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As genetic modification for food production has expanded, the United States (U.S.) public discourse about the acceptance and regulation of the use of these products has also expanded. Dissent is currently presumed to be widespread on these issues. However, assessments of public agricultural literacy around the technology alternatives are limited, especially in the context of food production versus medical genetic testing, about potential environmental risk and other reasons for dissent. Assessments also tend to focus on consumer knowledge in outdated deficit-model frameworks. In preparation for an assessment of U.S. adult public understanding of traditional breeding and genetic engineering technology, we reviewed existing agricultural literacy and science literacy literature to determine current understanding and locate existing instruments on which to build such an assessment. Of 323 peer-reviewed articles, we found only four that empirically examined U.S. adult public audiences in the context of literacy related to genetic modification for food. Results from agricultural economics and four gray literature pieces provided additional context and direction for our own survey development. We suggest ways to build a more representative and meaningful survey relying on more than knowledge deficits to characterize agricultural literacy and plant genetic literacy. This will lay the foundation for understanding why dissent over such agricultural topics exists.

Keywords: Genetic modification, science literacy, plant genetic literacy, genetic engineering, agricultural literacy, genetically modified food, genetically modified organisms, public understanding

Introduction

As the United States (U.S.) and the world face pressures to feed hungry populations, a global food crisis has arrived. By the year 2050, overall food production needs to increase by 70% to meet the demands of the world's populations (Food and Agriculture Organization of the United Nations, 2009).

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With this growing demand, agricultural scientists are turning to both technology-driven and traditional-breeding-based genetic engineering solutions. Genetically modified organisms (GMOs), also referred to as genetically engineered (GE) foods use genetic engineering technology to create new and improved crops, which people may consume directly as, or as a component of, genetically modified (GM) foods[1]. Genetically engineered foods promise higher production yields and net return with a decrease in pesticides used (Fernandez-Cornejo, Wechsler, Livingston, & Mitchell, 2014). Yet, controversy surrounds their use in the United States (e.g., Azadi & Ho, 2010; Funk & Kennedy, 2016; Funk & Rainie, 2015a), albeit less so than in Europe (Funk & Kennedy, 2016; Kahan, 2015). Recent ballot initiatives regarding labeling and attacks on scientists studying GMOs seem to be increasing (Council for Agricultural Science and Technology, 2014; Smith, 2012). However, some evidence suggests Americans are less split on the topic politically, and in fact, see GMOs to be a relatively moderate risk (Kahan, 2015).

Limited evidence on GE awareness and literacy makes it difficult to tell whether Americans truly understand the attendant risks of GMOs, particularly the direct risks to human health versus risks to the broader environment and ecological systems. Without a true understanding of the public risk awareness, we lack a true picture of whether U.S. adults prefer or disdain laboratory-based GE technology versus traditional cross-breeding. Of the information that does exist, little of it focuses on the reasons behind support or lack of support for GE-related agricultural technologies.

Many of these potential solutions to the global food crisis, whether GE, traditional cross-breeding, or hybrid approaches using DNA evidence to guide traditional breeding, rely on public tax dollars for research support. This research support, in turn, relies on public awareness of the utility of the research products (Ding, Maibach, Zhao, Roser-Renouf, & Leiserowitz, 2011; Miller, 2004). A body of research on student attitudes toward biotechnology as a whole exists (Gardner & Troelstrup, 2015), but the reported student conceptualizations of attitude toward biotechnology vary widely. However, adult public awareness of, understanding of, and support for either traditional or laboratory-based genetic engineering efforts have not been widely empirically researched. This understanding and awareness fall under the purview of *agricultural literacy* (Frick, Kahler, & Miller 1991).

Public agricultural literacy is a priority in the American Association for Agricultural Education's National Research Agenda (Doerfert, 2011; Roberts, Harder, & Brashears, 2016). Science literacy writ large is an objective of major research funding agencies in the U.S. (Roos, 2014). The understanding of genetic engineering technologies is a component of those literacies based on a rapidly-changing field. Traditionally, however, studies of literacy focus on public

[1] Throughout this paper, we will use the term *genetic engineering (GE)* to be most precise about the technology to which we are referencing. However, we will use the term *genetically modified (GM or GMO)* to reflect what particular authors in our review used in their research.

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knowledge in a deficit model framework (Biesta, 2007; Sturgis & Allum, 2004), rather than considering awareness, term familiarity, or applied knowledge for innovation adoption (Abrams, McBride, Hooker, Cappella, & Koehly, 2015). In this paper, we review relevant public GE literacy studies to determine what researchers have studied in order to build a survey related to GE agriculture that avoids the deficit model and more adequately assesses public attitudes toward GE food as compared to traditional breeding technologies.

Background

Jon Miller began nationwide public surveys of *science literacy* of American adults in the 1970s (Miller, 2010). While the surveys have been revised over time to include more contemporary science topics, the surveys are very knowledge- and fact-based surveys with little attention to the application of that knowledge as befits more contemporary definitions of literacy. Organizations such as the Pew Research Center (Funk & Rainie, 2015b) also report "gaps" between non-scientists and professionals on fact-based measures. This reliance on simply correct answers places respondents often in a place of deficit versus a standard of knowledge or expertise (Sturgis & Allum, 2004; Weiner, 2006). In 1975, Shen introduced the idea of "civic science literacy" (Shen, 1975, p. 49), which is having not only knowledge but also the ability to apply knowledge in the context of participating in democratic decision-making based on science.

Originally, many of these surveys focused on facts that were related to science broadly, such as: "All radioactivity is man-made" (Miller, 1998, p. 208). Miller (1998) argues this was necessary to provide durability of the measure over time, due to the rapidly changing nature of scientific issues in the news. While Miller reports some increase in literacy on these items over time (Miller, 2010), the lack of focus on specific current issues makes this measure alone less useful in understanding public conceptions of topics involved in contemporary decisions, such as legislation about labeling GMOs or supporting scientific research on plant genetic databases. Both Miller's survey (2010) and Kahan's Ordinary Science Intelligence scale (2014) lack specific fact-based questions related to genetics, let alone genetic engineering. Such knowledge-based surveys also neglect other stages of decision making, such as awareness and persuasion, that precede and follow knowledge acquisition (Rogers, 2003).

In the realm of decision-making, researchers have begun to advance the idea of cultural cognition (Kahan, 2008) or partisan-motivated reasoning (Bolsen, Druckman, & Cook, 2014; Hart & Nisbet, 2012), which suggests that people are more interested in preserving relationships than making fact-based decisions about potentially controversial or emerging issues. Their empirical examination of such affiliations, through a *worldview scale*, groups respondents into quadrants on two continua – hierarchical/egalitarian and individual/communitarian (Kahan, 2008). The authors argue these quadrant groupings tend to better predict how people feel about an issue and make decisions based on perceptions of risk (Kahan, 2008). Kahan (2014)

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developed an Ordinary Science Intelligence scale that includes numeracy. This scale has a mix of items from science facts to process questions, especially around risk.

More recently, research on literacy has started to move toward *public engagement with science*, wherein people outside professional circles are actively involved in critiquing and shaping science for their own ends (McCallie, 2010). This requires valuing not only academic knowledge but also other forms of knowing and affective dimensions, moving away from a deficit model. According to this movement, both reasoning based on relationships and fundamental science intelligence may contribute to overall perceptions of emerging technologies.

While media reports and some research find genetically engineered food to be controversial among consumers in the United States, especially regionally (Anderson, Ruth, & Rumble, 2014; Krause, Meyers, Irlbeck, & Chambers, 2015), some evidence suggests that such products are less controversial than topics such as climate change and gun control (Kahan, 2013). Specifically, Kahan (2013) reports consumers are less split on their perceptions of GMOs based on political ideology. Consumers in the U.S. also reported less overall human risk from GMOs than from climate change (Kahan, 2013). The lack of literature specifically addressing understanding of the various genetic modification technologies and their methods complicates the issue and makes it difficult to create effective outreach to inform public discourse.

Purpose and Objectives

As a precursor to the development of a national public survey incorporating facets of traditional breeding, GMOs, health versus environmental risks, and overall science understanding and worldview, we conducted a review of peer-reviewed and gray literature, that is, reports of systematic studies that have not undergone peer review, including evaluations, polls, and other reports found online. The purpose of the present study, therefore, is to determine what literature exists on the topic of public understanding and awareness of (i.e., literacy about) topics related to genetic technology in the context of food production. We also sought to determine the existence of any validated instruments or scales related to the same topics. We report the results of our literature review of journal articles published since 2000 on several terms related to genetic technology literacy. We had two main research questions:

(1) What empirical research exists on the U.S. public regarding understanding of genetic engineering technology related to food, particularly resulting in survey instruments?
(2) What research examines potential differences in the U.S. public attitudes toward the human health versus environmental risks of food-related genetic engineering technology?

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Methods

To conduct our literature search, we followed the systematic review process outlined in Frewer et al. (2013). This process included the following steps:

(1) Formulate study questions, including comparisons, contrasts, and population for study.
(2) Generate a list of search terms.
(3) Search relevant databases.
(4) Screen candidate papers using titles, keywords, and abstracts.

To gather literature, we first generated a list of search terms related to genetic engineering in consultation with other study team members, including a horticultural scientist/Extension agent and another social science researcher working on the larger grant funding this study. To produce the final search terms, we combined the genetic engineering terms with the word *literacy* to search for results specifically focused on participant understanding, not only perceptions. See Table 1 for our final search terms.

Table 1. Total Journal Articles Per Database and Term Searched

	Total Database Results	
Term	**Web of Science**	**ERIC**
"Genetic literacy"	72	6
Biotechnology literacy	86	50
Plant breeding literacy	21	0
Genetic engineering literacy	18	14
Genetically modified literacy	31	13
Genome literacy	74	6
Genomic literacy	67	2
Total	369	91

Note: "Genetic literacy" was the only phrase we searched with quotation marks.

We searched these seven terms in two different databases, Web of Science and the Educational Resources Information Center (ERIC). Web of Science includes publications in various natural sciences journals, as well as some social science sources, while ERIC focuses on journals related to education. The Web of Science searches in December 2015 included the entire collection of seven databases available through our university library subscription, including the Web of Science Core Collection, BIOSIS Citation Index, and MEDLINE. In ERIC, we used the "all databases" search option, including 34 databases made up of several newspapers and periodicals. To limit our results to most recent studies, we searched only the year 2000 through November 2015. Of the 460 articles found in the two databases, 98 were duplicated one or more times, yielding 137 duplicates. Subtracting these duplicates left 323 unique articles.

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We then screened the abstracts and articles for the comparisons of interest in our study. We included articles that: had participant populations within the United States over age 18 in public (non-school) settings, studied understanding rather than just perceptions, studied plant genetics rather than medical genetics alone, and offered empirical data to which we might ultimately compare our own survey results. This yielded only four papers. We then searched the reference lists of the identified articles meeting our criteria to identify any additional articles that were not in the two databases. We found no additional studies meeting our criteria using this search.

As our initial search turned up only four peer-reviewed studies, upon recommendation from colleagues who study consumer perceptions of GE, we also examined peer-reviewed literature from Jayson Lusk, a food and agricultural economist. Agricultural economists do not use the keyword *literacy* in their work, so these articles did not come up in our database searches. Lusk researches consumer demand for food, including GE food. As of 2013, Lusk also conducted a monthly non-peer-reviewed U.S. Food Demand Survey examining a variety of recurring metrics that also includes occasional questions on topics such as demand for GE foods. The occasional questions pertaining to GE foods identified in the Food Demand Surveys were not relevant to the current study, so we did not examine these surveys further.

We examined titles and abstracts from 160 published peer-reviewed articles from Lusk's curriculum vitae as of December 2015. All of these articles had been published since 2000. We found 43 articles with titles or keywords containing our search terms to examine further. We applied the same criteria of U.S. population, study topic covering understanding of plant-related genetics questions, and presence of empirical data to the Lusk articles as we applied to the other database results. However, none of the results from Lusk in our timeframe (2000–2015) concerned knowledge about GE, though several used national samples of U.S. adults.

Finally, the authors knew of several conference publications in agricultural education related to GE (Krause et al., 2015; Ruth, Gay, Rumble, & Rodriguez, 2015). These and additional public polls that were not peer-reviewed journal articles are part of the gray literature. Because of the potential relevance of these emerging studies, to examine gray literature, we examined The American Association for Agricultural Education's (AAEA) national meeting conference proceedings during our search timeframe (2000–2015) and their reference lists. This source of gray literature included unpublished reports mentioned in these conference articles and their reference lists or related works by authors identified in the reference lists. This search produced an additional three sources meeting our national sample criteria and one study that used a regional population but examined environmental and health risk separately. We kept this study due to a dearth of other studies containing this differentiation of environmental and health risk. Once we identified relevant peer-reviewed and gray literature papers, we examined them to determine sample size and quantitative versus qualitative sources of data. Next, we looked for the presence of questions related to food (as opposed to general plant genetics or genetic

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engineering), questions related to traditional plant breeding or other alternatives and questions related to health and environmental risk. Finally, we noted whether the authors performed any comparison to overall science literacy and worldview.

Results

Only four peer-reviewed articles from the database searches using the word *literacy* met our criteria. The review of agricultural economics studies from Lusk and co-authors yielded no additional articles. The final four studies that related to our study came from gray literature. Therefore, our total review resulted in eight articles and evaluation reports for investigation in more depth.

Peer-reviewed Articles from Database Searches

The four peer-reviewed articles from our database searches ranged in sample size from 62 for the one qualitative study to 1,200 for the largest of three quantitative studies. Table 2 displays the differences and commonalities in content covered in the research instruments of the four articles. For our research objectives, we noticed that all four articles showed little to no GE understanding research, and only one of the three quantitative studies discussed environmental risk separately from health risk. An explanation of these studies and the findings about participant awareness in more detail follows.

Table 2. Peer-Reviewed Articles Examined In-depth

				Topics covered in addition to non-medical GE		
Article	**N**	**Year Conducted**	**Quantitative Study**	**Environmental Risk**	**Food**	**Science Literacy**
Abrams et al. (2015)	1,016	2013	X			
Christensen et al. (2010)	1,200	2001	X			
Jang (2014)	238	2012	X	X	X	X
Lanie et al. (2004)	62	2000				

Abrams, McBride, Hooker, Cappella, and Koehly (2015) study. Abrams et al. (2015) collected data from 1,016 American adults through an electronic survey. The electronic survey from 2013 "captured genetic literacy with three measures that each assess[ed] a different dimension of genomic knowledge to align with Rogers' [diffusion of innovations] hierarchy" (Abrams et al., 2015, p. 3). The three factors were *familiarity*, *skills*, and *factual knowledge*.

An assessment of *term familiarity* measured awareness. Participants in the Abrams et al. study rated their familiarity of eight terms relating to genetics on a seven-point scale. *How-to knowledge* was assessed through practical skills where participants were given literature to help

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them answer six multiple choice and fill-in-the-blank questions relating to genetic testing and mutations. The authors assessed *principles knowledge* through factual knowledge, where participants responded to the veracity of 16 technical statements on the topic of genes and how they function. Results of the study showed that participants scored highest on self-reported term familiarity and that the factual knowledge portion had the fewest high scores. The study did compare the participants' demographics of race and ethnicity, as well as education and income level, to the results on the three scales. The authors provided their instrument for examination.

Christensen, Jayaratne, Roberts, Kardia, and Petty (2010) study. Christensen et al. (2010) "examined understandings of basic genetic concepts among Americans" (p. 467) via telephone interviews in 2001. The sample for this study consisted of 1,200 American adults with equal numbers of white and black men and women. The authors asked participants to agree or disagree with eight statements that were facts about genetics and therefore had a correct answer. The results showed that each sample category scored less than 50% correct on six of the eight statements, suggesting that many Americans at the time were uninformed on several genetic concepts across the racial/ethnic categories examined (Christensen et al., 2010).

Lanie, Jayaratne, Sheldon, Kardia, Anderson, Feldbaum, and Petty (2004) study. The oldest study in our sample used telephone interviews in the year 2000 (Lanie et al., 2004). Participants, sampled through random digit dialing, answered questions regarding their basic understanding and location of genes. Sixty-two American adults participated over two phases of the study and were compensated for their participation. Phase one consisted of 44 qualitative interviews conducted by professionally trained interviewers. Participants answered two broad questions, both relating to the understanding and location of genes. An additional 18 participants participated in Phase two, a pretest for a larger quantitative study, with open-ended questions also relating to the meaning and location of genes. Based on results from this study, the authors concluded that there is confusion among the definitions of "genetic" and "gene" (Lanie et al., 2004). The authors also indicated that there was much frustration when participants were asked questions to which they could not provide a well-thought-out answer. The authors provided no further description of the resulting quantitative study or the instrument used in their study.

Jang (2014) study. The last article we examined, by Jang (2014), studied "how citizens select science information online based on their preexisting issue attitudes" (p. 143). The authors used a national sample of American adult volunteers tasked with browsing an online news magazine with articles on four focal issues. Before the task, participants completed a survey asking questions on a six-point scale involving the attitude and importance of the four focal issues, including genetic modification of food, plus six additional social issues. The results showed that participants were more interested in literature that challenged their views rather than supported them for GM food, and their individual predispositions, such as perceived science knowledge and religiosity, did affect their views. This study did use a baseline scientific knowledge scale,

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which did not affect the views. However, this study did not assess participant knowledge related to the specific issues, and due to the context of a larger intervention study, had a limited sample size (*N* = 238).

Gray Literature

Two studies of regional audiences related to GM technology were identified in the 2015 AAAE conference proceedings (Krause et al., 2015; Ruth et al., 2015). As they did not use survey methods about GM food specifically with adult public audiences, we used them to identify other gray literature potentially related to GM food but do not discuss them further here. Ruth et al. (2015) directly referenced Anderson et al. (2014). Ruth et al. (2015) did not directly reference the national Hallman, Cuite, and Morin (2013) study but referenced other earlier work by Hallman (Hallman & Metcalfe, 1994) that led us to the 2013 survey which we reviewed. Similarly, Krause et al. (2015) did not directly reference Funk and Rainie (2015b) but did reference other GM related studies from the Pew Research Center, which led us to the Funk and Rainie (2015b) work from the Center. Therefore, we identified four sources from gray literature that we deemed related to our purposes as they covered GM food technology specifically in at least one question with U.S. adult audiences.

Of the four studies we examined in-depth from gray literature, two evaluation reports published online examined genetic modification technology and food specifically: one national population (Hallman et al., 2013) and one from Florida consumers (Anderson et al., 2014) that we kept for examination due to the dearth of studies with questions on environmental risk. GM food questions were included in the third study as part of a national survey of overall science topics for non-scientists and professionals conducted by the Pew Research Center (Funk & Rainie, 2015b). The fourth study, the National Science Board's biennial Science and Engineering Indicators report (National Science Board, 2014, p. Overview), presents findings "from a variety of national, international, public, and private sources." A summary of their characteristics, similar to those of the peer-reviewed literacy studies, appears in Table 3.

Of the two gray literature pieces shown in Table 3 that were entirely surveys related to GM food, the Florida consumer survey (Anderson et al., 2014) differentiated among environmental and health effects of GMO technology, with a larger percentage of respondents (40%) feeling that GMOs posed a risk to the environment than those who disagreed (26%) with that feeling. Neither study addressed traditional breeding (Hallman et al., 2013).

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Table 3. Characteristics of Examined Gray Literature

				Topics covered in addition to non-medical GE		
Article/Report	**National Sample**	**N**	**Year Conducted**	**Environmental Risk**	**Food**	**Science Literacy**
Anderson et al. (2014)		524	2014	X	X	
Hallman et al. (2013)	X	1,148	2013		X	
National Science Board (2014)	X	multiple	2000–2010	X		X
Funk & Rainie [Pew Research Center] (2015b)	X	2,002	2014			X

Note: The National Science Board report covers results from several surveys, each with $N > 1,000$.

The two surveys varied somewhat on the respondents' awareness of GM foods. The Florida consumer survey results indicated 83% of the respondents had heard of genetically modified foods (Anderson et al., 2014). In the national GM food survey (Hallman et al., 2013), 75% of respondents reported they were aware of GM foods before the survey.

The national GM food survey also showed that participants were evenly split on the safety of GM foods for consumption (Hallman et al., 2013). The respondents were not given an option to choose a neutral response. The Pew national survey (Funk & Rainie, 2015b) reported only 37% of the respondents felt GM foods were safe to eat versus 57% who did not. In contrast, the Florida survey indicated a slightly higher percentage of respondents, 45%, felt GM foods were not safe versus 22% who felt that GM foods were safe, with 34% being neutral on the subject (Anderson et al., 2014). The Funk and Rainie (2015b) national survey was the only one of the gray literature sources to break down findings by demographics such as age, education, and race/ethnicity. None of the gray literature studies contained questions on traditional breeding.

Conclusions, Implications, and Recommendations

Very few empirical, peer-reviewed studies of the entire U.S. public exist on the topic of literacy on genetically modified (GM) food or genetically modified organisms (GMOs). A large number of studies identified through the search terms used in this study concentrated on medical genetics, examined non-U.S. or non-adult populations, or did not collect empirical data. Only four out of 323 peer-reviewed studies that we found used a nationally representative U.S. adult population and did not exclusively concern medical technology genetic engineering. One of these four was qualitative in nature. In addition, two of the four studies were from the early 2000s and are therefore nearly 15 years old. Overall, our review demonstrated that there is little research examining U.S. public understanding of genetic engineering related to food production and of the separate risks of genetically modified foods to human versus environmental health.

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However, as the authors in Abrams et al. (2015) point out, based on Rogers' (2003) Diffusion of Innovations, consumers may still choose to adopt innovations despite low levels of factual knowledge if they have practical knowledge or awareness of the innovation. The other three peer-reviewed studies did not examine consumer awareness. Only one of the four studies (Jang, 2014) asked questions differentiating environmental and human health risks, but this study had a relatively small sample due to the overarching intervention study for which the assessment was a pretest.

In gray literature, we found several more studies that may or may not be nationally representative. However, their general trends do support the conclusion that U.S. adults are generally neither well-aware of nor well-versed on the topic of genetics and genetic modification (Anderson et al., 2014; Funk & Rainie, 2015b; Hallman et al., 2013; National Science Board, 2014). The gray literature reported demographic breakdowns and a separate examination of human versus environmental health risks more often than the peer-reviewed literature, especially in the regional studies such as Anderson et al. (2014). However, differences in the regional and national surveys suggest the results from regional audiences may not be completely generalizable. The questions available from the regional survey may be used in our own national survey for direct comparison. Finally, the peer-reviewed study from McFadden and Lusk (2016) conducted in September of 2015 did reveal a low overall self-reported awareness of and knowledge about genetic engineering (GE) and traditional breeding.

Evaluation data may exist for other intervention programs designed to help participants learn about genetic technology. The authors found a reference to a study with visitors to the Connecticut Science Center but were unable to obtain a full evaluation report (Nielsen, 2015). These data would also not be generalizable to a larger public population, but the findings alluded to in the blog post about the Connecticut study support the trends we identified in the other studies reported in this paper. In addition, the agricultural economics literature identifies a number of studies about consumer willingness-to-pay or willingness-to-accept GM foods (e.g., Lusk, Jamal, Kurlander, Roucan, & Taulman, 2005; Napier, Tucker, Henry, & Whaley, 2004), but many of these studies used both U.S. and non-U.S. populations or otherwise non-adult populations. *Consumer Reports* (Consumer Reports, 2014) and ABCNews.com (Langer, 2006) each have reported results online of their own national studies, but they do not share the questions asked or the demographic breakdowns that a peer-reviewed article or even an evaluation report does.

Few of the studies reviewed in this study included separate questions on human health and environmental risks. Only one of the peer-reviewed articles (Jang, 2014), one national evaluation report (Hallman et al., 2013), and the regional study of Florida consumers (Anderson et al., 2014) differentiated between the two. This is reflected in results from recent public media campaigns related to legislation for GMO labeling, which showed a strong preference (i.e.,

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approximately 4-to-1) for messaging in those campaigns about human health as opposed to environmental risk (Krause et al., 2015). While Lusk's studies do imply that food safety is of greater importance to consumers than environmental impact when considering organic food, it is not clear whether food safety is the same as health risk when considering genetic engineering. Without empirical data on awareness and understanding of environmental versus human health risk, it is unclear whether messaging about health risk is of more value to consumers than environmental risk of genetic engineering, or if they are truly unaware of associated environmental risks. A recent review by Nicolia, Manzo, Veronesi, and Rosellini (2014) suggests that scientists agree there is little risk to either the environment or human health, so we cannot tell whether consumers actually agree with scientists on these individual risks. The Pew national survey suggests a wide gap between public and scientists' perceptions of overall risk of genetically modified foods (Funk & Rainie, 2015b). Some of the items from survey instruments reported by these publications may be incorporated into our own instrument.

Finally, with the exception of Abrams et al. (2015), the peer-reviewed studies identified through this review examined knowledge only, reflecting a deficit framework and failing to account for other potential factors in U.S. adult decision-making about genetically modified foods, including awareness and practical knowledge. Two of the gray literature studies did assess awareness as well as factual knowledge (Anderson et al., 2014; Hallman et al., 2013). These instruments did not assess any overall science literacy or numeracy of the respondents, nor their political affiliation as assessed by their worldview (as opposed to mere self-report of political affiliation), which may be confounding factors in genetic literacy and perception of risk (Kahan, 2008; Kahan, Wittlin, Peters, Slovic, Ouellette, Braman, & Mandel, 2011; Kahan, 2014). Such divisions may also highlight differences among populations that may need different messaging for persuasion.

After our initial study that ended with articles that had been published through November 2015, and in the agricultural education literature specifically, we identified two additional sources of relevant information just outside the scope of this work. The original search in this study's 2000-2015 timeframe of Lusk's curriculum vitae revealed no published studies in that timeframe meeting our criterion of assessing understanding. However, a more recent study by McFadden and Lusk (2016) indicated a low level of knowledge about GMOs among American adults in a national survey. This survey asked about perceived health risk but not environmental risk. McFadden and Lusk's survey did also ask one question about knowledge of traditional methods of plant breeding, specifically, how many genes were modified in particular modification techniques. That study also indicated that while about one-third of consumers felt knowledgeable about GMOs, their confidence in their knowledge declined after responding to questions in the surveys about details of GM technology, suggesting that self-reported levels of knowledge may be overestimated.

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An additional non-peer-reviewed national survey from the Pew Research Center conducted in May and June 2016 (Funk & Kennedy, 2016) also reported that 20% of Americans had not even heard of foods with genetically modified ingredients.

In general, the existence of gray literature on an emerging controversial topic such as this and the dearth of studies from an agricultural literacy standpoint points to a larger need for more systematic sharing of such data. The potential existence of literacy-related literature in the agricultural economics realm means we need to continue to think broadly about literacy and its many forms. Better sharing of evaluation results and conference proceedings ahead of or even instead of full peer review would allow researchers to build on these results, despite their limitations, without completely re-inventing instruments.

Ultimately, to build a survey for further study of this topic, the results of this review will allow us to incorporate questions from previous instruments, including Abrams et al. (2015), and questions from the agricultural economics studies for direct comparison within the population of our proposed study. We will also revise items from regional surveys, such as Anderson et al. (2014), designed to disentangle ideas of environmental versus human health risk for genetic engineering of food through engineering and traditional breeding technologies. Finally, to address overall background on the role that science and ideology may play in acceptance, we will use the Ordinary Science Intelligence (Kahan, 2014) and Worldview scales (Kahan, 2008).

The melding of these various instruments will result in a comprehensive set of scales assessing not just self-reported knowledge of the topics, but also self-reported knowledge of the terms relating to genetic engineering, the alternatives of selective breeding and DNA-directed selective breeding, and an assessment of the importance of environmental risk separate from direct risk to human health. This newly created survey will also allow us to relate awareness of genetic engineering of plants to general science literacy, worldview, decision-making styles, and demographics to inform public outreach on genetic technologies related to food production.

Our purpose in creating the new survey is two-fold. First, we want to assess underlying public knowledge specifically in the realm of plant- and food-related genetic engineering to add to the body of knowledge on this topic. Second, we want to obtain information on public Extension audiences that will guide outreach and public engagement strategies on genetic engineering and genetically modified organisms.

We invite readers to use this survey with their audiences to add to the body of knowledge for specific groups and subgroups on these particular issues and to collaborate with us to create revised instruments to continue to build the knowledge base. We also hope that readers will be able to use the newly created survey to assess in pre- and post-fashion changes in their audiences based on interventions in outreach and engagement on genetic engineering.

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While we know that knowledge is not sufficient to change attitude, our current literature review suggests that previous studies may not have been correctly assessing attitudes or that people actually may have attitudes based on alternative conceptions about GE technology. Recent studies also did not consider the benefits of the technology or a risk-benefit ratio, which might better represent consumer attitudes (Gaskell et al., 2004). We must improve these assessments to understand why particular patterns of consumer attitudes toward agricultural innovations exist.

References

Abrams, L. R., McBride, C. M., Hooker, G. W., Cappella, J. N., & Koehly, L. M. (2015). The many facets of genetic literacy: Assessing the scalability of multiple measures for broad use in survey research. *PLOS ONE*, *10*(10), e0141532. doi:10.1371/journal.pone.0141532

Anderson, S., Ruth, T., & Rumble, J. (2014). *Public opinion of food in Florida* (IFAS Center for Public Issues Education No. PIE2011/12-17). Retrieved from http://www.piecenter.com /wp-content/uploads/2014/12/Food-Panel-Report_2014_Final_4.pdf

Azadi, H., & Ho, P. (2010). Genetically modified and organic crops in developing countries: A review of options for food security. *Biotechnology Advances*, *28*(1), 160–168. doi:10.10 16/j.biotechadv.2009.11.003

Biesta, G. (2007). Why "What Works" won't work: Evidence-based practice and the democratic deficit in educational research. *Educational Theory*, *57*(1), 1–22. doi:10.1111/j.1741-5446.2006.00241.x

Bolsen, T., Druckman, J. N., & Cook, F. L. (2014). The influence of partisan motivated reasoning on public opinion. *Political Behavior*, *36*(2), 235–262. doi:10.1007/s11109-013-9238-0

Christensen, K. D., Jayaratne, T. E., Roberts, J. S., Kardia, S. L. R., & Petty, E. M. (2010). Understandings of basic genetics in the United States: Results from a national survey of black and white men and women. *Public Health Genomics*, *13*(7–8), 467–476. doi:10.11 59/000293287

Consumer Reports. (2014, October). *GMOS in food*. Retrieved from http://www.consumerreports .org/cro/2014/10/where-gmos-hide-in-your-food/index.htm

Council for Agricultural Science and Technology (CAST). (2014). *The potential impacts of mandatory labeling for genetically engineered food in the United States* (Issue Paper No. 54). Ames, IA: CAST.

Ding, D., Maibach, E. W., Zhao, X., Roser-Renouf, C., & Leiserowitz, A. (2011). Support for climate policy and societal action are linked to perceptions about scientific agreement. *Nature Climate Change*, *1*(9), 462–466. doi:10.1038/nclimate1295

Doerfert, D. L. (Ed.). (2011). *National research agenda: American Association for Agricultural Education's research priorities for 2011-2015*. Lubbock, TX: Texas Tech University, Department of Agricultural Education and Communications.

Journal of Human Sciences and Extension Volume 6, Number 3, 2018

Review of U.S. Public Genetic Modification Literacy 73

Fernandez-Cornejo, J., Wechsler, S., Livingston, M., & Mitchell, L. (2014). *Genetically engineered crops in the United States* (Economic Research Report No. 162). Retrieved from https://www.ers.usda.gov/publications/pub-details/?pubid=45182

Food and Agriculture Organization of the United Nations. (2009). *Global agriculture towards 2050*. Retrieved from http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf

Frewer, L. J., van der Lans, I. A., Fischer, A. R. H., Reinders, M. J., Menozzi, D., Zhang, X., . . . Zimmermann, K. L. (2013). Public perceptions of agri-food applications of genetic modification – A systematic review and meta-analysis. *Trends in Food Science & Technology*, *30*(2), 142–152. doi:10.1016/j.tifs.2013.01.003

Frick, M. J., Kahler, A., & Miller, W. W. (1991). A definition and concepts of agricultural literacy. *Journal of Agricultural Education*, *32*(2), 49–57. doi:10.5032/jae.1991.02049

Funk, C., & Kennedy, B. (2016). *The new food fights: U.S. public divides over food science*. Washington, DC: Pew Research Center. Retrieved from http://www.pewinternet.org/wp-content/uploads/sites/9/2016/11/PS_2016.12.01_Food-Science_FINAL.pdf

Funk, C., & Rainie, L. (2015a). *Americans, politics and science issues*. Washington, DC: Pew Research Center. Retrieved from http://www.pewinternet.org/2015/07/01/americans-politics-and-science-issues/

Funk, C., & Rainie, L. (2015b). *Public and scientists' views on science and society*. Washington, DC: Pew Research Center. Retrieved from http://www.pewinternet.org/2015/01/29/public-and-scientists-views-on-science-and-society/

Gardner, G. E., & Troelstrup, A. (2015). Students' attitudes toward gene technology: Deconstructing a construct. *Journal of Science Education and Technology*, *24*(5), 519–531. doi:10.1007/s10956-014-9542-4

Gaskell, G., Allum, N., Wagner, W., Kronberger, N., Torgersen, H., Hampel, J., & Bardes, J. (2004). GM foods and the misperception of risk perception. *Risk Analysis*, *24*(1), 185–194. doi:10.1111/j.0272-4332.2004.00421.x

Hallman, W. K., Cuite, C. L., & Morin, X. (2013). *Public perceptions of labeling genetically modified foods* (Working Paper No. 2013-01). Retrieved from http://humeco.rutgers.edu/documents_pdf/news/gmlabelingperceptions.pdf

Hallman, W. K., & Metcalfe, J. (1994). *Public perceptions of agricultural biotechnology: A survey of New Jersey residents*. New Brunswick, NJ: Food Policy Institute, Cook College, Rutgers, The State University of New Jersey. Retrieved from http://core.kmi.open.ac.uk/download/pdf/6435312.pdf

Hart, P. S., & Nisbet, E. C. (2012). Boomerang effects in science communication: How motivated reasoning and identity cues amplify opinion polarization about climate mitigation policies. *Communication Research*, *39*(6), 701–723. doi:10.1177/0093650211416646

Journal of Human Sciences and Extension Volume 6, Number 3, 2018

Review of U.S. Public Genetic Modification Literacy 74

Jang, S. M. (2014). Seeking congruency or incongruency online? Examining selective exposure to four controversial science issues. *Science Communication*, *36*(2), 143–167. doi:10.1177/1075547013502733

Kahan, D. M. (2008). *Cultural cognition as a conception of the cultural theory of risk* (SSRN Scholarly Paper No. ID 1123807). Retrieved from http://papers.ssrn.com/abstract=1123807

Kahan, D. M. (2013, November 5). *We aren't polarized on GM foods -- no matter what the result in Washington state* [Blog post]. Retrieved from http://www.culturalcognition.net/blog/2013/11/5/we-arent-polarized-on-gm-foods-no-matter-what-the-result-in.html

Kahan, D. M. (2014). *"Ordinary science intelligence": A science comprehension measure for use in the study of science communication, with notes on "belief in" evolution and climate change* (SSRN Scholarly Paper No. ID 2466715). Retrieved from http://papers.ssrn.com/abstract=2466715

Kahan, D. M. (2015, July 2). *For the 10^6 time: GM foods is *not* polarizing issue in the U.S., plus an initial note on Pew's latest analysis of its "public-vs.-scientists" survey* [Blog post]. Retrieved from http://www.culturalcognition.net/blog/2015/7/2/for-the-106-time-gm-foods-is-not-polarizing-issue-in-the-us.html

Kahan, D. M., Wittlin, M., Peters, E., Slovic, P., Ouellette, L. L., Braman, D., & Mandel, G. N. (2011). *The tragedy of the risk-perception commons: Culture conflict, rationality conflict, and climate change* (SSRN Scholarly Paper No. ID 1871503). Retrieved from http://papers.ssrn.com/abstract=1871503

Krause, A., Meyers, C., Irlbeck, E., & Chambers, T. (2015). What side are you on? An examination of the persuasive message factors in Proposition 37 videos on YouTube. *Proceedings of the Annual National Research Conference* (pp. 122–138). The American Association for Agricultural Education, San Antonio, TX.

Langer, G. (2006, January 7). *Poll: Skepticism of genetically modified foods*. Retrieved from http://abcnews.go.com/Technology/story?id=97567&page=1

Lanie, A. D., Jayaratne, T. E., Sheldon, J. P., Kardia, S. L. R., Anderson, E. S., Feldbaum, M., & Petty, E. M. (2004). Exploring the public understanding of basic genetic concepts. *Journal of Genetic Counseling, 13*(4), 305–320. doi:10.1023/B:JOGC.0000035524.66944.6d

Lusk, J. L., Jamal, M., Kurlander, L., Roucan, M., & Taulman, L. (2005). A meta-analysis of genetically modified food valuation studies. *Journal of Agricultural and Resource Economics, 30*(1), 28–44.

McCallie, E. (2010). *Argumentation among publics and scientists: A study of dialogue events on socio-scientific issues* (doctoral dissertation). King's College London, University College London, London, England.

McFadden, B. R., & Lusk, J. L. (2016). What consumers don't know about genetically modified food, and how that affects beliefs. *FASEB Journal*, *30*(9), 3091–3096. doi:10.1096/fj.201600598

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Review of U.S. Public Genetic Modification Literacy 75

Miller, J. D. (1998). The measurement of civic scientific literacy. *Public Understanding of Science*, *7*(3), 203–223. doi:10.1088/0963-6625/7/3/001

Miller, J. D. (2004). Public understanding of, and attitudes toward, scientific research: What we know and what we need to know. *Public Understanding of Science*, *13*(3), 273–294. doi:10.1177/0963662504044908

Miller, J. D. (2010). The conceptualization and measurement of civic scientific literacy for the twenty-first century. In J. Meinwald & J. G. Hildebrand (Eds.), *Science and the educated American: A core component of liberal education*. Cambridge, MA: American Academy of Arts and Sciences. Retrieved from http://www.amacad.org/pdfs/slacweb.pdf

Napier, T. L., Tucker, M., Henry, C., & Whaley, S. R. (2004). Consumer attitudes toward GMOs: The Ohio experience. *Journal of Food Science*, *69*(3), CRH69-CRH76. doi:10.1111/j.1365-2621.2004.tb13344.x

National Science Board. (2014). *Science and engineering indicators 2014* (No. NSB 14-01). Retrieved from https://www.nsf.gov/statistics/seind14/content/etc/nsb1401.pdf

Nicolia, A., Manzo, A., Veronesi, F., & Rosellini, D. (2014). An overview of the last 10 years of genetically engineered crop safety research. *Critical Reviews in Biotechnology*, *34*(1), 77–88. doi:10.3109/07388551.2013.823595

Nielsen, J. (2015, September 21). *Genome ambassadors: Promoting public understanding of genomics*. Retrieved from http://www.informalscience.org/news-views/genome-ambassadors-promoting-public-understanding-genomics

Roberts, T. G., Harder, A., & Brashears, M. T. (Eds.). (2016). *American Association for Agricultural Education national research agenda: 2016-2020*. Gainesville, FL: Department of Agricultural Education and Communication. Retrieved from http://aaaeonline.org/resources/Documents/AAAE_National_Research_Agenda_20162020.pdf

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York, NY: Free Press.

Roos, J. M. (2014). Measuring science or religion? A measurement analysis of the National Science Foundation sponsored science literacy scale 2006–2010. *Public Understanding of Science*, *23*(7), 797–813. doi:10.1177/0963662512464318

Ruth, T., Gay, K., Rumble, J. N., & Rodriguez, M. T. (2015). Influences on undergraduate students' opinions toward genetically modified food. *Proceedings of the Annual National Research Conference* (pp. 88–105). The American Association for Agricultural Education, San Antonio, TX.

Shen, B. S. P. (1975). Science literacy and the public understanding of science. In *Communication of scientific information* (pp. 44–52). Basel, Switzerland: Karger.

Smith, J. M. (2012, September 19). GMO researchers attacked, evidence denied, and a population at risk. *Global Research*. Retrieved from https://www.globalresearch.ca/gmo-researchers-attacked-evidence-denied-and-a-population-at-risk/5305324

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Sturgis, P., & Allum, N. (2004). Science in society: Re-evaluating the deficit model of public attitudes. *Public Understanding of Science*, *13*(1), 55–74. doi:10.1177/0963662504042690

Weiner, L. (2006). Challenging deficit thinking. *Educational Leadership*, *64*(1), 42–45.

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