AgBioForum, 19(1): 44-53. ©2016 AgBioForum.

Can Science and Genetics Literacy Affect Student Perception of Genetically Modified Organisms?

Gerardo H. Nunez, Alisson P. Kovaleski, Bruno Casamali, and Rebecca L. Darnell
University of Florida

Observational studies have shown that educational attainment is related to heightened consumer perception of genetically modified organisms (GMOs) and genetically modified food (GMF). However, there is little information uncoupling the cognitive and social effects of educational attainment on the perception of GMOs and GMF. A survey experiment was designed to measure the effect of science and genetics literacy on consumer perception and acceptance of GMOs and GMF. A sample population of college students answered a questionnaire either before or after a 50-minute lecture about science and genetics concepts relevant to GMO development and cultivation. This lecture was assumed to increase science and genetics literacy in this population. Comparison of pre-lecture and post-lecture responses revealed that science and genetics literacy had—at least—a short-term effect on student perception of GMOs, which led to increased desirability of GMF, including food containing transgenic and first-generation GMOs.

Key words: cisgenic, consumer, desirability, genetically modified, student perception, transgenic.

Introduction

Genetically modified organisms (GMOs) continue to be a polarizing topic, especially when applied to the production of food (Costa-Font, 2011; Knight, Holdsworth, & Mather, 2008). GMOs contain genetic material that has been modified (the transformant) by receiving a gene or regulatory element from another organism (the donor) through human intervention. Foods that contain GMO ingredients are usually termed genetically modified foods (GMFs).

The elements that contribute to the public's perception of GMOs and GMF have been extensively studied. Anderson, Wachenhein, and Lesh (2006) identified five constructs relevant to this perception: health, environment, risk, ethics, and governmental regulation. Spanning across these concept areas is the cost-benefit assessment that several authors (Costa-Font & Gil, 2009; Hossain, Onyango, Schilling, Hallman, & Adelaja, 2003; Knight, 2007; Lusk et al., 2006) have found to be at the core of the decision to support or reject GMF. Price notwithstanding, the cost of consuming GMF lies in the perceived risk to health and the environment. Americans perceive that GMF consumption entails more risk than consumption of conventional (Anderson et al., 2006; Knight, 2009; Napier, Tucker, Henry, & Whaley, 2004) and organic (Anderson et al., 2006; Mather et al., 2011) foods. As the perceived risk of consuming GMF increases, the overall perception of GMF becomes increasingly negative (Napier et al., 2004), and the willingness to buy GMF decreases (Harrison, Boccaletti, & House, 2004). Perception of greater risk is a characteristic of consumers who oppose GMF at moderate and extreme levels (Ganiere, Chern, & Hahn, 2006; Knight, 2007).

There are also perceived benefits of the production and consumption of GMF, which include favorable outcomes for human health and the environment (Anderson et al., 2006; Knight, 2006). In this regard, it has been shown that consumers who perceive a benefit (personal or environmental) of the consumption of GMF have higher acceptance of these products (Anderson et al., 2006; Ganiere et al., 2006; Hossain et al., 2003; Knight, 2007). For instance, 49% of respondents approved of GMF when no direct benefit was specified, compared to 62% to 71% who approved of GMF when a benefit was explicitly stated (Hossain et al., 2003). Other work found comparable results (i.e., Bhavsar, Tegegne, Ekanem, & Singh, 2014; Knight et al., 2008). This suggests that consumer awareness and the nature of the perceived benefit might impact the public's perception of GMF.

Acceptance of GMF is higher when consumers perceive tangible benefits from GMF adoption (Bhavsar et al., 2014; Hossain et al., 2003; Knight, 2007). Comparisons between first-generation and second-generation GMOs illustrate this point. First-generation GMOs contain innovations with respect to agricultural inputs, such as improved pest and weed management (Le Marre, Witte, Burkink, Grünhagen, & Wells, 2007). On the other hand, second-generation GMOs contain innovations that add end-user value to the commodity, such as increased phytonutrient content, extended shelf life, or modified oil profile (Jefferson-Moore & Traxler, 2005). American and European consumers have more positive views of second-generation GMOs than first-generation GMOs (Gaskell, Stares, Allansdottir, & Allum, 2010; Le Marre et al., 2007), but they still find second-generation GMOs less desirable than conventional foods (Bech-Larsen & Grunert, 2003). The general public perceives agronomic benefits—which are enjoyed primarily by growers—as separate from benefits for consumers (Knight, 2009). In this context, agronomic traits are likely seen as product features rather than benefits (Anderson et al., 2006), thus lessening their positive impact in perception.

The development of alternative genetic modification technologies has further enriched the debate surrounding GMF. GMOs produced with transformants and donors from different species are termed *transgenic*, while GMOs produced with transformants and donors from the same species are termed *cisgenic*. The relatedness between transformants and donors is important for the general public and can affect public perception of GMF (Knight, 2009; Lusk & Rozan, 2006; Mielby, Sandoe, & Lassen, 2013). Foods produced with cisgenic crops are perceived more favorably than those produced with transgenic ones (Gaskell et al., 2010; Kronberger, Wagner, & Nagata, 2014; Lusk, Moore, House, & Morrow, 2002; Lusk & Rozan, 2006). This might in part be because cisgenic crops partially mitigate perceptions of GMOs as unnatural (Knight, 2009; Kronberger et al., 2014; Mielby et al., 2013) given they do not expand the ancestral gene pool of a species (Schouten, Krens, & Jacobsen, 2006) or transgress the sexual compatibility barrier (Kronberger et al., 2014). In this regard, some authors have argued that cisgenic crops are merely an extension of traditional plant breeding (Rommens, Haring, Swords, Davies, & Belknap, 2007; Schouten et al., 2006), while others have found evidence suggesting the general public does not make that connection (Knight, 2009; Kronberger et al., 2014).

Comparisons between first- and second-generation and transgenic and cisgenic organisms can often include technical language, which stresses the importance of consumer education about scientific and genetic concepts. While some authors have argued about a need for science-based consumer education (Bhavsar et al., 2014; Hoban & Katic, 1998), the relationship between science and genetics literacy and the perception of GMOs and GMF has not been thoroughly studied. Previous research relating formal education and perception of GMOs and GMF has provided some valuable insight into this relationship. While these studies did not distinguish between science and non-science education, they have revealed that college-educated consumers have more objective knowledge about GMOs and GMF (House et al., 2004) and perceive GMF more positively than less-educated consumers (Harrison et al., 2004; House et al., 2004). However, formal education has been typically measured as educational attainment (Harrison et al., 2004; House et al., 2004), a variable that is collinear with income, race, and other demographic descriptors. Thus, the reported heightened view of GMOs and GMF by more educated consumers might be a consequence of factors other than science and genetics literacy. To date, there is little information uncoupling the cognitive and social effects of formal education about science and genetic concepts on the perception of GMOs and GMF.

The present work sought to fill that void. While others have relied on observational approaches to study the relationship between formal education about science and genetics concepts and the perception of GMOs and GMF (Harrison et al., 2004; House et al., 2004), we chose to use an experimental intervention approach to isolate the effect of science and genetics literacy from the demographic effects of educational attainment. Treating formal education as an effective way to impart objective knowledge (House et al., 2004) and increase science and genetics literacy, we used a 50-minute lecture about the science and genetics concepts relevant to GMO development and cultivation as our intervention. Additionally, we investigated the impact that formal education about science and genetics concepts can have on the perception of first- and second-generation GMOs, as well as transgenic and cisgenic organisms.

Methods and Procedures

Survey Instrument

A 60-item questionnaire was designed and assigned as an extra credit assignment to a sample population of students enrolled in a 1-credit general interest horticulture course at the University of Florida. Online software surveymonkey.com (Survey Monkey Inc., Palo Alto, CA) was used to administer this survey. Participation in the study was voluntary and in compliance with guidelines set forth by the University of Florida Institutional Review Board. Accordingly, students younger than 18 years old were not admitted into the study.

The survey instrument consisted of three sections. The first section contained questions about the demo-

Table 1. Fictitious products presented to University of Florida students and their classification according to the biotechnological technology used to develop them and the stakeholder who directly benefits from it. Students were asked to rank these products according to their own preference and the information provided.

Product description	Technology	Generation of GMO[a]
P1. High-yielding wheat: Through conventional cross-pollination of various lines a high-yielding variety of wheat is developed. Objective: To increase yield.	Conventional breeding	--
P2. Wheat with improved nitrogen uptake: Through genetic modification genes are inserted into wheat to improve nitrogen uptake. The new genes are derived from the plant itself or from closely related varieties. Objective: To reduce the need for fertilizers.	Cisgenics	First
P3. Maize with resistance to insects: Through genetic modification a gene is inserted into the plant that causes it to produce a poisonous compound. Some insects die when they ingest the plant. The new gene is derived from a bacterium. Objective: To reduce the use of pesticides (insecticides).	Transgenics	First
P4. Herbicide-resistant rapeseed: Through genetic modification a gene is inserted into the plant that makes it tolerant to certain herbicides. The new gene is derived from a bacterium. Objective: To reduce the use of pesticides (herbicides).	Transgenics	First
P5. Rice with A-vitamins: Through genetic modification new genes are inserted into the rice plant that make the seeds accumulate vitamin A. The genes involved in the genetic modification process are derived from different garden plants and from a bacterium. Objective: To produce rice with vitamin A in order to combat vitamin A deficiency in developing countries.	Transgenics	Second
P6. Tomatoes with delayed softening: The gene that would normally cause tomatoes to rot is blocked using gene technology. Objective: To make tomatoes that last longer and have firmer flesh.	Vague[b]	Second
P7. Rapeseed with modified oil composition: The rapeseed genes are altered through radioactive exposure. The amended seeds (with high levels of healthy oils) are then selected and propagated. Objective: To produce a healthier rapeseed oil.	Mutagenesis	--
P8. Cold-resistant tomatoes: Using genetic engineering a gene is inserted into the plant that makes the tomato less vulnerable to frost. The new gene comes from a fish found in the Arctic. Objective: To make tomatoes that tolerate frost.	Transgenics	First

[a] Stakeholders who directly benefited from the innovation were described in the product description. First-generation GMOs contain grower-centric innovations, while second-generation GMOs contain consumer-centric innovations.
[b] More than one technology could have been used to develop this product.

graphic characteristics of the participants. The second section included eight fictitious examples of crops with brief descriptions that noted the biotechnological approach used to develop them and the objective pursued by the plant breeder (Table 1). Students were asked to rate these products according to their own preference using a seven-point Likert scale where 1 was "least desirable" and 7 was "most desirable." Mielby et al. (2013) designed these examples to reflect products that are currently in the market or in development by using various biotechnological approaches, including conventional breeding, transgenics, cisgenics, and mutagenesis. Additionally, some of these products match the description of first-generation (grower-centric products) or second-generation (consumer-centric products) GMOs (Table 1). While benefits to the grower could imply benefits to the consumer in the marketplace, and vice versa, the present study sought to distinguish between innovations that more directly benefited the grower from those that more directly benefited the consumer.

The last section of the survey contained a subset of questions from Anderson et al. (2006), who surveyed perceptions of college-aged consumers about organic and genetically modified produce. Only questions relevant to GMO production and GMF consumption were included in the present survey. The questions were designed around the five constructs identified by Anderson et al. (2006) as relevant for purchase and acceptance of GMF and GMOs: health, environment, risk, ethics, and governmental regulation (called policy/regulation, hereon). Students were presented with prompt statements and asked to indicate their level of agreement using a seven-point Likert scale where 1 represented "strongly disagree" and 7 indicated "strongly agree". Both positively and negatively worded prompt statements were presented in each construct. There were 51 prompt statements in total: 14 in the health construct, 10 in environment, eight in ethics, 10 in risk, and nine in policy/regulation. The reliability of this section of the survey instrument was assessed using a pilot study

Table 2. Topics covered in a 50-minute lecture delivered by a Ph.D.-level university professor in a general interest horticulture course at the University of Florida.

1) Basic biology of making a transgenic organism
   a. Central dogma of molecular biology
   b. Cell totipotency

2) Scientific explanation of GMO currently in the market
   c. Papaya ringspot virus resistance
   d. BT-corn
   e. Roundup ready crops
   f. Golden rice

3) Benefits of using GMO in agriculture
   g. Farmers
   h. Consumers
   i. Environment

4) Downsides of using GMOs in agriculture
   j. Appearance and spread of glyphosate-resistant weeds

5) GMOs in public media
   k. Non-experts are vocal about the issue
   l. Scare tactics and boycotts
   m. Pseudo-science through correlations

6) Where to get unbiased, scientific information

applied to a randomly selected group of individuals in the sample population (11.1% of the total). Data from this pilot study were regressed on the data from the entire sample population and found to be consistent ($r \geq 0.81$). The face validity of this section was assumed to be the same as that determined by the expert panel in the original source of the survey instrument Anderson et al. (2006).

To test the effect of science and genetics literacy on the perception of GMF, we used the same method as Nunez, Kovaleski, and Darnell (2014). The class roster was randomly divided into two treatment groups of 135 students each. One group took the survey during the week prior to a 50-minute lecture about science and genetics concepts relevant to GMO development and cultivation (pre-lecture group), and the other group took the survey within a week after the lecture (post-lecture group). A Ph.D.-level university professor whose work focuses on using biotechnology techniques to solve agricultural problems delivered the lecture (Table 2).

Product Desirability

When more than one product (Table 1) could be listed under an approach or generation, Likert-type data were aggregated into composite desirability scores by averaging individuals' responses. Cronbach's alpha coefficients were used to select which products' answers could be averaged and to gauge the internal consistency of the computed scores. Approach, generation, and treatment group were used as categorical variables and the composite desirability scores were used as continuous variables. Non-parametric Kruskal Wallis or Mann-Whitney-Wilcoxon tests were used to evaluate the statistical differences between the levels in the categorical variables at $P \leq 0.05$ in SAS (version 9.4; SAS Institute, Cary, NC). Pairwise comparisons were carried out with the Steel-Dwass-Critchlow-Fligner adjustment for the error rate.

The sample population was divided into three subgroups based on students' composite GMO desirability score. Students were labeled "GMO proponents" when their desirability scores were greater than 4, and "GMO opponents" when their desirability scores were less than 4. All others were labeled "GMO neutral." Differences in the ratio of proponents to opponents between selected demographic groups were tested via chi-square tests at $P \leq 0.05$.

Perception of GMOs and GMF

Participants were grouped according to whether they took the survey before or after the lecture. Likert-type responses to Section Three were coded as "in agreement" (Responses 5, 6, and 7), "neutral" (Response 4), and "in disagreement" (Responses 1, 2, and 3). Chi-square tests were then used to test differences in the ratio of responses between the pre-lecture and post-lecture groups.

Results

Demographics

A total of 234 students took the survey: 115 before the lecture and 119 after the lecture. Response rates were 85.9% and 88.1%, respectively. Overall, 58.6% of the respondents were females and 40.5% were male; 0.9% did not respond this question. Most participants were younger than 25 years old (97.4%), with the most represented group being those between 18 and 22 (92.6%). Students were asked what college they were enrolled in as a way to assess their exposure to science, biotechnology, and agriculture at large. Students enrolled in colleges that award science and non-science majors were asked to indicate which of these two better describes their field of study. The sample population contained students enrolled in all 10 colleges at the University of Florida, with the College of Liberal Arts and Sciences (33.6%), the Warrington College of Business (17.2%), and the College of Agriculture and Life Sciences (16.0%) being the most represented. Students majoring in science fields represented 32.8% of the sample. Stu-

Table 3. Desirability of products according to the technology used to develop them as determined from a survey taken by undergraduate students at the University of Florida before or after a lecture about science and genetics concepts relevant to GMO development and cultivation.

Approach	Pre-lecture group	Post-lecture group	Comparison *P* value
Conventional breeding	5.34 a*	5.34 a	0.9061
Mutagenesis	4.45 c	4.86 b	0.0806
Transgenics	4.85 bc	5.42 ab	0.0007
Cisgenics	5.17 ab	5.39 a	0.2723

** Responses entered on a seven-point Likert scale (1 was "least desirable" and 7 was "most desirable") were averaged across subjects within each technology, where available. Non-parametric Kruskal Wallis or Mann-Whitney-Wilcoxon tests were used to evaluate the statistical differences between technologies within a group (letters) and between groups within a technology (P values) at P ≤ 0.05. Means followed by the different letters represent populations with significantly different distributions.*

dents majoring in fields related to agriculture represented 16.0% of the sample. The sample population was approximately evenly distributed across class standings. When asked to describe their community of origin, 88.4% of respondents reported being from a city or small city, whereas 11.6% of the respondents reported being from a small town or rural settings.

Treatment Effect

Approach and Generation. Students indicated how desirable they found a product after reading a description detailing the approach used to develop it and the generation of GMO to which this product belonged (Table 1). Desirability of transgenic products was calculated as the average score of products P3, P4, and P8. Product P5, which was the only second-generation transgenic, was eliminated in order to optimize Cronbach's alpha coefficient to 0.84. Desirability of all other biotechnological approaches was gauged based on student responses about one product per each technology. Before the lecture, students indicated that crops developed through conventional breeding were more desirable than crops developed through transgenic and mutagenic approaches, but not more desirable than cisgenic crops (Table 3). After the lecture, students rated crops developed through conventional breeding, cisgenic approaches, and transgenic approaches to be equally desirable. This was the product of a significant increase in the desirability of transgenic crops after the lecture relative to before the lecture. The desirability of conventionally bred, mutagenic, and cisgenic crops was not affected in the same manner. In addition, transgenic and cisgenic crops were equally desirable both before and after the lecture. Mutagenesis was significantly less desirable than conventional breeding and cisgenics but not transgenics, in both groups.

Table 4. Desirability of GM products according to generation as determined from a survey taken by undergraduate students at the University of Florida before or after a lecture about science and genetics concepts relevant to GMO development and cultivation.

Generation of GMO	Pre-lecture group	Post-lecture group	Comparison *P* value
First	4.93 b*	5.41 a	0.0021
Second	5.41 a	5.68 a	0.0406

** Responses entered on a seven-point Likert scale (1 was "least desirable" and 7 was "most desirable") were averaged across subjects within each generation. Mann-Whitney-Wilcoxon tests were used to evaluate the statistical differences between generations within a group (letters) and between groups within a generation (P values) at P ≤ 0.05. Means followed by the different letters represent populations with significantly different distributions.*

In order to further explore the desirability of GMOs according to whom the main beneficiary of the technology was, two additional composite desirability scores were created. Desirability of first-generation GMOs was computed as the average score of P2, P3, P4, and P8 (Cronbach's alpha=0.86), and desirability of second-generation GMOs was computed as the average score of P5 and P6 (Cronbach's alpha=0.74). Before the lecture, students found second-generation GMOs more desirable than first-generation GMOs (Table 4). Receiving a lecture about science and genetics concepts relevant to GMO development and cultivation led to significant increases in the desirability of both first- and second-generation GMOs. However, the increase in desirability of first-generation GMOs was greater than the increase in desirability of second-generation GMOs. As a consequence, first- and second-generation GMOs were equally desirable after the lecture.

Overall. Receiving a lecture about science and genetics concepts relevant to GMO development and cultivation was able to influence student perceptions of GMOs and GMF (Table 5). Generally, more students agreed with positively worded statements in the post-lecture group than in the pre-lecture group across all constructs. Similarly, fewer students agreed with negatively worded statements in the post-lecture group than in the pre-lecture group. Altogether, students who took the survey

Table 5. Responses to statements where significant differences were found in a sample population of undergraduate students surveyed at the University of Florida between subjects who were surveyed before or after a 50-minute lecture about science and genetics concepts relevant to GMO development and cultivation.

Statement[a]	Before lecture (%)			After lecture (%)			Chi-square[e]
	A[b]	N[c]	D[d]	A	N	D	
Health							
Consumption of GMF can improve your overall healthy appearance. (P)	31.0	41.6	27.4	38.1	44.9	16.9	0.017
I will live longer if I eat GMF. (P)	14.2	44.2	41.6	19.7	51.3	29.1	0.019
GMFs are useful in preventing disease. (P)	61.9	19.5	18.6	51.7	30.5	17.8	0.048
GMF may combat our nation's problem with obesity. (P)	38.7	25.2	36.0	54.7	25.6	19.7	<0.001
My overall health will decline if I consume GMF. (N)	21.4	30.4	48.2	6.8	14.4	78.8	<0.001
GM ingredients in food pose hidden dangers to my health. (N)	36.6	30.4	33.0	12.7	22.0	65.3	<0.001
GMF is not as healthy as traditional food. (N)	35.4	31.0	33.6	11.9	18.6	69.5	<0.001
Regularly eating GMF will harm my health. (N)	23.0	37.2	39.8	10.2	20.3	69.5	<0.001
GMFs present a grave danger to my health. (N)	16.2	29.7	54.1	6.8	16.1	77.1	<0.001
Environment							
The balance of organisms is better managed by humans using GM techniques. (P)	27.4	39.8	32.7	32.2	45.8	22.0	0.035
I am worried about unknown effects of GM crops on our ecosystem. (N)	67.3	13.3	19.5	53.4	13.6	33.1	0.010
The balance of nature has been upset by the use of GM crop production. (N)	35.4	33.6	31.0	15.3	28.8	55.9	<0.001
Genetic modification will introduce new organisms that may harm our society. (N)	41.1	37.5	21.4	17.8	36.4	45.8	<0.001
Production of GM crops could harm other species in ways we do not understand. (N)	72.6	19.5	8.0	39.0	26.3	34.7	<0.001
Raising GM species is dangerous to the gene pools of those species. (N)	51.3	32.7	15.9	29.7	30.5	39.8	<0.001
Risk							
I see no risks in the consumption of GMF. (P)	31.0	22.1	46.9	59.8	17.9	22.2	<0.001
GMFs are completely safe to eat. (P)	31.3	33.9	34.8	68.4	18.8	12.8	<0.001
I would be willing to serve GMF to my friends. (P)	60.4	27.0	12.6	78.8	14.4	6.8	<0.001
GMFs present no danger for future generations. (N)	15.0	38.9	46.0	41.9	31.6	26.5	<0.001
Eating GMF will subtract from my quality of life. (N)	16.2	27.9	55.9	5.9	18.6	75.4	<0.001
It is dangerous to use GM techniques to alter what we eat. (N)	30.1	26.5	43.4	11.0	16.9	72.0	<0.001
The risks to people associated with GMF far outweigh the benefits. (N)	21.2	34.5	44.2	11.9	19.5	68.6	<0.001
GMF will harm society more than help. (N)	20.4	31.0	48.7	7.7	15.4	76.9	<0.001
Ethics							
Scientists are fulfilling moral obligations to society by improving food using GM means. (P)	49.6	34.5	15.9	63.2	24.8	12.0	0.017
Improving crop production by using GM methods is the right thing to do. (P)	45.5	40.2	14.3	65.3	30.5	4.24	<0.001
Scientists are playing God when altering the genes of plants by GM means. (N)	26.5	20.4	53.1	13.6	22.0	64.4	0.001
Changing the makeup of plants by using genetic modification means is not morally acceptable. (N)	20.4	23.9	55.8	11.0	19.5	69.5	0.003
It is unethical for scientists to conduct research involving GM means. (N)	11.6	24.1	64.3	2.5	13.6	83.9	<0.001
Crops should only be enhanced by natural means. (N)	32.7	25.7	41.6	14.4	28.0	57.6	<0.001
GMFs threaten the natural order of things. (N)	45.0	20.7	34.2	37.4	18.8	53.8	<0.001
GM crop production will harm future generations. (N)	29.1	38.2	32.7	11.0	26.3	62.7	<0.001
Government							
Government does not adequately regulate the private sector when it comes to production of GMF. (N)	27.4	46.9	25.7	16.9	41.5	41.5	0.001
Government has too little regulation when it comes to GM crop production. (N)	25.7	43.4	31.0	16.2	33.3	50.4	<0.001
Government has failed to regulate GMF. (N)	28.3	38.9	32.7	18.6	37.3	44.1	0.018

[a] Statements were positively worded (P) or negatively worded (N) in order to account for any agreeability bias.
[b] Percentage of subjects found "in agreement" with the statement. [c] Percentage of subjects found "neutral" with respect to the statement.
[d] Percentage of subjects found "in disagreement" with the statement. [e] Chi-square tests were used to evaluate the differences between A:N:D ratios between students who took the survey before and after a 50-minute lecture about GMOs.

Table 6. Percentage of respondents classified as GMO opponents, GMO neutral, and GMO proponents based on their responses to product desirability questions in a survey applied to undergraduate students at the University of Florida.

Demographic (no. respondents)	GMO opponents (%)	GMO neutral (%)	GMO proponents (%)	Chi-square [a]
Total (234)	17.17	6.87	75.97	--
Gender				
Male (94)	14.89	7.45	77.66	0.611
Female (136)	16.91	6.62	76.47	
Age group				
18-20 years (135)	14.81	5.93	79.26	0.241
21-23 years (96)	18.75	8.33	72.92	
Field of study				
Science (76)	14.47	9.21	76.32	0.412
Non science (156)	17.95	5.77	76.28	
Formal education				
Pre-lecture (115)	22.81	7.02	70.18	<0.001
Post-lecture (119)	11.76	6.72	81.51	

[a] Chi-square tests were used to evaluate the differences in the ratios of GMO opponents to GMO proponents after the data was split according to formal education. Small expected percentages can bias the P value estimated by Chi-square tests. Hence, the percentage of GMO neutral respondents was not included in comparisons.

after the lecture held more positive views of GMOs and GMF than students who took the survey before the lecture.

Perception of GMOs by Proponents and Opponents

The sample population was divided between GMO proponents, GMO neutral, and GMO opponents based on each student's composite desirability score of products made with GMOs (Table 6). In total, 76.0% of students were classified as GMO proponents, 6.9% were classified as GMO neutral, and 17.2% were classified as GMO opponents. The proportion of GMO proponents to GMO opponents was compared between the levels of the demographic variables through Chi-square tests. Between 3.7% and 9.2% of the sample population was classified as GMO neutral. GMO neutral was omitted from the Chi-square analysis to avoid the underestimation of the *P* value caused by the small number of individuals found in this category. Gender, age, and field of study did not significantly affect the ratio of proponents to opponents in the sample population. On the other hand, formal education significantly affected the proportion of proponents to opponents, with a higher proportion of GMO proponents in the post-lecture group than in the pre-lecture group.

Discussion

Participating in a lecture about science and genetics concepts relevant to GMO development and cultivation can make GMF more desirable to students and positively impact students' perception of GMOs and GMF. Students who took the survey after the lecture found GMF more desirable than students who took the survey before the lecture. Additionally, more students were proponents of GMF after the lecture than before. Le Marre et al. (2007) suggested that recommendations from scientific entities could affect consumer preference for GMF. While the topics and tone of the lecture in the present research were aimed at providing a scientifically-accurate image of GMOs and GMF, scientists and other practitioners are on average more favorable about these technologies than the general public (Malyska, Maciag, & Twardowski, 2014). Hence, students might have interpreted the lecture materials as an endorsement of GMF; combined with the trust placed on university scientists by the general public (Lang, 2013), this could have caused the measured increase in consumer desirability of GMF.

Alternatively, this shift in consumer desirability could be the result of a post-lecture reassessment of the risks and benefits of the production of GMOs and the consumption of GMF. After the lecture, consumption of GMF and production of GMOs were perceived as better regulated and more environmentally and ethically sound activities than before the lecture. While ethical and moral values seem to underlie perception differences between distant groups of people (Gaskell et al., 2010; House et al., 2004), in our sample, as well as other geographically narrow ones (Anderson et al., 2006; Nunez et al., 2014), ethical and moral values were relatively homogenous. Students who took the survey after the lecture perceived GMF as having more health benefits than students who took the survey before the lecture. Formal education was also capable of mitigating some of the perceived risk in consuming GMF. These findings suggest that the increased desirability of GMF by students who received a lecture about the topic is likely the product of a more positive perception of GMOs.

A positive perception might be the consequence of greater perceived benefits and fewer perceived risks in the consumption of GMF and cultivation of GMOs. Previous work has shown that benefits of GMO use are not as broadly known as risks (Costa-Font, 2011). Hence, the lecture about science and genetics concepts relevant to GMO development and cultivation might have been the first time that many of the students learned about the benefits—especially agronomic—of using this technology. Additionally, this lecture might have affected students' risk perception. The public generally gathers information about GMOs from mass media outlets (Knight, 2009), which commonly attach negative connotations to the use of GMOs for food production (Augoustinos, Crabb, & Shepherd, 2010). The lecture used for this research likely helped in dissociating GMOs and GMF from negative connotations, because the content, language, and tone employed were according to the standard of an academic setting. Moreover, the risk perception of students was likely further affected by the introduction of the role of regulatory entities in the GMO and GMF market. Consumers are generally uninformed about the role of government in the regulation of the food marketplace (Nunez et al., 2014), particularly the GMF marketplace (Hallman, Hebden, Cuite, Aquino, & Lang, 2004). Thus, the lecture might have mitigated the risk perception of students by elucidating the government's precautionary role in the regulation of GMO safety and trade.

The increase in consumer desirability of GMF as a consequence of participating in a lecture about science and genetics concepts relevant to GMO development and cultivation was most evident in regards to transgenic organisms. Students in the present population found transgenic crops as desirable as cisgenic crops both before and after the lecture. This is in contrast with previous research where American consumers found cisgenic crops innocuous but transgenic crops problematic (Knight, 2009) and less desirable (Lusk & Rozan, 2006). Unlike previous survey-based studies (Lusk & Rozan, 2006), our research presented the transformation event and the benefit side by side in the description of transgenic and cisgenic products. Acceptance of GMF has been found to be higher when the benefits of using genetic modification technologies are explicitly stated (Hossain et al., 2003). Hence, it is possible that the converging desirability of transgenic and cisgenic products described here might have been influenced by the language of the product descriptions. Additionally, in the present population, students found cisgenic crops as desirable as conventionally bred ones, independent of the education effect. These findings give some credence to the argument that intra-species genetic transformation can be considered an extension to traditional breeding (Rommens et al., 2007; Schouten et al., 2006); however, they also highlight that the public does not necessarily perceive cisgenic crops as fundamentally different than transgenic ones. Given that the present study gauged the desirability of cisgenic crops based on responses about a single product, further research will be required to explore the relative desirability of conventional, transgenic, and cisgenic products beyond this limitation.

Participation in a lecture about science and genetics concepts relevant to GMO development and cultivation was also able to increase the desirability of first-generation GMOs. As expected from the literature (Gaskell et al., 2010; Le Marre et al., 2007), prior to any treatment effect, students found second-generation GMOs more desirable than first-generation GMOs. However, both generations were equally desirable to students after the lecture. It is possible that individuals with exposure to agriculture and the science of plant genetic transformation might have a better appreciation for the motivations behind the biotechnological improvement of crops. For instance, agriculture students in France did not always perceive differences between first- and second-generation GMOs (Le Marre et al., 2007). The disproportionally low number of respondents majoring in agriculture in the present study prevented us from testing if a similar effect was observed. Alternatively, it is possible that the lecture about science and genetics concepts relevant to GMO development and cultivation used here was only able to increase student familiarity with the agronomic benefits brought about by first-generation GMOs, rather than increase awareness of agricultural issues. The present study was not able to distinguish between these two possibilities.

Altogether, the student surveys indicated that information presented in a lecture about science and genetics concepts relevant to GMO development and cultivation heightened the perceived benefits and mitigated the perceived risks of producing GMOs and consuming GMF. This led to greater desirability of GMF, including products developed through transgenic approaches and products containing first-generation GMOs. Further work will be necessary to establish whether these findings about college students can be extended to the entire population of college-educated consumers. Additionally, future research will be necessary to establish the duration of the effect of this intervention beyond the short term tested here. Nevertheless, the present study provides direct evidence about a positive relationship between education about science and genetics concepts and the perception of GMOs and GMF.

References

Anderson, J.C., Wachenheim, C.J., & Lesch, W.C. (2006). Perceptions of genetically modified and organic foods and processes. *AgBioForum*, *9*(3), 180-194. Available on the World Wide Web: http://www.agbioforum.org.

Augoustinos, M., Crabb, S., & Shepherd, R. (2010). Genetically modified food in the news: Media representations of the GM debate in the UK. *Public Understanding of Science*, *19*(1), 98-114.

Bech-Larsen, T., & Grunert, K.G. (2003). The perceived healthiness of functional foods. A conjoint study of Danish, Finnish and American consumers' perception of functional foods. *Appetite*, *40*(1), 9-14.

Bhavsar, H., Tegegne, F., Ekanem, E., & Singh, S.P. (2014). Awareness and attitudes of Tennessee consumers towards agricultural biotechnology: Survey results. *Journal of Food Research*, *4*(1), 97-104.

Costa-Font, M. (2011). Mapping social and environmental concerns and the acceptability of genetically modified organisms in the European Union. *The Journal of Socio-Economics*, *40*(6), 903-908.

Costa-Font, M., & Gil, J.M. (2009). Structural equation modelling of consumer acceptance of genetically modified (GM) food in the Mediterranean Europe: A cross country study. *Food Quality and Preference*, *20*(6), 399-409.

Ganiere, P., Chern, W.S., & Hahn, D. (2006). A continuum of consumer attitudes toward genetically modified foods in the United States. *Journal of Agricultural Economics and Resource Economics*, *31*(1), 129-149.

Gaskell, G., Stares, S., Allansdottir, A., & Allum, N. (2010). *Europeans and biotechnology in 2010—Winds of change?* Brussels: European Commission.

Hallman, W.K., Hebden, W.C., Cuite, C.L., Aquino, H.L., & Lang, J.T. (2004). *American and GM food: Knowledge, opinion and interest in 2004* (Food Policy Institute Report No. RR-1104-007). New Brunswick, NJ: Food Policy Institute at Rutgers, the State University of New Jersey.

Harrison, R.W., Boccaletti, S., & House, L. (2004). Risk perceptions of urban Italian and United States consumers for genetically modified foods. *AgBioForum*, *7*(4), 195-201. Available on the World Wide Web: http://www.agbioforum.org.

Hoban, T.J., & Katic, L. (1998). American consumer views on biotechnology. *Cereal Foods World*, *43*(1), 20-22.

Hossain, F., Onyango, B., Schilling, B., Hallman, W., & Adelaja, A. (2003). Product attributes, consumer benefits and public approval of genetically modified foods. *International Journal of Consumer Studies*, *27*(5), 353-365.

House, L., Lusk, J., Jaeger, S., Traill, W.B., Moore, M., Valli, C., & Morrow, B. (2004). Objective and subjective knowledge: Impacts on consumer demand for genetically modified foods in the United States and the European Union. *AgBioForum*, *7*(3), 113-123. Available on the World Wide Web: http://www.agbioforum.org.

Jefferson-Moore, K.Y., & Traxler, G. (2005). Second-generation GMOs: Where to from here? *AgBioForum*, *8*(2&3), 143-150. Available on the World Wide Web: http://www.agbioforum.org.

Knight, A.J. (2006). Does application matter? An examination of public perception of agricultural biotechnology applications. *AgBioForum*, *9*(2), 121-128. Available on the World Wide Web: http://www.agbioforum.org.

Knight, A.J. (2007). Biotechnology, industrial agriculture, and the risk society. *Society & Natural Resources: An International Journal*, *20*(1), 21-36.

Knight, A.J. (2009). Perceptions, knowledge and ethical concerns with GM foods and the GM process. *Public Understanding of Science*, *18*(2), 177-188.

Knight, J.G., Holdsworth, D.K., & Mather, D.W. (2008). GM food and neophobia: Connecting with the gatekeepers of consumer choice. *Journal of the Science of Food and Agriculture*, *88*(5), 739-744.

Kronberger, N., Wagner, W., & Nagata, M. (2014). How natural is "more natural"? The role of method, type of transfer, and familiarity for public perceptions of cisgenic and transgenic modification. *Science Communication*, *36*(1), 106-130.

Lang, J.T. (2013). Elements of public trust in the American food system: Experts, organizations, and genetically modified food. *Food Policy*, *41*, 145-154.

Le Marre, K.N., Witte, C.L., Burkink, T.J., Grünhagen, M., & Wells, G.J. (2007). A second generation of genetically modified food. *Journal of Food Products Marketing*, *13*(1), 81-100.

Lusk, J.L., Traill, W.B., House, L.O., Valli, C., Jaeger, S.R., Moore, M., & Morrow, B. (2006). Comparative advantage in demand: Experimental evidence of preferences for genetically modified food in the United States and European Union. *Journal of Agricultural Economics*, *57*(1), 1-21.

Lusk, J.L., Moore, M., House, L.O., & Morrow, B. (2002). Influence of brand name and type of modification on consumer acceptance of genetically engineered corn chips: A preliminary analysis. *International Food and Agribusiness Management Review*, *4*(4), 373-383.

Lusk, J.L., & Rozan, A. (2006). Consumer acceptance of ingenic foods. *Biotechnology Journal*, *1*(12), 1433-1434.

Malyska, A., Maciag, K., & Twardowski, T. (2014). Perception of GMOs by scientists and practitioners—The critical role of information flow about transgenic organisms. *New Biotechnology*, *31*(2), 196-202.

Mather, D.W., Knight, J.G., Insch, A., Holdsworth, D.K., Ermen, D.F., & Breitbarth, T. (2011). Social stigma and consumer benefits: Trade-offs in adoption of genetically modified foods. *Science Communication*, *34*(4), 487-519.

Mielby, H., Sandoe, P., & Lassen, J. (2013). Multiple aspects of unnaturalness: Are cisgenic crops perceived as being more natural and more acceptable than transgenic crops? *Agriculture and Human Values*, *30*(3), 471-480.

Napier, T.L., Tucker, M., Henry, C., & Whaley, S.R. (2004). Consumer attitudes toward GMOs: The Ohio experience. *Journal of Food Science*, *69*(3), 69-76.

Nunez, G.H., Kovaleski, A.P., & Darnell, R.L. (2014). Formal education can affect students' perception of organic produce. *HortTechnology*, *24*(1), 64-70.

Rommens, C.M., Haring, M.A., Swords, K., Davies, H.V., & Belknap, W.R. (2007). The intragenic approach as a new extension to traditional plant breeding. *Trends in Plant Science*, *12*(9), 397-403.

Schouten, H.J., Krens, F.A., & Jacobsen, E. (2006). Cisgenic plants are similar to traditionally bred plants: International regulations for genetically modified organisms should be altered to exempt cisgenesis. *European Molecular Biology Organization Reports*, *7*(8), 750-753.