Research Article

Game-Based Learning in Extension Education: An Assessment of the Impact on Consumer Learning and Behavior

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Abstract
Despite clear science-based evidence of the benefits of bioengineering, consumers hold a negative attitude toward genetic modification that has been increasing over time. As a consequence, the market for food labeled as not genetically modified continues to grow, with price premiums ranging from 10 percent to 62 percent. The mixed messaging consumers receive can cause them to doubt their own food choices and harm them economically. Extension educators are increasingly focused on developing participative activities and game-based learning that can improve Extension programming methods. We created a learning game that simulates a shopping experience. In an online survey, compared to those who viewed an Extension website providing information on genetic modification, consumers who played the game were more likely to believe they learned something and correctly answered a question regarding deceptive labeling. While those who viewed the website were more likely to accurately characterize foods as having a genetically modified version, they were also more likely to select a carrot labeled as not genetically modified, even though no genetically modified alternative exists. Our results suggest a role for game-based learning in Extension programming, though there are cost tradeoffs.

1 Introduction

Despite clear science-based evidence of the benefits to human medicine, animal welfare, food security, agricultural production, and the environment (National Academies of Sciences, Engineering, and Medicine 2016), engineering an organism's genetic makeup is often misunderstood and rejected by the public (Kampourakis 2017). Surveys conducted by the Pew Research Center in 2016 and 2018 suggest that nearly 50 percent of consumers fear the impact of genetically modified organisms (GMOs) on human health, an attitude that has increased over time (Funk and Kennedy 2016; Funk, Kennedy, and Hefferon 2018). Additionally, a majority of respondents believed that scientists disagreed on the safety of genetic modification, despite the fact that scientists overwhelmingly agree on the safety of bioengineered food (Plumer 2015). While consumer perceptions of genetic engineering impact their purchasing decisions (Funk et al. 2018; Wunderlich, Gatto, and Smoller 2018; Zhu et al. 2018), providing knowledge or education can ameliorate these effects (Funk et al. 2018; Maes et al. 2018; Farid et al. 2020). In this study, we measure the impact of providing different modes of education resources on consumer knowledge and preferences.

Economic research has demonstrated a clear consumer willingness to pay for food labeled as non-GMO, even as they remain confused about the technology and its implications (Lusk et al. 2005; Bernard and Bernard 2010; He and Bernard 2011; Funk et al. 2018; Drugova, Curtis, and Akhundjanov 2020). Additionally, the non-GMO market is expected to continue growing at over 16 percent annually between 2019 and 2025, to an overall size of $948 million (Grand View Research 2019), and food labeled as GMO-free can command price premiums ranging from 10 percent to 62 percent, depending on the product category (Kalaitzandonakes, Lusk, and Magnier 2018). One consequence is that foods without a GMO version are also labeled as non-GMO, either to address consumer concerns or to reap economic benefits. This can harm consumers economically, regardless of the label's motive (Wilson and Lusk 2020), which is especially salient for low-income consumers facing strict budgetary tradeoffs. Additionally, the mixed messaging consumers receive can cause them to doubt their own food choices (International Food Information Council Foundation 2018), and consumers generally overestimate the attributes promised by a food label (Priven et al. 2015; Song and Im 2017; Dominick et al. 2018; Syrengelas 2018). In order to address consumer spending on labeled products resulting from misinformation or a halo effect, the University of Connecticut Extension developed a learning game providing facts about genetically modified food.

Extension educators are increasingly focused on developing participative activities, and game-based learning can improve Extension programming methods by providing entertaining and consumable educational tools (Worker, Ouellette, and Maille 2017; Erickson, Hansen, and Chamberlin 2019). Multimedia learning theory suggests that people learn better through multimodal materials, and online games allow consumers to interact with the material in cognitively engaging ways, leading to improved learning outcomes and behavioral change (Gee 2003; Dede 2009; Mayer 2009; Clark and Lyons 2010; Plass, Mayer, and Homer 2019). Online games are also appealing as consumers can engage with the material on their own time, allowing access to learning without an educator being present. However, they are also expensive to develop, and efficacy uncertainties can impact the decision to devote scarce funds to this new learning form. For instance, while studies suggest that game-based educational materials can improve student learning outcomes and confidence, especially for moderately complicated topics (Trujillo et al. 2016; Hsiao, Tsai, and Hsu 2020; Ulery et al. 2020), research is less clear on the use of game-based learning for college students (Ebner and Holzinger 2007; Wardaszko and Podgórski 2017) and the elderly (Jin, Kim, and Baumgartner 2019; Wang, Hou, and Tsai 2020).

In this paper, we explore the impact of providing information on genetic engineering to adult consumers through a traditional Extension website or a newly developed learning game. Through an online survey, Connecticut respondents are directed to either an Extension website on genetic modification or a food shopping game about GMOs. Respondents then answer several knowledge questions about GMOs and participate in a hypothetical choice experiment. We find that respondents who played the game were more likely to believe they had learned something new and less likely to select carrots labeled as non-GMO for purchase. Our results suggest a potential role for game-based learning in Extension education programming, though its efficacy may depend on the type of information presented.

2 Game Design

Developing a full digital game is expensive and can take months or years, depending on the game (Cezarotto et al. 2021). In collaboration with the New Mexico State University (NMSU) Learning Games Laboratory, we developed an interactive game prototype that simulates a shopping experience to teach consumers about what a non-GMO label does and does not mean. Successful educational games cannot merely be electronic versions of traditional worksheets or rote learning, but instead must transport players to contexts that require them to use their academic knowledge to progress in the game world (Barab, Gresalfi, and Ingram-Goble 2011; Lester et al. 2013). We outlined the content and key learning objectives for the game, which was then reviewed with stakeholders, including dietitians, before our game jam. Game jams are typically two- to three-day events where designers collaborate to create a game, but we modified the model for an Extension context (Cezarotto et al. 2021). Through a one-week game development session, we rapidly prototyped the food marketing label game, with two weeks of follow-up development (Cezarotto et al. 2021).

Game engagement theory has five factors that impact motivation and learning: challenge, control, immersion, interest, and purpose (Whitton 2011). A noir theme was selected in part to enhance interest and purpose from game engagement theory. Players collect clues at three different locations to address the immersion, challenge, and control factors. Motivation and learning are met through helping the consumer answer their question. Flow theory was incorporated to set clear goals for players and provide immediate feedback during the game (Whitton 2011).

We followed an iterative design process, including multiple formative assessments (Ulery et al. 2020). Relative to youth players, adult learners are less engaged by games that are complicated to learn or have complex puzzles that are difficult to solve (Whitton 2011), and we made changes to our game such as highlighting only playable books in the library scene to reduce the time players spent searching for them. After the game jam and further development, we conducted formative testing through multiple approaches, using both our 4-H and Expanded Food and Nutrition Education Program (EFNEP) audiences, and to a broader audience through social media marketing. A Qualtrics survey at the end of the game asked respondents if they thought the game was enjoyable, if they learned something, their opinion on the length, and if it was easy to play. Open-ended questions asked respondents to state one thing they learned and for suggested changes. We also collected demographic information so that we could segment respondents and weight answers from our target audience—young mothers who are the primary grocery shoppers. Additionally, the game was presented at the Association for Communication Excellence conference, and feedback was gathered from instructional designers and other communications specialists. This data was analyzed and used to make additional development changes before the game officially launched.

The final game incorporates a noir mystery theme, where the players follow Maya (Figure 1), a food detective helping solve a confused shopper's dilemma about whether to purchase conventional orange juice, or one labeled non-GMO (Stearns et al. 2021).

The noir theme was popular in the World War II era and includes cynicism and contrasts lights and shadows (Conrad 2005). We selected the noir theme because we could add elements of play into a more serious character, making Maya McCluen a detective and having each food label become a case. Players visit locations such as a library for reference materials, an orange grove where they meet with a farmer, and a grocery store to speak with a registered dietitian (Figure 2).

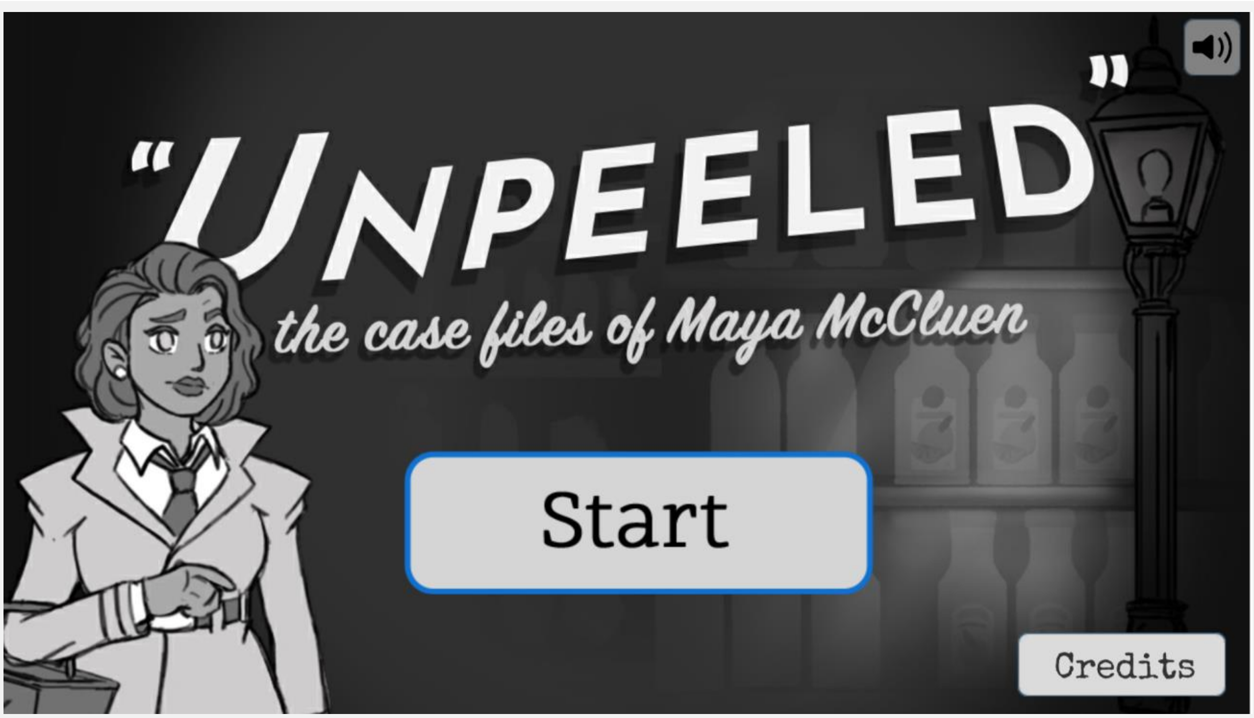

Figure 1: Maya McCluen, the Noir Detective in the Unpeeled Game

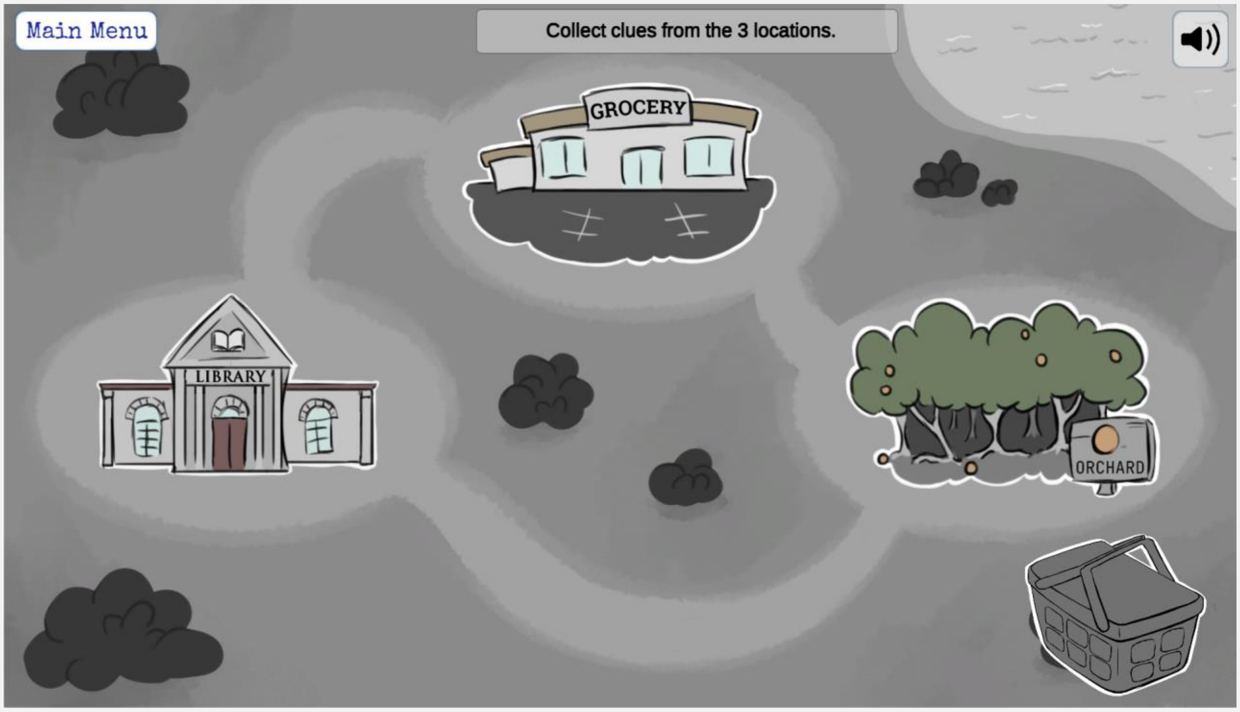

Figure 2: The Map in the Game Where Players Select Locations to Visit

At each of these three locations, the player, through the noir-detective character Maya, collects clues to learn the facts about genetically modified food and the non-GMO food marketing label as it pertains to orange juice and salt (Figure 3). These products were chosen as salt does not contain DNA, and thus cannot be genetically modified, while oranges do not have a genetically modified alternative.

When the game was first released, it included a short survey to measure player engagement. In

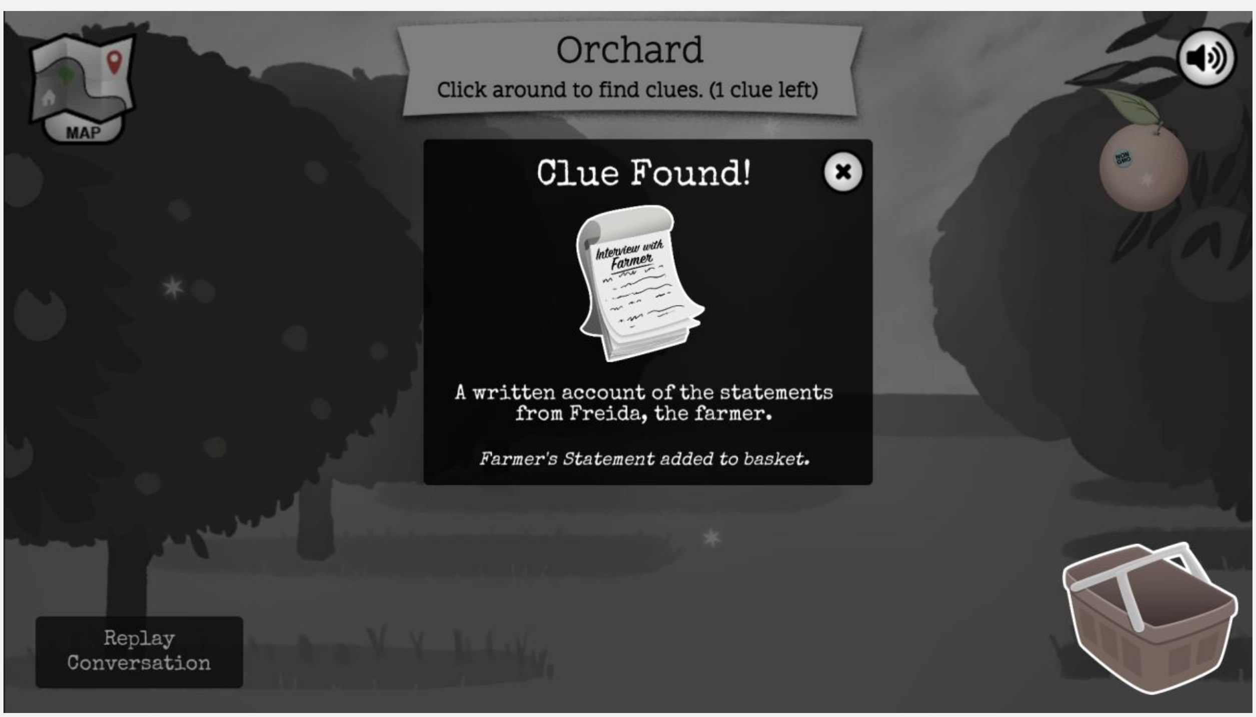

Figure 3: A Clue Collected After Visiting the Farmer at the Orchard

total, 92 percent of respondents stated they learned something about GMOs, and 82 percent thought the game was enjoyable. In the open-ended question, many respondents said that they learned about the GMO crop list, that salt does not have DNA, and to look into their food labels. We asked respondents what they thought about when they do think about GMOs, and responses included, “genetically made, might be unhealthy”; “better for you, less pesticides used”; and “the marketing gimmick,” among others. Garris, Ahlers, and Driskell (2002) describe three types of learning outcomes: skill-based (technical or motor skills such as flying), cognitive (knowledge about facts or how to perform a task), and affective (attitudes or behavior). This game addresses cognitive and affective learning outcomes, and the questions on learning indicate the game impacted cognitive learning. However, the question about GMO perceptions suggests the game may not have significantly altered the affective realm—their attitudes or behavior.

3 Survey Methodology

In order to assess the impact of the newly developed game on cognitive and affective outcomes, in comparison to traditional website materials, a survey was distributed to Connecticut consumers through a Qualtrics research panel. Respondents were divided into treatment and control groups. Baseline knowledge was assessed using a pre-intervention question concerning GMOs and the certified organic label. Treatment participants then played the game while control consumers were provided the link to a Connecticut Extension website “Science of GMOs” that provides consumers with information on genetic modification, its applications, and its impacts. To measure cognitive outcomes, all participants were asked whether they learned something new from their assigned resource, followed by four additional questions that measured knowledge about GMOs (Zhu et al. 2018; Hasell and Stroud 2020).

To measure changes in behavior (affective outcome), each respondent then completed a choice experiment consisting of one choice question, where they were asked to decide between two packaged carrots, one of which had a non-GMO label. Carrots were selected for the product as they are a commonly purchased item that has no genetically modified alternative but can often be seen in stores carrying a non-GMO label. The only attribute that differed between respondents was the price of the non-GMO labeled product. The baseline unlabeled price of $1.26 was selected based on the average grocery price of five retailers. The package labeled as non-GMO had either a 29 percent or 49 percent premium, representing the average values identified in a meta-analysis of willingness to pay studies (Lusk et al. 2005). To adjust for potential primacy bias, the order in which the labeled and unlabeled version appeared was randomized. As our choice task is relatively simple, we employed a dual response design for the opt-out alternative (Brazell et al. 2006; Schlereth and Skiera 2017; Mohammadi et al. 2020). An example of the choice question is shown in Figure 4.

The survey ended with five demographic questions, including age, education, income, gender, and shopping behavior, which can be found in Table 1.

Discrete choice experiments traditionally use the stated preferences of survey respondents to assess willingness to pay for various attributes of multi-attribute products (Green 1974; Green and Srinivasan 1990), and this method has also been used by economists to measure consumer preferences for food labeled as free from genetically modified ingredients (Burton et al. 2001; Lusk et al. 2005; Drugova et al. 2020; Zhang et al. 2021). Under this model, according to random utility theory, a consumer’s utility-maximizing product choice can be decomposed into an observable and stochastic component:

$$U_{ij} = v_{ij} + \varepsilon_{ij} \quad (1)$$

where v_{ij} is the indirect utility function and ε_{ij} is the random component. A consumer’s choice can then be used to estimate preferences, with willingness to pay serving as a proxy for utility.

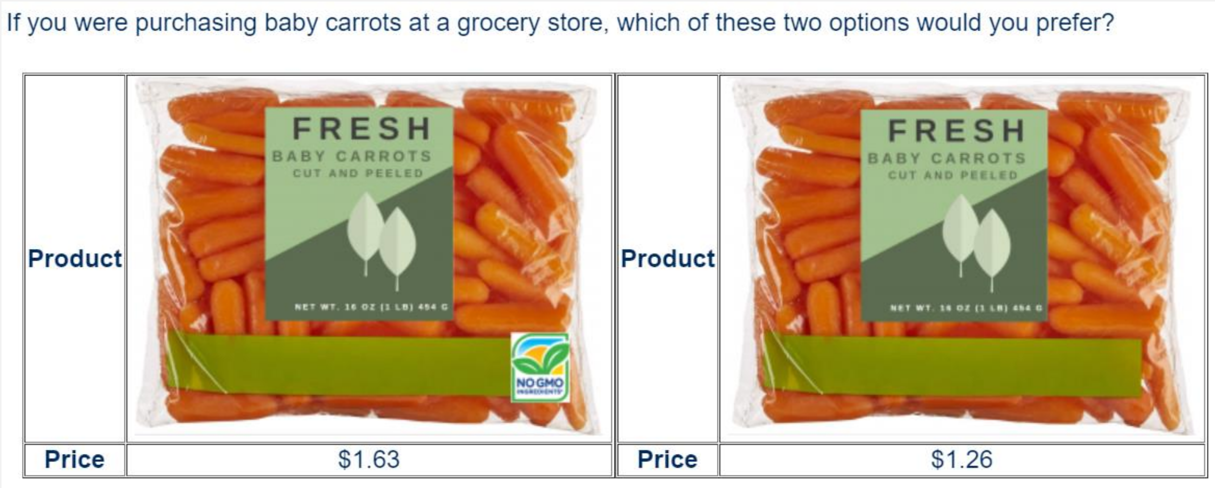

Figure 4: Example Question for the Choice Experiment

Our intent is not to measure willingness to pay, which is a well-studied topic. Instead, as the purpose of the game is to combat misinformation, our behavioral measure is willingness to pay any type of premium for a food labeled as non-GMO, even when there are no genetically modified alternatives. Specifically, both the game and the website provide information on what products have genetically modified versions; there are no genetically modified carrots commercially available. In this case, the non-GMO label could be considered misleading or superfluous. As such, we instead estimate a logistic regression model of consumer preferences:

$$Y_i = \beta_0 + \beta_1 * GMOPrice + \beta_2 * Treatment + \beta_k * X_k + \varepsilon_i \quad (2)$$

where $Y_i = 1$ if the respondent selected the non-GMO labeled carrot package. Each respondent saw the unlabeled carrot package for $1.26 and one of two potential non-GMO packages, priced at either $1.63 or $1.79. Our primary variable of interest is Treatment, which is equal to 1 if the respondent played the game. X_k is a vector of demographic attributes, and the beta coefficients represent marginal utility parameters.

4 Results

Data was collected from Connecticut residents through a Qualtrics survey panel between the dates of May 27 and July 29, 2022. While 2,349 respondents began the survey, our final sample consists of the 418 respondents that completed the survey and passed all attention checks. Respondent demographics are in Table 1.

The mode age category was 25–40 years old, followed by 41–64, which is consistent with the Connecticut median age of 41; however, we have a lower percentage of those over the age of 65 than seen in the general Connecticut population (18 percent). A total of 39.71 percent of our respondents have a bachelor's degree or higher, which perfectly mirrors the Connecticut rate (40 percent). While the median income in Connecticut is $79,885, we specifically sought to ensure a high response rate from those in the lowest income bracket as they are the most income-constrained shoppers. In line with other survey populations (Wu, Zhao, and Fils-Aime 2022), we have fewer male respondents than the general population (49.1 percent). Of note, over 75 percent of our respondents are the primary grocery shopper in their household.

Table 1: Demographics of Survey Respondents		
Variable	*N*	Frequency (%)
Categorical Demographic Variables		
Age		
18 – 24	88	21.1 %
25 – 40	158	37.8 %
41 – 64	124	29.7 %
65+	48	11.5 %
Education		
Some high school, no diploma	16	3.8 %
High school diploma or GED	95	22.7 %
Some college	93	22.2 %
Associate's degree	48	11.5 %
Bachelor's degree	103	24.6 %
Master's degree	45	10.8 %
Professional degree	11	2.6 %
Doctorate	7	1.7 %
Annual Household Income		
Less than $20,000	58	13.9 %
$20,000 - $29,999	49	11.7 %
$30,000 - $39,999	43	10.3 %
$40,000 - $49,999	37	8.9 %
$50,000 - $74,999	77	18.4 %
$75,000 - $99,999	73	17.5 %
Greater than $100,000	81	19.4 %
Dummy Demographic Variables		
Primary Shopper (= 1 if primary grocery shopper for household.)	317	75.8 %
Male (= 1 if identifies as male.)	165	39.5 %
Older (= 1 if age is 41 or greater.)	172	41.1 %
High Income (=1 if income is greater than $100,000.)	81	19.4 %
College (=1 if has at least a Bachelor's degree.)	166	39.7 %

Extension programming seeks to impact both knowledge and behavior, so respondents were given several questions concerning their knowledge of genetic modification, the results of which can be seen in Table 2. While participants were randomly assigned to either the website or game treatment, there was some heterogeneity in survey completion. Specifically, 54 percent of our final sample ended up playing the game, compared to 46 percent that were shown the website. Looking at the pre-treatment question, a test on the equality of proportions demonstrated no difference in respondent knowledge concerning whether organic certification implied non-GMO status, measured as the percentage that answered the question correctly. In terms of perceived knowledge post-intervention, those who played the game were significantly more likely to believe they learned new information. However, they were not more likely to know that regular food contains genes, and GMO foods do not lead to chronic health problems, though they did correctly answer a question concerning labeling at a higher rate.

The most difficult question concerned correctly selecting the three products with a genetically modified version (corn, soy, and papaya) of five agricultural products (wheat and grapefruit). Those who saw the website were more likely (at the 10 percent level) to select only the correct three. We hypothesize this is because information in list form, such as agricultural products, may not be best displayed in a game format; the website allows you more time to consider the list. However, given our

Table 2: Baseline and Post-Treatment Knowledge of Genetic Modification

Question	Website Treatment *N*	Website Treatment (%)	Game Treatment *N*	Game Treatment (%)	P-value
Overall response.	191	45.7 %	227	54.3 %	
Pre-Treatment Knowledge Question					
All organic food is also non-GMO (T).	59	30.9 %	72	31.7 %	0.8557
Perceived Knowledge Gain					
Strongly agree that learned something new about GMOs.	80	41.9 %	119	52.4 %	0.0316
Post-Treatment Knowledge Question					
Regular food does not contain genes, but GM food does. (F)	138	72.3 %	160	70.5 %	0.6908
Eating GM foods can lead to chronic health problems. (F)	110	57.6 %	126	55.5 %	0.6684
Products without a GM version can be labeled non-GMO. (T)	133	69.6 %	195	85.9 %	0.0001
Select which foods have a GM version. (Selected 3 correct.)	32	16.8 %	24	10.6 %	0.0646
Select which foods have a GM version. (Selected less than 3.)	80	41.9 %	95	41.9 %	0.9943

concern that consumers incorrectly perceive items as having a genetically modified version, and are correspondingly confused by non-GMO labeling on these products, we also calculate the percentage of respondents that only selected food items with a genetically modified version, even if they did not select all three. Slightly more than 40 percent of respondents only selected products with a genetically modified alternative, and this did not differ between the two treatments.

We next assessed whether playing the game had an impact on behavior, specifically the willingness to pay more in a choice experiment for a package of carrots with a non-GMO label. Table 3 provides results from our logistic regression on the factors that impact the probability of selecting the carrot package with the non-GMO label. We find that those who played the game were 10 percentage points less likely to select the non-GMO label than those that viewed the website. Meanwhile, those who were more knowledgeable about genetic modification (defined as correctly answering the pre-intervention knowledge question), as well as those who identified as male, were more likely to select the carrots with a non-GMO label. As a robustness check, we ran a second model using dummy variables for demographics, specifically being older than the median age of 4, having an income above $100,000, or having at least a college education. The results are generally similar.

To further assess the robustness of our findings, Table 4 includes only those respondents who stated they would actually purchase their chosen package. We still see that those who played the game are significantly less likely to select the non-GMO option, though the results are slightly attenuated. Those residents above the median age are more likely to select the non-GMO label in our second specification, which mirrors findings that those who are younger are more likely to approve of genetic modification (Hassell and Stroud 2020). Of interest, baseline knowledge no longer impacts the decision to select a non-GMO label.

Our results suggest a potentially complex relationship between knowledge and behavior. Hassell and Stroud (2020) found that consumers who knew the science of GMO foods had more positive attitudes toward their safety, while the converse was true for consumers who could accurately name which products have genetically modified versions. These potentially represent two different types of knowledge. Similarly, our baseline knowledge question concerned labeling around organic and non-GMO, which could be considered political, rather than scientific, information. Our resources provided science-based information, and the finding in our primary model that those who played the game were less likely to select a product with a misleading label suggests the resource was successful in imparting knowledge. However, those with a baseline knowledge of organic and non-GMO labeling were still more likely to select the non-GMO product. Presumably, these well-informed consumers may also have a stronger interest in, and pre-existing attitude toward, genetically modified foods. Thus, it could be that our science-based game was successful at imparting information and impacting attitudes for the average consumer, but not those with strong or politically held beliefs.

Table 3: Logistic Regression Results Predicting Selection of Non-GMO Choice (Full Sample).

Variable	Model 1		Model 2	
	Marginal Effect	P-Value	Marginal Effect	P-Value
Played Game	-0.103**	0.030	-0.100**	0.035
Price of Non-GMO Choice	0.284	0.336	0.283	0.340
Baseline Knowledge Correct	0.111**	0.035	0.113**	0.031
Primary Shopper	-0.003	0.954	0.002	0.975
Male	0.097**	0.046	0.093*	0.057
Age	0.042	0.115		
Education	-0.008	0.656		
Income	-0.015	0.235		
Age is 41 or Greater			0.080	0.105
Income is Greater than $100,000			-0.031	0.614
Has a College Degree			-0.026	0.603
Observations (*N*)	418		418	
Pseudo-R^2	0.034		0.032	

Note: *** p < 0.01, ** p < 0.05, and * p < 0.1.

Table 4: Logistic Regression Results Predicting Selection of Non-GMO Choice (Subset).

Variable	Model 1		Model 2	
	Marginal Effect	P-Value	Marginal Effect	P-Value
Played Game	-0.090*	0.070	-0.089*	0.073
Price of Non-GMO Choice	0.336	0.277	0.33	0.286
Baseline Knowledge Correct	0.083	0.125	0.086	0.114
Primary Shopper	0.003	0.967	0.008	0.890
Male	0.113**	0.027	0.108**	0.034
Age	0.047*	0.092		
Education	-0.007	0.694		
Income	-0.019	0.140		
Age is 41 or Greater			0.100*	0.055
Income is Greater than $100,000			-0.044	0.493
Has a College Degree			-0.035	0.508
Observations (*N*)	383		383	
Pseudo-R^2	0.033		0.032	

Note: *** p < 0.01, ** p < 0.05, and * p < 0.1.

5 Conclusion

In order to address consumer misinformation surrounding bioengineering that leads to overpaying for products labeled as non-GMO, we created a learning game that simulates a shopping experience. Compared to those who viewed an Extension website providing information on genetic modification, consumers who played the game were more likely to believe they learned something and correctly answer a question regarding deceptive labeling. While those who viewed the website were more likely to accurately characterize foods as having a genetically modified version, they were also more likely to select a carrot labeled as non-GMO, even though no genetically modified alternative exists. Thus, playing the game appears to have had a more salient impact on adult learners than the website learning resource.

The relationship between information and attitudes is not linear. While both objective and subjective knowledge measures are correlated with improved perceptions of bioengineering, Hasell and Stroud (2020) found that knowing that genetically modified foods do not change a consumer's genetic makeup increased the perceived safety of these foods while knowing which types of foods have GMO alternatives was negatively associated with their perceived safety. We provided similar information in our game and website, with disparate effects. Though most of our respondents understood that all food contains genes after viewing our resources, more than 40 percent still believed that eating genetically modified foods can lead to chronic health problems. Similarly, a pilot study among undergraduate students at UConn found that willingness to consume GMO products decreased when knowledge about GMOs increased (Chase et al. 2023). Regardless of the type of resource, combating misinformation among consumers is difficult, especially when attempting to overcome strongly held biases.

Our results suggest a role for game-based learning in Extension programming for adult consumers. While the website and game were better at imparting different types of knowledge, the game environment may have had more of an impact on behavior. As the game was designed to be accessible to those with an 8th-grade education, in order to reach all consumers, it could also be targeted toward a youth audience because this population similarly lacks knowledge on genetic modification (Ozel et al. 2009; Jurkiewicz et al. 2014; Ruth et al. 2016; Lachowski et al. 2017; Niankara and Adkins 2020). However, developing a game is costly. Our game prototype was created as part of the New Technologies for Agricultural Extension program, which provided $10,000 in funding, which was directly spent on the game creation at New Mexico and was augmented by an additional $5,000 in funds from other sources, as well as $20,000 in mentorship activities in developing and marketing the game. These costs must be compared to the benefit of a 10 percentage point reduction in the number of consumers purchasing a product with a misleading label. While game-based learning provides a different format for education, and can successfully change both knowledge and behavior, there are clear cost tradeoffs.

Future research on the impact of game-based learning in Extension education could include observational studies to measure true behavioral change, such as partnering with a grocery store to disseminate food-based games and track purchase behavior. Our primary audience of interest was low-income households, and game designers included educators from our Supplemental Nutrition Education Program and Expanded Food and Nutrition Education Program. While our survey oversampled low-income consumers, there are many more areas for research within this population. Additionally, design cost constraints did not allow us to track game engagement rates, such as completion rate or number of locations within the game visited, which could provide future insights for game design.

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