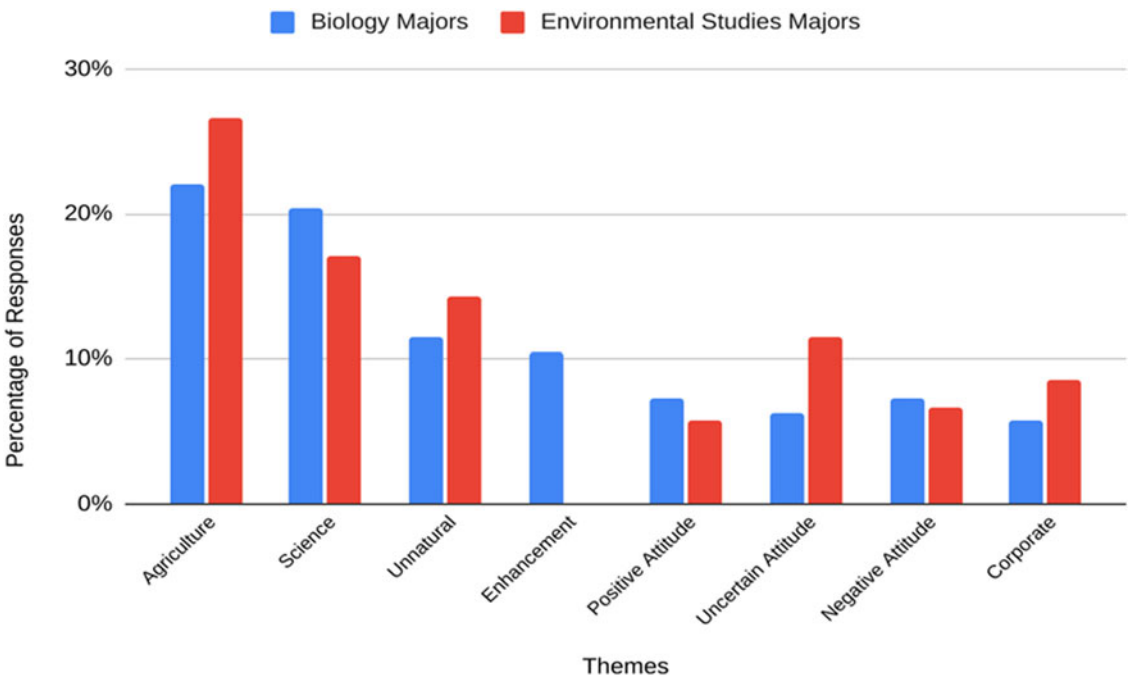

Fig. 1. 'Genetically modified food' word association.

Participants were also asked to rank how important the factors of price, brand name, GMO/non-GMO, organic, fair trade and locally sourced in their purchasing decisions. Price was ranked extremely important and very important by the majority of respondents, 40% ($n = 58$) and 41% ($n = 59$), respectively, while a product being GMO or non-GMO had the largest percentage of respondents rating it as 'not at all important'. Only 14% ($n = 20$) of respondents ranked the 'other' category with 6% ($n = 8$) ranking it as 'extremely important'. Participants who ranked the 'other' category were asked to define what the factor influencing their purchasing decision was. These respondents reported allergy restrictions, food having artificial ingredients, their views on the company, food being within its growing season, food being halal/kosher and food being vegan as 'other' factors that influence their purchasing decisions (Fig. 3).

In the choice experiment questions, over 50% of respondents chose the Non-GMO Project verified label version of every product, except for the salt. The percentage of participants choosing

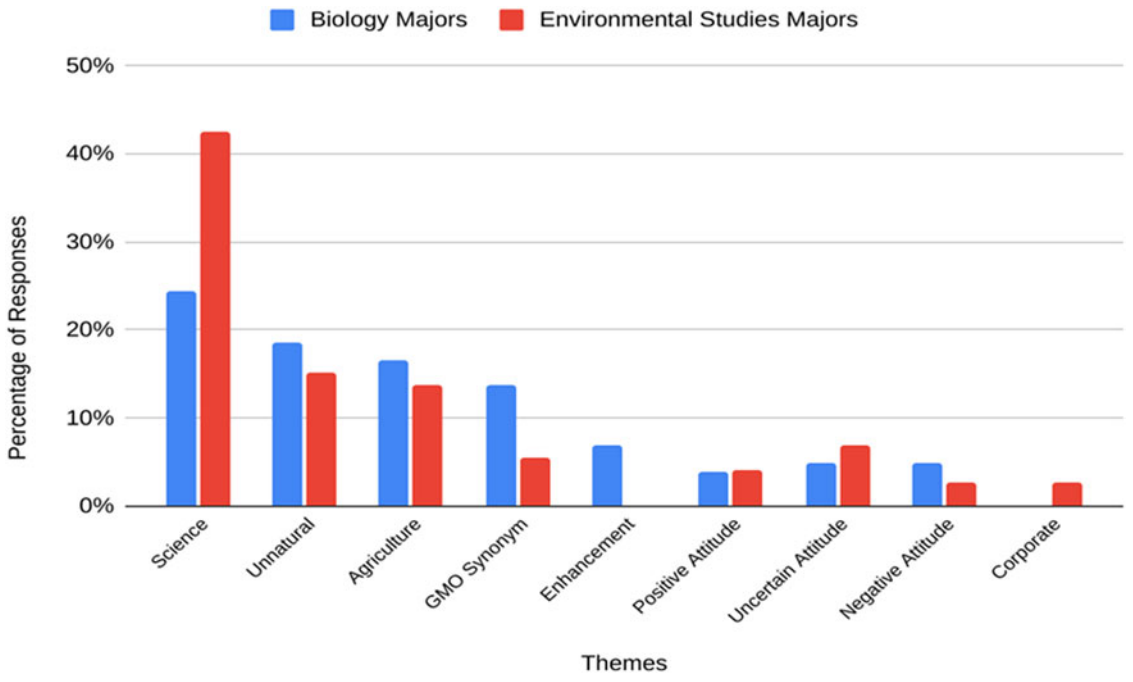

Fig. 2. 'Bioengineered food' word association.

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Table 3. Impact of label on purchasing decision

'How does this label impact your purchasing decisions?'	More likely to purchase	Less likely to purchase	No influence on purchasing
Non-GMO Project verified label	30% ($n = 47$)	1% ($n = 1$)	69% ($n = 105$)
USDA bioengineered label	4% ($n = 6$)	19% ($n = 28$)	77% ($n = 113$)

products with the Non-GMO Project verified label was consistent across products (with the exception of salt). The percentage of participants choosing the bioengineered label was maintained between 2 and 6% across all categories. With the exception of salt, roughly 11–15% of respondents chose the non-labeled product for each category, while 33% chose the non-labeled version of salt. Across all categories, 20–30% of respondents reported they had no preference when choosing a product, the highest rate being for salt (Fig. 4). The result of the choice experiment questions appears to contradict the previous ranked product factor responses and responses in which the majority of participants stated the Non-GMO Project verified label and the bioengineered label both had no influence on their purchasing decisions.

Discussion

As new labeling policies related to genetic engineering are being rolled out it is important to understand people's perceptions of different terms associated with genetic engineering and their labels. This information can provide insight into ways in which to better inform the public about these different technologies to ultimately uphold the notion of informed consumer choice. We found that all participants had heard of the term 'genetically modified foods' while just over half had heard of the term 'bioengineered foods'. Critics of the new USDA label and the decision to use the terminology 'bioengineered' instead of 'genetic engineering' or 'genetically modified' claim that the decision was purposeful to further obstruct transparency for consumers (Dumas, 2018). It is apparent from our study that respondents are less familiar with the term 'bioengineered'. Participants also associated different types of words with each of the two phrases. With 'genetically modified foods' the most common type of words associated with it were those in an agricultural theme, likely based on the

Table 4. Impact of label on purchasing decision by major

'How does this label impact your purchasing decisions?'	More likely to purchase	Less likely to purchase	No influence on purchasing
Environmental studies majors:			
Non-GMO Project verified label	46% ($n = 24$)	0%	54% ($n = 28$)
USDA bioengineered label	4% ($n = 2$)	27% ($n = 13$)	69% ($n = 34$)
Biology majors:			
Non-GMO Project verified label	22% ($n = 21$)	1% ($n = 1$)	77% ($n = 73$)
USDA bioengineered label	4% ($n = 4$)	15% ($n = 14$)	80% ($n = 74$)

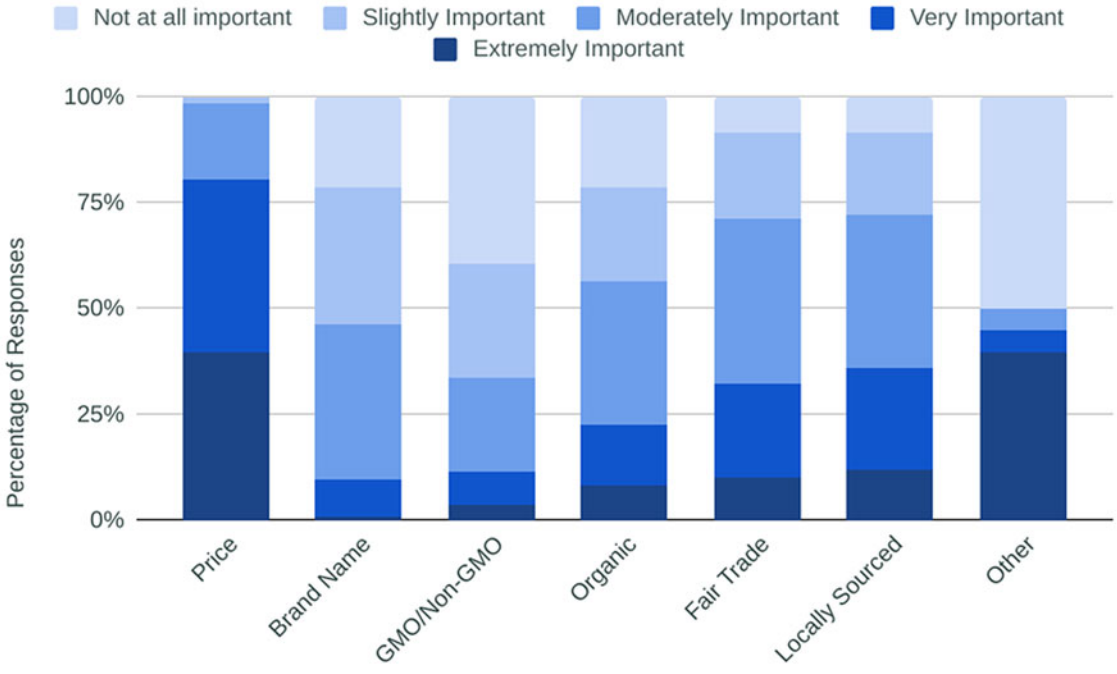

Fig. 3. Purchasing factor rating responses ($n = 145$).

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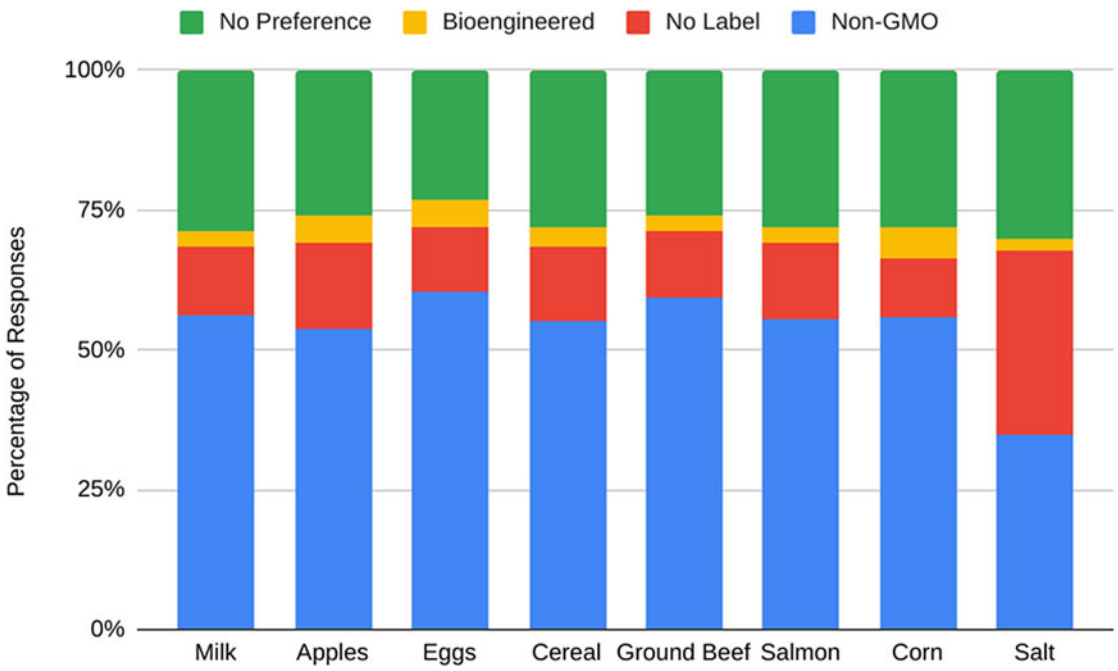

Fig. 4. Total choice experiment responses ($n = 143$).

prevalence of the term associated with crop production in the US. The other common themes found with 'genetically modified foods' were science, unnatural, negative attitude and corporate. Compared to words associated with 'bioengineered foods', there were a greater number of words that fell under the negative attitude thematic category and corporate thematic category for 'genetically modified foods'. This finding illustrates why it is likely that the USDA did not use the term 'genetically modified' in the new label based on the public's negative connotations associated with GMOs, as indicated in Selfa *et al.*'s (2021) findings related to the future governance of gene editing. Alternatively, for 'bioengineered foods' respondents wrote more words that fell under a science theme. Respondents also noted words related to unnatural and agriculture. Interestingly, while the USDA decision to use the term 'bioengineered' may have been purposeful to differentiate from the more familiar term 'GMO', a thematic category emerged where individuals noted how 'bioengineered' was synonymous with 'GMO'. Specifically more biology majors listed these words than environmental studies majors. In general, there was not a stark difference between biology and environmental studies majors when it came to word association for the different terms. A greater percentage of words for 'bioengineered food' from environmental studies students was associated with the term 'science' compared to biology students. In addition, only biology students associated words with both 'genetically modified food' and 'bioengineered food' under the thematic category enhancement and we saw slightly higher percentages of environmental studies students associating words in the corporate thematic category compared to biology students.

In terms of labels influencing purchasing decisions, the majority of respondents said that the Non-GMO Project verified label did not impact their purchasing decisions, with only 30% indicating they would be more likely to purchase products with the Non-GMO Project verified label. Similarly, the majority of individuals (77%) said the bioengineered label did not influence their purchasing decisions, with fewer individuals (4%) indicating that they would be more likely to purchase products with the bioengineered label and 19% indicating they would be less likely to purchase a product with a bioengineered label. When comparing these findings across majors, we find that the majority of both environmental studies students and biology students say the Non-GMO Project verified label has no impact on their purchasing decisions with the biology students at a larger percentage. We find similar responses for the bioengineered label. More environmental studies students would purchase Non-GMO Project verified labeled products compared to biology students, and more biology students would purchase products with the bioengineered label compared to environmental studies students. While we did not specifically test knowledge related to genetics and GMOs, the assumption was that biology students would have a specific content knowledge related to genetics and thus the process of genetic engineering. If they do in fact have more scientific knowledge tied to genetic and genetic engineering then this finding aligns with previous studies that have found weak correlations between knowledge and acceptance or less apprehension (Christoph *et al.*, 2008; Sorgo and Ambrozic-Dolinsek, 2010; Mielby *et al.*, 2012; Hekmat and Dawson, 2019). However, due to the interdisciplinary nature of the environmental studies major, it is difficult to ascertain those students' level of knowledge related to genetics and genetic engineering to draw a distinct conclusion.

When assessing importance of product attributes, price was found to be ranked of most importance by respondents, which is consistent across other consumer studies surrounding food purchases, including those specifically among university students (Koutsimanis *et al.*, 2012; Silva *et al.*, 2019; Hillmire and Schnitker, 2020). Interestingly, for the GMO/non-GMO product attribute, 39% of respondents stated this attribute was 'not at all important', which culminated the largest selection of responses, followed by 'slightly important' and 'moderately important'. However this finding, and the previous findings on the labels influencing purchasing decisions, appears to contradict findings in the choice experiment question. Unlike Oselinksy *et al.*'s

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(2021) findings that GMO labels did not have an impact on food choice, in our choice experiments, students predominantly chose foods labeled as 'Non-GMO'. When asked to choose between three products—the only differences being labeled as non-GMO, bioengineered or not labeled—the majority of participants (>50%) chose the non-GMO version of every product except salt. This consistency was maintained regardless of if there are actually GMO versions of the product on the market. For example, the majority of respondents chose non-GMO versions of eggs and milk where there are currently no 'GMO' eggs or milk on the market. Thus this highlights how the label specifically influenced their purchasing decision. It is also interesting to note that although not the majority, 35% ($n = 50$) of respondents chose non-GMO salt, a product of which a GMO version is impossible as it is not an organism and therefore incapable of genetic modification. This again highlights the power a label can have on the consumers' perception of information tied to the product and how there can be a discrepancy in the meaning of the label and how consumers interpret that information.

It appears based on the choice experiment that the bioengineered label creates a signaling effect where consumers choose to avoid these products (Lusk and Rozan, 2008; Liaukonyte *et al.*, 2013; Costanigro and Lusk, 2014). However, due to the lack of familiarity with the term 'bioengineered' from the majority of participants this avoidance may be based on the wording and type of label in and of itself, rather than the actual attributes of the product tied to its production process. Liaukonyte *et al.* (2013) suggested that the labels for 'contains' and 'does not contain' send different signals to consumers about the quality of the food. They also found that the 'contains' labeling had a negative impact on a consumer's willingness to pay when it was not followed up with any secondary information. In addition, Costanigro and Lusk (2014) found that mandatory labeling and voluntary labeling may also send different signals to consumers, with the mandatory labels having a negative signal to consumers. Mandatory and voluntary labeling may also have an impact on unlabeled products which we found in our study. Similar to Kanter *et al.* (2009), when confronted with a voluntary value-added label, such as the non-GMO label, participants chose that product over conventional (unlabeled) products, regardless of the product type. This may in effect be a version of the 'health halo effect' Crawford (2017) discussed as a potential outcome in the implementation of a mandatory label. The disconnect found between participants stating that bioengineered or non-GMO labeling does not influence their purchasing behaviors and their actual purchasing decisions suggests that the label itself serves as some type of signal to individuals while shopping. Thus, labels pertaining to genetic engineering may not just serve as informational cues (Kolodinsky, 2008; Kolodinsky *et al.*, 2018), but rather influence purchasing decisions when consumers are given a multitude of labels in the marketplace (Kanter *et al.*, 2009). Based on the fact that the majority of participants stated that the non-GMO label and the bioengineered label had no impact on their purchasing decisions, we are inclined to conclude a similar finding as Kanter *et al.* (2009).

Conclusion

Perceptions of GE products and their corresponding labels are ever evolving, as is the research aimed at understanding these perceptions. As public knowledge and perceptions of genetic engineering are dynamic, these survey participants provided useful insight into the perceptions of GMOs and bioengineered foods and their corresponding food labels. As the bioengineered label has hit the marketplace, this understanding and interpretation of the term and label is especially pertinent. Overall our findings highlight that there is a lack of familiarity and understanding of the term 'bioengineered' and reluctance from consumers to purchase products bearing that label. We recommend the USDA and the Food and Drug Administration (FDA) launch a more proactive educational campaign informing consumers what the term 'bioengineered' means with the corresponding label. Informing the public on different terminology in food production and labeling will be especially paramount as the field of crop production continues to evolve such as with the development of gene editing where a crops' genome can be altered without the insertion of foreign DNA. Based on the USDA's definition of 'bioengineered', gene-edited crops will not fall under labeling requirements (Selfa *et al.*, 2021), which is a valuable clarification for the public to have in the name of informed choice. Overall, there should be greater educational effort explaining the process of bioengineering and a comparison with GMOs, which consumers are more familiar with. Explaining these concepts through storytelling with farmers or producers who grow genetically modified food may be helpful as we found in our study that many respondents associate 'bioengineered' with science and less so with agriculture. In addition, individuals associate these terms with 'corporate'. Giving examples of crop production by way of genetic modification from actual people may change people's perceptions of the products and how they interpret the labels. In addition, having a greater understanding of what genetic modification is and what crops are genetically modified in the US may also help consumers more clearly understand when there is not a genetically modified version of the food product in the first place (i.e., salt) so they are informed beyond the label. There is also the consideration of how this new label will affect the overall sustainability of the food system. For those critical of GMOs for environmental and social justice reasons, it is questionable whether this label will effectively address those areas of concern, based on previous analyses of similar phenomena (Guthman, 2007; Szasz, 2007). This should be an area of further research in understanding the effect of these labels on the overall sustainability of the food system.

Our exploratory study was interested in understanding perceptions of genetically modified and bioengineered organisms along with corresponding labels among a college population of biology and environmental studies students in New York State. In order to gather a representative sample of consumers in the US, future studies should sample a much larger demographic of consumers in terms of age, income and geographic location. Future studies should also simulate a 'real-world' scenario with individuals choosing products at a supermarket with specifically labeled products. In addition, a valuable insight in understanding perceptions of different technologies in the food system would also be to understand how these perceptions are formed and evolve over time. Continued research in understanding perceptions of genetic engineering, including the new technology of gene editing, and the different terms associated with these processes as well as corresponding labels is paramount to achieving goals of transparency and a more informed citizenry in the marketplace.

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