Communication of Genetic Modification Science: Consumers' Critical Thinking Style, Perceived Transparency of Information, and Attitude

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Abstract

Consumers' attitude toward GM science is not only an important factor to determine the industry's development, it is also a crucial topic across various countries. How people express their judgment of GM science, involves a highly complicated process. Because of this complexity, influence on attitude toward GM science has become a popular research topic and has been examined through various variables. This study sought to examine the effects of critical thinking styles and perceived transparency of GM science on attitude toward GM science. To fulfill the purpose of the research, an online survey was conducted. A total of 1,047 adults across the United States were recruited using non-probability sampling techniques. The results of the study found critical thinking style had a significant impact on the perceived transparency of GM science information and attitude toward GM science. However, consumers with higher perceived transparency of GM science information reported lower attitudes toward GM science than those who had lower perceived transparency. An interaction effect of critical thinking styles and perceived transparency of GM science on attitude toward GM science was found. Further research examining perceived transparency was recommended. In addition, it was recommended that extension agents or agricultural communicators could develop various communication strategies based on various attribution of consumers.

Introduction

GM (genetically modified) science, or GMOs (genetically modified organisms), which can modify plants or animals more quickly than traditional breeding, has brought a rapid revolution in the contemporary biotechnology industry (Grun, 2004; Lang & Hallman, 2005). These technologies can develop herbicide, disease, and pesticide-resistant crop varieties, increase shelf-life, improve the nutritional value of foods, and increase production yields, all of which can lead to greater global food security (Mahgoub, 2016, p. 6; Wunderlich & Gatto, 2015). Although the literature shows that the advantages of GM science outweigh the risks, consumers' attitude toward GM science remains polarized (Mahgoub, 2016; Wunderlich & Gatto, 2015) due to food safety, human health, and environmental concerns.

To understand public support and opposition toward GM science development, attitude toward GM science communication has become an important research topic that has been examined worldwide (Aerni, 2005; Friedel, Meyers, Mamontova, & Irani, 2007; Gaskell et al., 2000; Gaskell, Bauer, Durant, & Allum, 1999; Li, Curtis, McCluskey, & Wahl, 2003; Macer & Ng, 2000; Ruth & Rumble, 2016). Human perception involves a complicated cognitive process, which may vary by individual differences. Therefore, it is necessary to explore and continuously examine the relationship of various variables related to attitude. This study aimed to explore if two variables related to information seeking, critical thinking style and perceived transparency of information, impact attitude toward GM science. Additionally, this exploratory study sought to examine if there was an interaction between these variables.

Literature Review

Public's attitude toward GM science

Attitudes are critical to emerging research or technology, such as biotechnology, energy, or other topics because they are the main factor driving the adoption of new technologies and the growth of industries (National Science Board, 2018). Marques, Critchley, and Walshe (2015) stated that public attitudes could have an impact on the consumption of GM products, and frame government policy and regulation which are related to the industry's development, production, and distribution.

Practically, attitude is recognized as individual psychological judgments of the worthiness and favorableness toward a specific issue (Roberts, Reid, Schroeder, & Norris, 2011), which involves a process of evaluation. Evaluative attitudes could be expressed as liking or disliking, approval or disapproval, approach or avoidance, and attraction or aversion (Frewer, 2003). Attitudes have been used to explain why some people support specific ideologies, policies, products, while others do not. In other words, a person who favors a particular issue is said to have a positive attitude. However, attitudes are not able to directly observed but can be deduced from observable responses, for instance, responses to interviewers or self-reporting questionnaires (Frewer, 2003).

Attitude has long been a focus in theories and research about consumer behavior (Ajzen, 2008). Ruth (2018) stated that most research has shown attitude could be a main and reliable factor of trust toward specific issues or organizations (Muñoz, 2012; National Science Board, 2018; Roberts et al., 2011). Roberts et al. (2011) found public attitude may differ by demographic variables such as gender, age, educational background, and social status.

Perceived Transparency of Information

Rumble and Irani (2016) examined the effects of transparent communication and personal relevance on participant' attitudes and found transparency had a significant effect on attitude. Researchers have tried to improve communication between consumers and scientists by releasing information and publications about the benefits of GM food, but many consumers remain skeptical due to perceptions of researcher bias and subjective interpretation of results (Funk & Kennedy, 2016; Mahgoub, 2016). Transparency has been recognized by the scientific community as one of the vital features of science, but research suggests transparency of science is not well supported or commonly examined (Nosek et al., 2015). We can define transparency from various perspectives, but visibility is recognized as a fundamental meaning of transparency. According to Grimmelikhuijsen and Welch (2012), transparency can be explained as a composite construct which involves multiple components, such as external accessibility and active disclosure. It is also applicable to include inferability of information (Michener & Bersch, 2013), or completeness and understandability (Grimmelikhuijsen, Porumbescu, Hong, & Im, 2013). Meijer (2013) defined transparency as "the availability of information about an actor that allows the other actors to monitor the workings or performance of the first actor" (p. 430).

Previous studies have focused on how to promote governmental or organizational transparency as a communication strategy. Song and Lee (2016) stated that organizations are able to promote transparency by actively revealing news about their activities and decisions, and then making citizens able to access, monitor, and evaluate their updates. People assume that they will perceive government transparency when government information is publicly available. But even though the information is available, if people are not effectively informed of government activities and decisions, they will not perceive transparency from the government (Song & Lee, 2016). Even in cases where science is transparent, the skepticism of consumers can only be overcome if they perceive the information as transparent (Goodwin, 2013). In other words, if the public does not know or cannot see the information, they will not trust the information (Grimmelikhuijsen, 2009). Therefore, the examination of consumers' perceived transparency toward science information may be critical in practical science communication throughout the world. Scholars have gradually realized trust associated with transparency has just as much to do with consumer access and perception as it does the organizations' efforts to be transparent (Goodwin, 2013; Song & Lee, 2016).

There are few studies focused on "perceived transparency." van der Cruijsen and Eijffinger (2010) found insufficient transparency perceptions influence people's actions which were reflected in their perceptions and expectations, also in their trust of the organization. The study also indicated higher transparency perceptions are aligned with higher levels of trust. To study the company-consumer relationship, Kang and Hustvedt (2014) used perceived transparency in predicting consumers' trust-building with a company. The results indicated consumers' perceived transparency of a company's production, labor conditions, and community responsibility influences their trust and attitude, and further affected their intentions to purchase from the company and spread positive news about the company and its products. Zhou, Wang, Xu, Liu, and Gu (2018) focused on how perceived transparency influenced online purchasing behaviors. Perceived transparency was examined under the consumer service life cycle framework. One of the results revealed perceived transparency of information significantly increased consumers' online purchasing intentions (Zhou et al., 2018). Based on the available literature, perceived transparency may have a positive impact on consumers' attitude toward GM science.

Consumers' Critical Thinking Style

Consumers' attitude involves a series of cognitive processes that may be influenced by demographic variables. Understanding consumers' information seeking behaviors could be helpful in determining their perception of transparency when they encounter GM science information as well as their resulting attitude. People rely on media, primarily that available on the Internet, to obtain science information; including listening to the radio, reading print media, watching television, and surfing online (Schäfer, 2016). The Internet is commonly accessed first and provides a rich source of product and service information that can influence consumers' information seeking behaviors (Peterson & Merino, 2003; Ratchford, Talukdar, & Lee, 2001).

However, consumers' information seeking behavior is inherently complicated (Peterson & Merino, 2003). Lamm (2015a) has proposed that individuals obtain information through either seeking or engaging. Seekers prefer to pursue information actively and take an elaborate research approach to decision making. They are willing to adjust their own biases and investigate topics from all aspects. Seekers are eager to know the truth, even if the truth does not correspond with their own beliefs. Conversely, engagers participate in information gathering through interactive communication. Engagers gain more benefit from open group discussions because they prefer to collect information from their surroundings and via word of mouth. They have faith in their beliefs and are confident to share their opinions with others (Gay, Terry, & Lamm, 2015; Lamm & Irani, 2011).

Understanding information seeking behaviors can help educators and communicators understand how individuals learn and gather information. Additionally, gaining this understanding can allow for information to be customized to appeal to those with different critical thinking styles to seek or engage with information (Leal, Rumble, & Lamm, 2017). For instance, Lamm and Irani (2011) found consumers with different critical thinking styles prefer different media sources: A seeker will prefer one-way communication, like print media; while an engager will prefer collecting information through conversations, such as blogs, social media, consumer email, forums, and email (Lamm, 2015b). Gorham, Lamm, and Rumble (2014) applied critical thinking style to examine the feasibility of developing communication strategies to promote water conservation behaviors. The results showed a relationship between critical thinking style and engagement in water conservation behaviors. Seekers were more likely to participate in more conservative water behaviors, while engagers were less likely to participate in water conservation behaviors. Leal et al. (2017) conducted an online survey to examine consumers' preference for food safety information and their critical thinking style. The results indicated seekers preferred printed fact sheets, bulletins or brochures, and demonstration or displays, while engagers preferred websites, which were consistent with previous studies.

Purpose and Objectives

The purpose of this study was to determine how individuals' critical thinking style and perceived transparency of GM science information influenced their attitude toward GM science. The study was driven by the following research objectives:

1. Examine if consumers' critical thinking style influences their perceived transparency of GM science information.
2. Examine if consumers' critical thinking style influences their attitude toward GM science.
3. Examine if consumers' perceived transparency of GM science information influences their attitude toward GM science.

    4. Examine if consumers' perceived transparency of GM science information and critical thinking style interact to influence their attitude toward GM science.

    The conceptual model guiding this study is shown in *Figure 1*. To illustrate the interaction effect of consumers' perceived transparency of GM science information and critical thinking style on attitude toward GM science, the relationship of the variables is shown as H4. We predict that the pre-existing critical thinking style of individuals will interact with their perceived transparency of information to influence attitude.
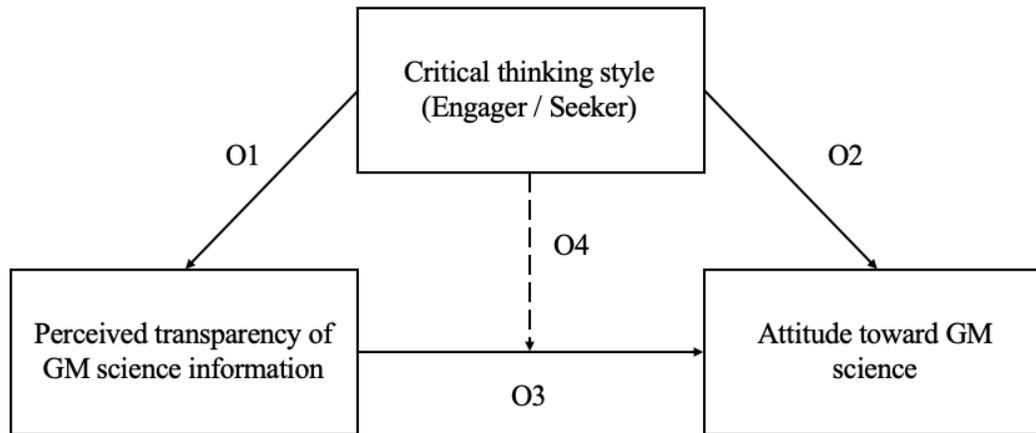
Figure 1. Conceptual model of consumers' critical thinking style, perceived transparency of GM science information, and attitude toward GM science

Methods

    The study applied non-probability sampling techniques to collect data from 1,047 adults, 18 years of age and older, across the United States (US) using an online survey. To compensate for selection, exclusion, and non-participation bias, weighting was utilized to lessen the limitations associated with non-probability sampling (Lamm & Lamm, 2019). The research was part of a larger study (Rumble, Lamm, Beattie, & Ruth, 2018) that examined US citrus consumers' perceptions toward and acceptance of combating citrus greening technologies. However, only three sections were used to meet this study's objectives: perceived transparency of GM science information, attitude toward GM science, and critical thinking style.

    Perceived transparency of GM science information was measured using 12 opposing word pairs on a five-point semantic differential scale with 1 indicating negative attitude, and 5 indicating positive attitude. Item responses were averaged to create a perceived transparency index, which was found reliable ($\alpha = .93$). The attitude was measured using eight opposing adjectives on a five-point semantic differential scale ranging from 1 = *Negative* to 5 = *Positive*. Item responses were averaged to create an attitude index, which was found reliable ($\alpha = .97$). Respondents' critical thinking style was measured using the University of Florida Critical Thinking Inventory (UFCTI; Lamm & Irani, 2011). The UFCTI is a tool to measure how an individual adopts critical thinking skills to learn and think about an issue (Gay et al., 2015). The instrument is composed of 20 items on a five-point Likert-type scale ranging from 1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, and 5 = Strongly Agree. The UFCTI was used to identify respondents as either an information engager or seeker. Item responses were averaged to create a UFCTI index ($\alpha = .93$). Critical thinking style scores could range from 26-130. Respondents with a score of 78 or below were categorized as information

engagers. Respondents scoring a 79 or above were categorized as information seekers (Lamm & Irani, 2011). The survey was reviewed by a panel of experts and pilot tested before distribution.

SPSS® 25.0 was used to analyze the data from this study. Objectives 1 to 3 were analyzed using simple linear regression to examine the relationship between consumers' perceived transparency of GM science information, critical thinking style, and attitude. Moderation was applied in objective 4 to see if there was an interaction between perceived transparency of GM science information and critical thinking style on attitude toward GM science. Initially, an examination of a boxplot was applied to detect outliers. For the standard errors and *t*-values to be valid in linear regression analysis, the variables needed to meet specific assumptions: 1) normality of residuals, 2) linear relationship; 3) homoskedasticity, and 4) Leverage (Cohen, Cohen, West, & Aiken, 2003). The examination of normality of residuals showed residuals were normally distributed. A linear relationship was observed between prediction and actual scores. For homoskedasticity, constant error variance indicated residuals were equally distributed about zero across the breadth of the plot. As for testing leverage, there was one case diagnosed with both high leverage and residuals outside [-2, 2] range. But the case did not change the result after removing from the data, for substantive purposes, it was not opted out for regression analysis. Demographic analysis of the respondents can be found in Table 1.

Table 1
Demographics of respondents

Characteristics	*n*	*%*
Gender		
Male	511	48.8
Female	536	51.2
Education Level		
Less than 12th grade (did not graduate high school)	7	0.7
High school graduate (includes GED)	152	14.6
Some college, no degree	289	27.6
4-year college degree (Bachelor's, etc.)	305	29.1
Graduate or Professional degree (Master's, Ph.D., M.B.A., etc.)	168	16.0
2-year college degree (Associates, Technical, etc.)	126	12.0
Household Income		
Less than $25,000	198	18.9
$25,000 to $49,999	268	25.6
$50,000 to $74,999	211	20.1
$75,000 to $149,999	296	28.2
$150,000 to $249,999	54	5.1
$250,000 or more	21	2.0

Results

Respondents' perceived transparency of GM science information had a mean score of 3.16 (*SD* = .02). Their attitude toward GM science had a mean of 2.40 (*SD* = .03). As for respondents' critical thinking style, 651 participants were denoted as engagers and 396 as seekers.

Objective 1. Examine if consumers' critical thinking style influenced their perceived transparency of GM science information

A simple linear regression analysis was applied to model the relationship between critical thinking style and perceived transparency of GM science information (see Table 2). The regression model was statistically significant, $F_{1, 1045} = 20.79$, $p < .001$. Hence, there was sufficient evidence to claim that the 1.9% of the variability in perceived transparency of GM science information accounted for by the model was statistically greater than would have been observed by random variation. Furthermore, consumers who were denoted as information seekers had a perceived transparency score .22 points lower ($t_{1045} = -4.56$, $p < .001$) on average than the consumers who were denoted as information engagers.

Table 2
Effect of critical thinking style on perceived transparency of GM science information

		Adjusted	Unstandardized Coeff.		Stand. coeff	
Predictor	R^2	R^2	B	SE	B	t
Critical thinking style	.020	.019	-.223	.049	-.143	-4.560**

** $p < .01$.

Objective 2. Examine if consumers' critical thinking style influenced their attitude toward GM science

Simple linear regression analysis was used to model the relationship between critical thinking style and attitude toward GM science (see Table 3). The regression model was statistically significant, $F_{1, 1045} = 13.4$, $p < .001$. Hence, there was sufficient evidence to claim that the 1.2% of the variability in attitude toward GM science accounted for by the model was statistically greater than would have been observed by random variation. Respondents who were categorized as information seekers exhibited an attitude toward GM science score that was .25 points higher ($t_{1045} = 3.66$, $p < .001$) on average than the respondents who were categorized as information engagers.

Table 3
Effect of critical thinking style on attitude toward GM science

		Adjusted	Unstandardized Coeff.		Stand. coeff	
Predictor	R^2	R^2	B	SE	B	t
Critical thinking style	.013	.012	.246	.067	.113	3.661**

** $p < .01$.

Objective 3. Examine if consumers' perceived transparency of GM science information influenced their attitude toward GM science

Simple linear regression was used to model the relationship between perceived transparency of GM science information and attitude toward GM science (see Table 4). The regression model was statistically significant ($F_{1, 1045} = 542.11$, $p < .001$), hence there was sufficient evidence to claim that the 34.1% variability in attitude toward GM science accounted for by the model was statistically greater than what would have been observed by random variation. Furthermore, the results showed that when consumers perceived transparency of GM science information increased by 1 point, the expected difference in their attitude toward GM

science decreased by .79 (t_{1045} = -23.28, $p < .001$). On average, consumers with higher perceived transparency of GM science information had lower attitudes toward GM science.

Table 4
Effect of attitude toward GM science on perceived transparency of GM science information

| Predictor | R^2 | Adjusted R^2 | Unstandardized Coeff. | | Stand. coeff | |
			B	SE	B	t
Perceived transparency of GM science information	.342	.341	-.786	.034	-.584	-23.283**

** $p < .01$.

Objective 4. Examine if consumers' perceived transparency of GM science information and critical thinking style interact to influence their attitude toward GM science

Regression was used to determine whether consumers' perceived transparency of GM science information and critical thinking style were related to attitude toward GM science (see Table 5). The model was statistically significant ($F_{3, 1043}$ = 185.204, $p < .001$), hence there was sufficient evidence to claim that 34.6% of the variability in attitude toward GM science accounted for by the model was statistically greater than would have been observed by random variation. Furthermore, for two consumers with the same perceived transparency of GM science information, the consumer who was categorized as an information seeker was expected to have a lower (-.489) attitude toward GM science (t_{1044} = -2.174, $p = .03$) than information engager. Additionally, for two consumers who had the same critical thinking style, if one consumer had a higher level of perceived transparency of GM science information than the other consumer, he or she was expected to have a lower (-.845) attitude toward GM science (t_{1044} = -20.105, $p < .001$) than the consumer who scored lower on perceived transparency of GM science information.

This finding suggests that critical thinking style amplified the effect of perceived transparency of GM science information. The amplification was statistically significant, $b = .188$, $t = 2.647$, $p = .008$.

Table 5
Effect of perceived transparency of GM science information and critical thinking style on attitude toward GM science

Model	SS	df	MS	F	p
Regression	403.499	2	201.750	272.735	.000**
Residual	772.276	1044	.740		
Total	1175.775	1046			
Regression	408.652	3	136.217	185.204	.000**
Residual	767.124	1043	.735		
Total	1175.775	1046			

** $p < .01$.

Conclusions and Recommendations

The results revealed that perceived transparency of GM science information and attitude toward GM science varied among seekers and engagers. Seekers reported lower perceived transparency of GM science information than engagers. This may be explained by the tendency

of seekers to deeply investigate topics and seek to know the truth (Gay et al., 2015; Lamm & Irani, 2011). If their investigations have not left them feeling effectively informed on the topic, then literature would suggest that their perceived transparency would be lower (Song & Lee, 2016). Engagers may have the opportunity to get all of their questions answered through conversations, while seekers are still looking for answers, thus resulting in differences in perceived transparency.

Despite having lower perceived transparency of GM science information, seekers' attitude toward GM science was higher than information engagers. The attitude difference between seekers and engagers adds to the literature regarding attitude variations among different demographics of individuals (Roberts et al., 2011). In addition, literature has revealed that consumers are generally skeptical of GM science (Funk & Kennedy, 2016; Mahgoub, 2016). Through their investigations, a seeker may be able to overcome the popular opinion of skepticism by finding more balanced resources that discuss the pros and cons of GM science and thus hold a more positive attitude. On the other hand, engagers may never be exposed to a balanced conversation about GM science as the popular opinion of skepticism may dominate their word of mouth information gathering (Gay et al., 2015; Lamm & Irani, 2011). Further research is needed to confirm this explanation, but the differences in critical thinking styles between seekers and engagers provide a plausible explanation for the observed differences in perceived transparency and attitude.

Collectively, respondents in this study exhibited lower attitudes toward GM science overall; however, consumers who reported having higher perceived transparency were more likely to report lower attitudes toward GM science. The negative relationship between perceived transparency and attitude observed in this study differs from the positive relationship observed between the variables in previous research (Rumble & Irani, 2016). This finding may be explained by the information and sources accessed by respondents. It is possible that the respondents in this study perceived information that does not support GM science to be more transparent than information that does, thus resulting in the high perceived transparency and low attitude. Future studies should experimentally manipulate different information sources, or control for the information source, to further understand the nature of the relationship between perceived transparency and attitude in this context. The lack of data regarding information sources of the respondents is a limitation of this study.

When two consumers have the same perceived transparency of GM science information, the consumer categorized as an information seeker was expected to have a lower attitude toward GM science. This finding shows that the interaction of perceived transparency and critical thinking style is important, as seekers had higher attitudes than engagers when perceived transparency was not considered. The reversal of results provides evidence that caution should be taken when evaluating the results of the isolated critical thinking style variable on attitude. Additionally, for two consumers who had the same critical thinking style, the one with a higher level of perceived transparency of GM science information, was expected to have a lower attitude toward GM science. These results are consistent with the influence of perceived transparency on attitude observed in objective 3.

Based on the results of this study, practitioners are encouraged to customize information for different critical thinking styles (Leal et al., 2017). However, practitioners should consider other audience analysis characteristics, such as culture, demographics and psychographics, as well as perceived transparency when customizing information. Practitioners should also be

cognizant of the influences perceived transparency and critical thinking style can have on attitude as attitude can influence consumption, policy, and regulation (Marques et al., 2015).

As previously mentioned, further research should control or experimentally manipulate information sources to better understand the relationship between perceived transparency and attitude. Examination of additional background information about respondents' experience and knowledge with GM science could also help to explain consumers' attitudes toward GM science. Additionally, future research should examine the influence of the study variables on behaviors related to GM science, such as consumption of GM food. Gorham et al. (2014) found that behaviors, beyond information seeking, differed among seekers and engagers and further investigation of behaviors in the present context is warranted. This study should also be replicated in different countries. GM science is regulated differently among different nations and perceptions and opinions vary as well. Cultural differences among countries may also reveal alternative critical thinking styles or views on transparency. Caution should be taken when interpreting the results for populations and contexts beyond the sample and topic studied in this manuscript.

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