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The effects of different types of text and individual differences on view complexity about genetically modified organisms

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ABSTRACT

View change about socio-scientific issues has been well studied in the literature, but the change in the complexity of those views has not. In the current study, the change in the complexity of views about a specific scientific topic (i.e. genetically modified organisms; GMOs) and use of evidence in explaining those views was examined in relation to individual factors and type of text (informational, persuasive, or narrative). Undergraduate students completed measures of their prior views about GMOs their epistemic beliefs about the nature of science, and activities related to food consumption. Participants then read either an informational, persuasive, or narrative passage about GMOs and again answered a question related to their views about GMOs. Participants who read the persuasive passage decreased in the complexity of their views, while those who read the narrative and expository passage increased in the complexity of their views. Additionally, while cultural activities related to the complexity of individuals' views during the pretest, these significant differences were not evident at posttest after the text intervention. These findings can be used to help scientists and teachers better understand how to communicate information critical to understanding complex science and environmental issues to the public and their students.

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Individuals' perspectives about contentious scientific issues (e.g. vaccines, climate change) have been a particular area of interest in psychological research, particularly in the last decade (e.g. Nisbet, 2009; Streefland, 2001). One of the main foci for investigations such as these has been why overwhelming scientific evidence is often ignored in forming and holding views about these contentious issues. There are various explanations for views counter to established scientific evidence ranging from the tentativeness of science (e.g. Pidgeon & Fischhoff, 2011), socio-scientific issues (e.g. Feinstein, 2014; Kahan et al., 2012), to cognitive (Koehler, 2016) explanations. That is, even after exposure in various forms to topics such as global warming (which may include formal schooling),

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people hold onto views that are inaccurate and more importantly find it difficult to use scientific evidence to support their view.

While these studies have certainly helped build a better understanding about individuals' views about contentious scientific issues, past studies have typically examined these issues either with greater depth and less breadth, or with greater breadth and less depth. For example, Abd-El-Khalick (2006) used the *Views on Nature of Science Questionnaire* (*VNOS-C*) and gave follow-up interviews to 153 undergraduate students to determine their views on the nature of science. While there was great depth on participants' views on the nature of science, there was limited breadth as to what factors influenced these perspectives. On the other hand, Kahan et al. (2012) examined notions of hierarchy, individualism, and what they termed *scientific literacy* on their opinions about climate change. While this study included a large number of participants, the use of a true/false measure for scientific literacy limits our depth of understanding of subtle differences between respondents as well as the influence of prior knowledge on these perspectives as the reliability of these items is often quite poor (Burton, 2005).

Drawing on this past research, the purpose of the current study is to connect these disparate areas of study from cognitive psychology and science education fields with the necessary depth and complexity to understand how variables such as individuals' previous understanding of the scientific issue, their epistemic beliefs about science and the nature of science, and their participation in cultural activities relate in meaningful ways to influence their views about contentious scientific issues after further exposure. In other words, this study will examine cognitive, motivational, and social factors that affect individuals' views and how they influence one's ability to learn about science.

One specific area of research that has been used to examine changes in people's views about scientific issues has been the use of different text types – both informational and persuasive. However, narrative texts have been understudied. The current study examines not only why certain opinions may exist, but how exposure to different types of text may (or may not) change those opinions and the evidence individuals use to support their views, with the addition of narrative text as a possible text type that may influence view change.

Specifically, text was chosen as the medium in which individuals interacted with content about a contentious scientific issue. Text is particularly salient to learning in science due to the synergies between inquiry in science and literacy instruction (Pearson, Moje, & Greenleaf, 2010), with various studies demonstrating how individual differences related to text processing can influence science learning (e.g. perceptions of vocabulary knowledge; Brown & Concannon, 2016). While it is certain that individuals would be exposed to these issues from multiple forms of media (e.g. television, newspaper), the current study was limited to written text because there is substantial evidence regarding the effects of different types of text on various reading comprehension outcomes (e.g. Buehl, Alexander, Murphy, & Sperl, 2001; Carrell & Connor, 1991; Dinsmore, Loughlin, Parkinson, & Alexander, 2015).

Theoretical framework

Since text comprehension and text comprehension frameworks have a rich history of examining how various constructs such as epistemic beliefs and emotions (e.g. Broughton, Sinatra, & Nussbaum, 2013; Ho & Liang, 2015) influence text processing and resulting reading outcomes, and since the intervention for this study manipulated the type of text participants encountered, we utilised a reading framework to situate the current study. Specifically, the Rand Research Study Group (2002) defined reading comprehension as the interaction between reader and text which incorporates: the characteristics of the reader, the characteristics of the text, and the broader context in which comprehension is taking part. While there has been much research that has examined the interaction of reader and text (e.g. Ozuru, Dempsey, & McNamara, 2009), examinations of the broader context, specifically in terms of contentious scientific issues, are less common.

Additionally, the goal of the current study is to uncover not only how well a reader can comprehend the text, but how these texts may ultimately change how individuals formulate their opinions based on evidence presented in the text (or not), and, equally as important how this may or may not change their use of evidence. In other words, the theoretical framework for this study allows an examination of reader characteristics and their mediating influence on the relation between the text itself and the readers' resulting views after reading the text. Each of these three areas (characteristics of the text, characteristics of the reader, and the broader context) will be discussed in terms of their influence on their perspectives and the use of evidence for a contentious science issue.

Characteristics of the text

Past examinations of text processing with science topics have focused primarily on expository or informational (i.e. text meant to inform; Williams, Stafford, Lauer, Hall, & Pollini, 2009) text (Dinsmore & Alexander, 2016). These studies have predominately examined reading comprehension outcomes (e.g. Cromley, Snyder-Hogan, & Luciw-Dubas, 2010; Höffler, Prechtl, & Nerdel, 2010), but have also examined interaction effects of constructs such as epistemic beliefs (e.g. Ferguson & Bråten, 2013), text structure (e.g. Armand, 2001), text coherence (Kintsch & Kintsch, 1995), and comprehension question type (e.g. Ozuru et al., 2009) on individuals' reading comprehension. In addition to expository text, there has also been an interest in text processing with science topics that have focused on refutational or persuasive (i.e. argumentative text designed to change a reader's knowledge, beliefs, or point of view, Murphy, Long, Holleran, & Esterly, 2003) text. Persuasive text has been shown repeatedly to have a greater potential to change individuals' knowledge and beliefs than expository text (Hynd, 2001). Indeed, persuasive text has been shown to have differential effects not only on comprehension of text (e.g. Gilabert, Martínez, & Vidal-Abarca, 2005), but also on conceptual attainment (e.g. Mason, Gava, & Boldrin, 2008) and metacognitive monitoring and control (Dinsmore et al., 2015).

While there is potential to change knowledge and beliefs through different types of text such as expository and persuasive text, the role of narrative text (i.e. text that describes everyday experiences, people's actions, and emotional reactions) has not received as much attention, particularly with science topics. These texts have typically centred on plots like a trip to the supermarket (Leeser, 2007) and buying a house (Pulido, 2007). Less well known is how narrative texts may influence individuals' conceptual attainment of complex, science topics.

Indeed, the argumentative nature of persuasive texts for those individuals with existing strongly held views may not be the most effective method towards either belief change or the use of evidence to support those views, particularly if there is an imbalance in the proportion of experts on both sides when both sides are represented (Koehler, 2016). As Slater and Rouner (2002) have argued, the way individuals process narrative texts may preclude their use of cognitive resistance or counter-arguing for those narrative texts, thereby lessening the influence of their more naïve prior beliefs and rudimentary evidence about the topic when faced with more complex arguments and evidence. Therefore, argument presented via narrative texts may hold more promise to effectively change individuals' beliefs about a topic and use of evidence, particularly for readers with less knowledge about a topic but more entrenched beliefs prior to encountering text on a scientific topic.

Characteristics of the reader

While text type in and of itself may influence reading comprehension, metacognitive monitoring and control, and conceptual attainment, characteristics of the reader also play an important role in influencing reading outcomes. Two such characteristics germane to the current study are prior views and epistemic beliefs.

Prior knowledge and views

Before turning to prior views, it is worth considering that initial viewpoints about a topic and the beliefs that frame that viewpoint may be influenced by an individual's prior knowledge. Perhaps one of the most oft-studied characteristics of the reader is their prior knowledge. This is not surprising as prior knowledge has long been assumed to have a major influence in learning more generally (e.g. Ausubel, 1968; Bartlett, 1932) and reading more specifically (e.g. Anderson & Pearson, 1984; Gates, 1939; Hall, 1989) over the past century. While the effects of prior knowledge on reading comprehension are a bit mixed, most of these studies demonstrate moderate to strong effects (Dinsmore & Fox, 2015).

For expository text, these large effects are expected as the purpose of these texts is to communicate information, however, introducing argument and evidence into the text may open the door for other factors, such as topic beliefs to have more influence during text processing and on reading outcomes. In particular, views about a topic may play a role in one's ability to evaluate objective argument quality, depending on their dispositions for active, open-minded thinking (Stanovich & West, 1997). What has not been investigated is whether the type of text, specifically narrative text with its different argument structure, may help readers more objectively evaluate evidence even in the face of strongly held prior beliefs.

Epistemic beliefs about science

With this in mind, particularly considering the issues that argument may play in mediating the role of text and learner, we turn to epistemic beliefs as a possible mechanism important to how text might change individuals' viewpoints. The role of epistemic beliefs during text processing has been studied over a wide range of academic domains including mathematics (Schommer, Crouse, & Rhodes, 1992) and psychology (Schommer, 1990). Additionally, these studies have also examined contentious scientific issues. Specifically, Kardash and Scholes (1996) argued individuals' epistemic beliefs (i.e. beliefs about the certainty of knowledge or scientific evidence) influenced both the strength of their beliefs, about HIV-AIDS, and the change in their initial beliefs after reading a refutational text. Not only do studies like this one indicate that epistemic beliefs influence text processing, but that there are further direct interactions between the characteristics of a text (refutational in this case) and characteristics of the reader.

At issue here, is that knowing in science is fundamentally a complex process with multiple facets; this complexity is revealed when individuals undertake a conscious reflection on how and why evidence is scientific. This counters the common perception that understanding science means simply learning a catalogue of facts (i.e. declarative knowledge). Thus, there would be an expectation that one's understanding or beliefs about the scientific process would be a more relevant indicator of scientific knowledge than a set of facts about certain topics. For this study, individuals' beliefs about the nature of science were measured using scales of epistemological thinking (e.g. Kuhn & Weinstock, 2002; Stahl & Bromme, 2007) of science, rather than declarative knowledge.

Additionally, to examine the nature of the argumentation and evidence our participants brought to bear, we used several constructs from the VNOS-C questionnaire (Abd-El-Khalick, Bell, & Lederman, 1998) to frame our examination of their open-ended responses to socio-scientific prompts. We chose to use the constructs from this questionnaire because they were consistent with seminal science education reform documents (e.g. AAAS, 1989; 1993; National Research Council, 1996) that serve as consensus definitions of the nature of science. While the constructs focus on the nature of science as practised by scientists, we believe these elements are analogous to how individuals may approach a socio-scientific topic and useful in our analysis of participant argumentation.

In looking at participant arguments around socio-scientific topics, we first focused on tentativeness within scientific practices, defined by Abd-El-Khalick et al. (1998) as: 'Scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations. All other aspects of [the nature of science] provides rationale for the tentativeness of scientific knowledge.' This component of the nature of science speaks to the certainty about researchers' claims when making arguments. We used this aspect to examine how participants' viewed disputed science through the certainty of their claims. Some responses might include statements that the evidence was clear and convincing, while others 'hedged their bets' by stating there may be research supporting a particular view, but contradictory data may exist.

When examining the nature of the evidence that participants drew upon (e.g. studies, data, issue-based websites), we focused on aspects of empiricism and subjectivity. Abd-El-Khalick et al. (1998) described empiricism as: 'scientific knowledge is based on and/or derived from observations of the natural world' and subjectivity as:

> Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also contribute to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable. Personal values, agendas, and prior experiences dictate what and how scientists conduct their work. (p. 17)

In this study, we examined notions of both empiricism (drawing upon evidence) and subjectivity (the filters by which evidence is examined and interpreted) within arguments. For instance, while participant responses might include observational evidence obtained from scientific sources, these data are likely interpreted from personal experience or perception. For example, they may cite industry-funded research, but cast this evidence in a sceptical light based on their perception the particular company commissioning the study.

Socio-scientific issues

Socio-scientific and cultural practices

In addition to the three constructs of the VNOS detailed previously, we focused on a third aspect as well – examining the participants' perspectives around the social and cultural embeddeness of issues surrounding a socio-scientific topic, as these cultural issues play an important role in science learning (Brown & Crippen, 2016; Grace, Yeung, Asshoff, & Wallin, 2015). Abd-El-Khalick et al. (1998) defined this NOS component as:

> Science is a human endeavor and, as such, is influence by the society and culture in which it is practiced. The values and expectations of the culture determine what and how science is conducted, interpreted, and accepted. (p. 17)

Our focus here was the interpretation and acceptance of the science when discussing viewpoints about socio-scientific topics relative to the everyday cultural and social interactions that participants have related to that topic. For instance, individuals' cultural activities such as hiking or swimming in state or national parks may play a big role in the viewpoints they hold about nature conservation. Further, if individuals participated in activities that were not supported by evidence, they may choose to view this evidence negatively or ignore it entirely. For instance, if one brushed their teeth in the shower to save water, despite the evidence to the contrary, they may continue that practice once it becomes habit. For the current study, we examined their responses from open-ended questions.

Genetically modified organisms

There are two reasons we chose the topic of genetically modified organisms (GMOs) as our socio-scientific issue. One, there have been numerous previous studies that have indicated consumer reaction to GMOs have been overwhelmingly negative (e.g. Arvanitoyannis & Krystallis, 2005; Curtis, McCluskey, & Wahl, 2004). However, these studies have been from a consumer perspective (rather than a learning perspective) and have not investigated ways in which those views might be changed. The few studies that have examined GMOs in teaching and learning situations have indicated that prospective teachers do not favour GMOs for food consumption (Šorgo & Ambrožič-Dolinšek, 2009; Šorgo & Ambrožič-Dolinšek, 2010). Additionally, while these studies demonstrated some relation between attitudes and readiness to accept GMOs for purposes other than for food, there have been no studies that we are aware of that have investigated interventions to change beliefs about GMOs in classroom teaching and learning situations.

The second reason we chose this topic was that it was particularly salient in the region of the country in which the study participants live. Agricultural industries (e.g. Florida citrus growers) are petitioning state and federal house subcommittees for the resources to combat new pests and diseases that threaten to eradicate economically important crops (e.g. citrus greening destroys groves of orange trees, Florida Agricultural & Natural Resources Appropriations Subcommittee, 2013). At the same time, many groups are lobbying to label foods with ingredients that contain GMOs as a matter of public information and choice (e.g. The Non-GMO Project). Media coverage of these issues rarely includes scientific information about GMOs or any potential relations between their use and positive or negative outcomes for the environment, human health, or political and economic systems. Thus, this is an issue that has direct local consequences on the economy.

Research questions

Therefore, this study examined the complex interrelations between text, reader characteristics, and a relevant socio-scientific issue. Specifically, we have set out to understand the relative influence of the characteristics of text (by manipulating the type of text each participant read, characteristics of the person (i.e. epistemic beliefs and prior views about GMOs), and social factors (their activities related to food) to better understand why individuals believe what they do as well as the evidence they use to support their views. In other words, we are investigating how epistemic views and engagement in certain relevant cultural activities influence the relation between text and subsequent complexity of views and use of evidence.

Specifically, this investigation was guided by two research questions:

(1) How do individuals' use of evidence and viewpoints about GMOs change after reading different types of text (i.e. expository, persuasive, and narrative) about this contentious scientific topic?

We expect the complexity of individuals' viewpoints to increase most for the narrative passage, followed by the persuasive passage, and the least increase in complexity of the informational passage.

(2) How do individual differences (i.e. epistemic beliefs and cultural activities) impact the nature of individuals' belief changes about a contentious science topic (i.e. GMOs)?

We expect the complexity of individuals' notions of the nature of science to relate positively to the complexity of the evidence presented to support their views. Conversely, we expect that engagement in activities relating to fresh fruits and vegetables will not have a positive relation with the complexity of the evidence related to their views about GMOs.

Methods

Participants

Participants for the study consisted of 81 undergraduate students recruited from natural science and social science courses. These participants consisted of natural science (e.g. biology and chemistry) majors (70%), social science (e.g. criminal justice) majors (10%), and education (e.g. English education) majors (20%) and were recruited during the fall semester of 2014. Participants were 60% female and somewhat diverse (70% Caucasian, 10% Hispanic, 10% African-American, and 10% Asian) with over 80% native English speakers. Mean age of the participants was 22.63 years (SD = 4.57) with a mean grade-point average of 3.36 (SD = .37).

Procedures

Participants were recruited via email and all study measures and materials were given online and data were collected on a secure server after consenting to participate. Participants completed the measures of initial views about GMOs, cultural activities related to consuming fresh fruits and vegetables (6 items), and epistemic beliefs about the domain of science (21 items). Participants were then randomly assigned to one of three conditions:

an informational text (meant to inform but not persuade), a persuasive two-sided refutational text (presents both sides but is meant to persuade the reader towards a pro-GMO position), or a narrative text (a story is presented about GMOs used in farming). After reading the text, participants completed the posttest about their views of GMOs (same as the initial views instrument) and one passage interest question which was not analysed for this study.

Instruments

Cultural activities relating to eating fresh fruits and vegetables

We developed an instrument measuring participants' cultural activities that we thought would directly relate to GMOs. Participants' responses for the cultural activities relating to fresh fruits and vegetables were captured via 100-pixel lines ranging from almost never to very frequently. An example item is, 'How often do you go to farmers markets or fresh produce stands?' Principal components analysis was used to create a factor score for each individual (scores having a mean of one and a standard deviation of zero). Eigenvalues and a scree plot indicated a one factor solution that explained 49.79% of the total variance of the items. High factor loadings indicated strong construct validity, ranging from .56 to .89. Construct reliability was also high ($H = .89$; Hancock & Mueller, 2001).

Epistemic beliefs about science

Similarly, participants' responses for epistemic beliefs about science were also captured via 100-pixel lines. The endpoints of the scale were opposing adjectives used to describe science and were adapted from connotative aspects of epistemological beliefs (CAEB; Stahl & Bromme, 2007). Participants were asked to, 'Place a mark on the line according to the words below that best describes what knowledge and knowing about science means to you.' An example item contained the opposing adjectives 'sure' and 'tentative'. Principle components analysis was used to create a factor score for each individual (scores having a mean of one and a standard deviation of zero). Eigenvalues and a scree plot indicated a three-factor solution that explained 50.71% of the total variance of the items. Further, these factors were subjected to varimax rotation. High factor loadings indicated strong construct validity on each of the three factors, ranging from .51 to .86, .31 to .71, and .62 to .80 for the three factors, respectively. Construct reliability was also high for all three factors ($H = .89$, .79, and .70, respectively). The three factors were stability, tentativeness, and social construction.

Pre- and posttest views about GMOs

The Structured Outcome of the Learning Observation (SOLO) taxonomy (Biggs & Collis, 1982) examines the structure and complexity of individuals' knowledge, rather than just the declarative content of that knowledge. Specifically, SOLO enables an examination of the datum or data used to reach a conclusion from a given cue. At the *prestructural* level, no data or datum is used, thus no evidence (empirical or otherwise) is used to support a conclusion. At the *unistructural* and *multistructural* one or multiple pieces of datum or data, respectively, are used to support a conclusion. At the *relational* level, there are multiple pieces of data used to support a conclusion and these data are related to each other, not just as a list. Finally, at the *extended abstract* level these data are related using an overriding abstract principle with that may generate multiple conclusions. For this study, SOLO was used to examine the conclusions participants drew (i.e. their viewpoint on GMOs) and the relevant data (i.e. evidence) used to draw that conclusion.

SOLO was used to score both the pre and posttest views on GMOs to compare the structure and complexity of these views before and after reading text about GMOs. The pre- and posttest viewpoints about GMOs consisted of two questions. First, participants were asked to respond to the question, 'What are the effects of GMOs?' Second, they were asked, 'Do you think farmers should use GMOs, why or why not?' The first question at both the pre- and posttest was coded using elements related to the nature of the participants' scientific understanding, while the second question was coded using the structure of the observed learning outcome (SOLO) taxonomy and quantified for subsequent analysis.

With regard to the second question, the SOLO taxonomy was used (Table 1) and responses were coded as prestructural (quantified as 0), unistructural (quantified as 1), multistructural (quantified as 2), relational (quantified as 3), and extended abstract (quantified as 4). Additionally, any responses that were determined to fall in between these levels were given a transitional score of .5 (e.g. a response between the multistructural and relational levels was scored a 2.5). Examples of each level are included in Table 1.

Interrater reliability was established through a training and independent coding process. First, the first and fifth authors jointly coded five participants' pretest responses and five participants' posttest responses. Once the raters felt comfortable with the scoring, each rater independently coded fifteen additional responses. Exact agreement was reached for twelve of those fifteen responses (80% exact agreement across eight coding categories). All disagreements were rectified in conference, with the first author coding the remaining responses.

Additionally, we used the three aspects of the nature of science identified in the introduction (i.e. certainty, evidence, and perspective) to further probe these open-ended responses to supplement the quantitative data produced by the SOLO scoring. The first centred on the certainty of the statement made by the participant (coded either 'certain' or 'uncertain'). This is meant to capture the tentativeness of the research supporting the understanding of GMOs and their impacts in both the human food supply and the ecosystems in which they come in contact. If the participant used phrases 'I think,' 'might,' or 'could,' to qualify the veracity of statement(s) and/or claims, the statement was coded 'uncertain.' An example of a statement that would be coded for demonstrating uncertainty would be:

> [I'm] not really sure one way or the other. Some say that there are great benefits from GMOs and others say that GMOs are harming us every time we eat them. The benefits could be that a farmer would be able to produce more crop and make more money but the downside is that the genetic modification could be harming us.

A statement that would be coded 'certain' if it had no qualifying statements, like the example below:

> GMOs are genetically altered fruits and vegetables. The alteration could be anything from changing it to not having seeds on the inside (seedless watermelon) to changing the shape or potentially color of the fruit or vegetable. It is not always a negative thing in my opinion. The mustard seed plant altered [its] genes many times and now we have a variety of vegetables from it.

Table 1. SOLO taxonomy for question two.

Taxonomy level	Score	Response characteristics	Sample response
Prestructural	0	Cue and response undifferentiated No logical interrelation for cue and response High closure or low consistency Cue linked with irrelevant feature(s)	*No, because non-GMO products are healthier*
Unidimensional	1	Relate question with one piece of relevant data with a logical operation Drawing a conclusion from a particular instance Responses equally correct but inconsistent with each other One relevant feature to link question and response	*No, while GMOs have desired traits such as resistance to disease or tolerance of pesticides, in the long run this can alter other DNA and make irreversible unhealthy effects*
Multistructural	2	Two or more relevant concepts or data Uses several features but does not link them Closure but lack of consistency Several relevant features link question and response	*I think they should because, overall, it creates more of a profit for farmers than traditional farming in most cases and provides the population with needed food*
Relational	3	Response which interrelates multiple concepts Overall concept or principle accounting for data presented Waits for all aspects before interrelating to make coherent whole Definite overgeneralised answer tied to concrete experience Uses relevant data in a conceptual scheme	*Yes, farmers should choose a more cleaner and natural alternative to their stocks. Even introducing one new animal or plant can have many effects on the genetic make-up of the surrounding stocks. If let to breed with their non-modified counterparts, it produces offspring with the flawed genetic make-up which could cause problems with the breed*
Extended abstract	4	Give information comprehended in relevance to an overriding abstract principle True logical deduction Heavily qualifies set out principle to application in given situations Question left relatively open Relevant data with interrelations under hypothetical abstract structure with alternative outcomes and no definite closure	*Yes, It has economical benefits and allows for specific hybrids to be chosen rather than spending years selectively breeding for a specific trait. However this does come with the caveat that GMOs are often of the same genetic make-up allowing a disease to kill off entire lineages of crops. This effect was seen when a banana disease killed almost all of the bananas that farmers were using and since they all used the same clone of banana all banana plants were killed. While this problem is not specific to GMOs, they will amplify the issue as companies sell GMOs from a single genetic clone reducing diversity*
Transitional responses	0.5; 1.5; 2.5; or 3.5	At a level of the taxonomy but marked by confusion or inconsistency Handles more information than able to cope with Loses track of the argument Forced to give up before reaching the next SOLO level	

Note: From Biggs and Collis (1982).

Although seedless watermelons are a product of selective breeding (considered non-GMO here), the response indicates a solid level of certainty.

For the second area of focus we examined the nature of the evidence the participant used to support their statement. This examination focused on the nature of the scientific habits of mind participants brought to bear in their statements. If the participant used verified scientific evidence, discussed studies they have read or fully utilised correct scientific principles to support claims, the statement was coded 'formal scientific.' An example a statement coded 'formal scientific' can be seen below. In this case, the participant discusses research evidence and correctly characterises the state of current findings.

> I think they can improve the quantity and quality of produce yields. It might also be able to help improve the yields and quality in the meat industry. I do think there may be some health risks in consuming genetically modified food, but would need to see more substantial research. I'm not sure that organic foods are always better either. I would need to see substantial research proving that organic is better genetically modified.

If scientific terms were used, but it was unclear whether the participant used them deeply to support the claim, the statement was coded 'informal scientific.' In the example of a statement coded 'informal scientific' below, the participant alludes to some possible related side effects (e.g. possible human allergies to GMOs), but fails to discuss specifics that would indicate scientific support for their claims: 'Not only are GMOs unhealthy, but they are contaminated forever. It also unleashes a host of unpredictable side effects. They also harm the environment because they reduce [biodiversity] and pollute water resources.' If scientific evidence was not invoked, it was unclear about the verification of this evidence (in these cases the participants might make statements like 'I heard' or 'someone told me'), or the statements were not supported by research, the statement was coded 'folk.' An example of a 'folk' statement would be: 'I feel like the [GMOs] make the food last longer. However, whatever is being shot into the food to "enhance" [its] quality is killing our bodies.'

Finally, we examined statements to determine whether the respondents' perspectives were positive or negative, or whether the participants offered a balanced view of the issues regarding GMOs. In statements that were coded as having a perspective, it was clear participants developed a strong opinion or view regarding GMOs. Additionally, it was also noted whether the viewpoint was negative (discussing cons of GMO use) or positive (discussing pros of GMO use). An example of a statement with a positive perspective was:

> I think GMOs have caused more controversy than actual adverse effects in the health of Americans. People get so caught up in the idea of their food being 'mutated', but it's only done to improve the quality of food and provide for the growing demand for food in America. If we did not eat as much, there would possibly be less of a need for GMOs because the natural agricultural products would be satisfactory.

Those statements that were coded as having a balanced perspective describe both pros and cons of GMO use, as can be seen in the following example participant response:

GMO potentially offer nutritional benefits for human consumption. Protein, vitamins, and useful macromolecules are often found in greater quantities in GMOs than in natural food sources. However, because GMOs altered at the molecular level are relatively new, there could be potentially multiple harmful effects for human consumption. [Long-term] consumption of the altered amino acid chains in GMOs could affect the molecular structures and processes of the human body.

Materials

The texts for the study were developed by the fourth and third authors. The fourth author is an expert in biology and the third author is an expert in reading comprehension. Three parallel texts were developed about the potential of GMOs with explanations as to the scientific basis behind their use, particularly in farming. The informational text presented information about GMOs without advocating a particular position. The persuasive text advocated for the use of GMOs in farming. The narrative text advocated for the use of GMOs from the viewpoint of a farmer. Each passage was approximately 1000 words and was written on a 12th-grade level (Flesch reading ease of 39.3).

Study design and plan of analyses

The design of this study is a quasi-experimental, mixed-methods approach. The quasi-experimental aspect refers to the random assignment of text to participants. Thus, between-subjects examinations of these groups (informational, persuasive, and narrative) can help elucidate the influences of these texts on view complexity and use of evidence.

Further, it is helpful to explicitly state our epistemology, specifically, how we see the role of the quantitative and qualitative evidence collected here. First, the quantitative data that were collected should support the theoretical model we proposed in the introduction, or if not, may direct us towards another possible model. Thus, the statistical tests based on means and variances that we have used are not interpreted in the null hypothesis significance testing (NHST) sense, rather how does these data and evidence help us better build a workable model that explains the relation between various types of text, reader characteristics, and their resulting view complexity and evidence. Rodgers (2010) described criticisms of NHST and the advantages to using mathematical models (including the means and variances used here) to determine model fit, rather than simply comparing the data to a null model. Second, we use the qualitative evidence from the open-ended questions as additional context to better explain the quantitative findings – both in support of and contrary to. Examining these data holistically, rather than narrowly interpreting a particular statistical significance test (e.g. $\alpha < .05$) should help build a better model, particularly since theoretical models have not included narrative text or view complexity as important aspects.

Results and discussion

Descriptive statistics

Bivariate correlations are presented for each of the study variables in Table 2. Distributions of scores for the SOLO coding are included in Figure 1 for the pretest and Figure 2 for the posttest. The effect sizes among these variables suggest that overall the text intervention did appear to change view complexities from pre- to posttest. The means and standard deviations for the pre- and posttest scores by narrative passage are included for all participants in Table 3. This is evidenced by the rather large changes in how both epistemic beliefs (NOS factors 1 and 3) and the activities questionnaire related at pre- and posttest to view complexity. The analyses for research questions one and two can help further elucidate the nature of these changes.

Research question 1: change in the use of evidence and the structure of knowledge about GMOs after reading

To help answer this first research question, we analysed participants' responses to the second outcome question following the reading. For that second outcome question posed to participants, 'Do you think farmers should use GMOs? Why or why not?', we began by running a repeated measures ANOVA with the pre- and posttest responses to question two as the repeated measures (i.e. two levels of the factor). We only used participants who had completed both the pre- and posttest data as well as the items for the between-subjects factor and covariate, which was a smaller subset of the total sample ($n = 40$). Additionally, we entered the type of text as a between-subjects factor and the activities factor score for each participant as a covariate. Both the between-subjects factor and covariate are discussed in subsequent sections. Given the very low bivariate correlations for CAEB, we did not add that to the statistical model at this time. In terms of the repeated measures effect for this question, the change from pre- to posttest test was not significantly different than 0 ($M = .08$, SD = 1.36, $F = 1.26$, df = 1.36, $p = .27$, $p\eta^2 = .034$). Not surprisingly, there were quite a few participants whose response remained the same ($n = 22$), with some not even reiterating their answer (e.g. 'still the same answer').

However, we were surprised that there were quite a few participants who dropped in score (i.e. complexity) from pre- to posttest (distributions of change scores are presented in Figure 3). In fact, some of these scores dropped rather dramatically (from a SOLO score of 3.5 to 0 in two cases). Given this surprising finding, we probed the qualitative responses to try to better understand these changes. One of these participants in the pretest left open the conclusion given some conditions albeit with weak evidence stating that:

> Yes and no. Yes a farmer should use GMOs is his crop is not surviving very well and he is not able to make a profit, but that farmer should be required to state that his farm contains GMO's. No a farmer should not use GMO's if he is able to produce a good amount of crop and be able to make a profit.

However, at posttest there was no evidence presented and a very quickly drawn conclusion, 'No, I believe that the risk outweighs the reward.' There are two possible explanations for these declines in the responses to this question. First, it is possible that by the time participants got to the posttest they were fatigued and no longer felt like writing a detailed response. Second, actually reading a passage about evidence related to GMOs might actually turn off individuals' conscious reflection about scientific evidence (Stanovich & West, 1997). We do not rule out that fatigue may have had an effect, but given the relatively short passage and some of the strong negative opinions for the posttest responses (e.g. 'No! They are not necessary and could ultimately harm us more than benefit us!), the latter conclusion seems more probable.

Given both the increases and decreases in view complexity about GMOs discussed in the previous section, we wanted to see if the type of text (i.e. narrative, informational, or persuasive) could explain some of the differences in change from pre- to posttest. Changes in SOLO score for question two from pre- to posttest by text condition were a

Table 2. Correlation table of quantitative study variables.

	Pre	Post	NOS 1	NOS 2	NOS 3	Act
Pretest structure	–					
Posttest structure	.24	–				
NOS factor 1	−.32	.03	–			
NOS factor 2	.27	.19	.00	–		
NOS factor 3	−.11	.14	.00	.00	–	
Activities	−.31	−.08	−.02	.10	−.03	–

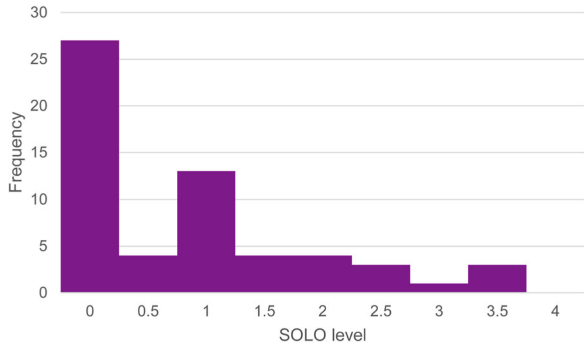

Figure 1. Distribution of scores for question two (pretest).
Note: $n = 72$.

.35 point increase for narrative text (SD = 1.34), a .28 point increase for informational text (SD = 1.40), and a .45 point *decrease* for the persuasive (SD = 1.28) text. These differences had a moderately large effects size, but likely due to the smaller sample were just above the .05 threshold for significance ($F = 2.86$, df = 2, 36, $p = .070$, $p\eta^2 = .14$).

This moderately large effect size supports Slater and Rouner's (2002) notion that counter-argument (in the persuasive text) may actually promote cognitive resistance and *de*complexify their responses, whereas the narrative text was associated with the highest increase in complexity. This may also be due to an effect that Koehler (2016) described whereby presenting counter viewpoints with which experts would agree with nonetheless gets a lot of attention from the reader, even if that counter viewpoint is only supported by a few scientists. Without sufficient background knowledge, this added complexity in terms of argument in text may actually decrease the complexity of their views in terms of the relevant data readers can bring to bear on the given cue.

We again turn to the qualitative data from the short-answer questions to deepen our understanding of the trends identified in the prior quantitative analysis. Qualitative coding using certainty did reveal some differences due to text type. After reading the persuasive text, some participant responses to the questions indicated an overall shift towards being more certain of the claims being made. For example, prior to reading the persuasive passage, this participant stated that GMOs: 'Provide more crop growth and better

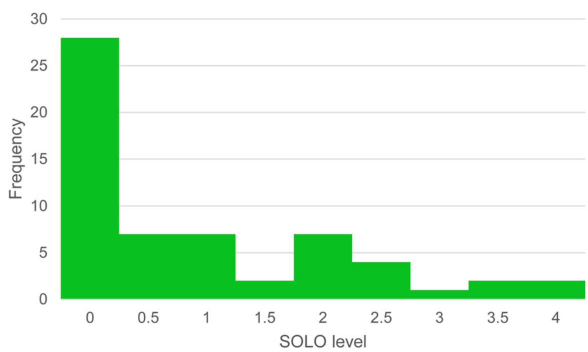

Figure 2. Distribution of scores for question two (posttest).
Note: $n = 60$.

Table 3. Means and standard deviations of the pre and posttest scores by type of text for all study participants.

Type of text	Pretest	Posttest
Narrative	0.72 (0.84)	1.06 (1.23)
Informational	1.00 (1.11)	1.09 (1.14)
Persuasive	0.95 (1.06)	0.63 (0.78)

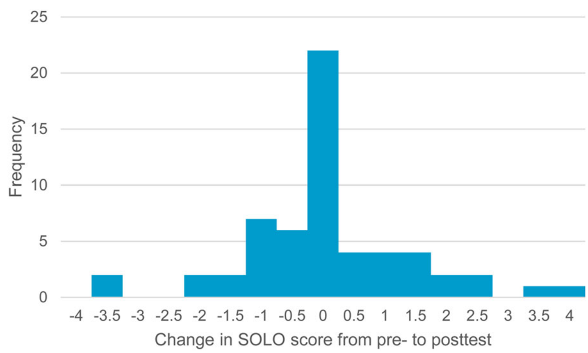

Figure 3. Distribution of change scores from pre- to posttest.

developed plants. However, there could be concern with the unknown long-term effects, as this is a more recent revelation.' While noting some positives, they were unsure about possible adverse effects that they thought might be emerging from further, longer term research. After the reading, this participant showed a greater sense of certainty about the effects of GMOs:

> The effects of GMOs are beneficial to the economy, the farmers, and the consumers thus far as I'm unaware of any significant health risks. The negative effect of GMOs however is their effects on plants and animals such as caterpillars. Some of these plants have been modify to kill their predators but can end up harming several others.

Unlike the earlier passage, the participant provided a clearer sense of the risks as described in the reading while showing less tentativeness towards the effects of GMOs.

While most statements were coded as *folk* prior to the persuasive text, the nature of the evidence for statements was more evenly spread across all codes after participants had read the text. This suggests that participants may have used the scientific content of the reading in their discussion of GMOs, as was indicated by this participant:

> I am also deeply disturbed by the possibility that whatever GMOs we put out there now can never be taken back. They will remain in the environment via wind dispersion for years and years. In my opinion these negatives far outweigh the benefits without more rigorous testing of GMOs. I would like to see protocols similar to drug trials, under controlled conditions for GMOs before releasing them into the environment.

No apparent trends existed for the type of perspective taken by the participants assigned the persuasive reading. This may not be surprising, as both sides of the issues surrounding GMOs were presented in this text.

The participants who read the narrative text showed a small increase in statements coded *certain* from pre-reading to post-reading of the text; however, there appeared to be a decrease in statements coded *folk* after participants read the text. Similar to the data for participants assigned the persuasive text, the findings suggest that readers of the narrative text were able to draw upon the text to increase the scientific content of their responses. For example, this participant was unsure and described the effects very generally prior to the reading: 'I do not believe there are any noticeable effects of GMOs as just saying a modified organism doesn't state that it should have any effect,' but was able to be more specific, drawing upon some scientific information after the reading:

> I don't believe that are any long lasting effects of GMOs on humans as most of the genes are selected to only grow on specific portions of the plants and because the pesticides used have been selected to not be harmful. There may be effects in the ecology by using cloned GMOs that have similar genetics.

There was a small increase in the number of statements coded with a positive perspective towards GMOs, but there appeared to be a shift away from negative perspectives to a balanced view of them. Overall, while it appeared that the narrative text did not shift opinions towards supporting GMOs, it may have moderated these views.

For participants assigned the informational text, their certainty of claims did not change a great deal overall; however, the degree of certainty that participants had in their statements was a bit surprising, considering the controversial nature of GMOs and the conflicting information in the public sphere. Like the persuasive and narrative texts, there was a decrease in the number of post-reading statements coded as *folk*. The perspective type totals remained unchanged pre- and post-reading. This would correspond with the non-persuasive intent of the text.

Overall, the statements exhibited greater certainty after participants read the persuasive text, while they remained relatively unchanged for participants who read the narrative and informational texts. It is unclear why this was the case and further examination of the nature of certainty is necessary for this study. For example, it was difficult to determine whether a participant's uncertain views were due to their unfamiliarity with the subject (reflecting a more novice view of the science surrounding GMOs) or that they were reflecting the tentative nature of the current scientific understanding of GMOs (a more sophisticated scientific worldview). The findings indicate that post-reading responses across all text types were supported by a more sophisticated scientific conceptualisation of GMOs. This may be reflective of the scientific content of each reading and its influence on the post-reading statements. Perspectives on GMOs changed only in the case of participants who were assigned the narrative text. This may be explained by the fact that the informational text provided a balanced view and the persuasive, while having a more positive spin towards GMOs, also included arguments for both sides of the issue.

Research question 2: effects of individual differences on view complexity about GMOs

We also sought to explain some of the differences in change from pre- to posttest as a result of individuals' cultural activities around fresh fruits and vegetables (which may contain GMOs). As with the effect of the type of text on the change from pre- to posttest, changes as a result of the interaction with the cultural activities were just shy of the .05 threshold for significance ($F = 3.08$, df = 1, 36, $p = .088$, $p\eta^2 = .079$) albeit with a smaller effect. Additionally, we did detect a change in the correlations between the activities, which were statistically significantly negatively correlated with pretest scores ($r = -.31$, $p = .033$), but were no longer significantly different than zero at posttest ($r = -.075$, $p = .64$). Thus, there is the possibility that these activities influenced viewpoints on GMOs (or vice versa) before the text, but upon reading the text there were enough change in views and complexity of views that the variance in complexity was more related to the text than that of their cultural activities related to food. Specifically, reading text that presents evidence that can be used as data to support a viewpoint may have mediated the previous relation between those cultural activities and the complexity of their views.

Although we did not model the interaction of participants' NOS in the within-subjects model, our qualitative examination of participants' comments revealed some interesting patterns. For instance, some participants that changed very little from pre- to posttest quantitatively discussed the effects of the passage in their answer to the posttest question that related to the nature of science. For example, one participant stated that:

> Even though I have read the study, I still feel the same about GMOs. The science and technology is still young and needs to be developed further before we can say its [sic] completely safe for us and our environment.

Similarly, for those participants with higher scores on the activities measure (over one standard deviation greater than the mean), the comments definitely reflected not only a distaste for GMOs, but also many arguments against GMOs unrelated to scientific evidence. For example, Monsanto (who produces many GMO products including seeds as well as pesticides and herbicides designed to work with these seeds) was a popular target:

> I think that it should be up to the farmer but that any product that contains GMOs should be labeled so that people can make their own decision as to what they put into their body. I do not think companies like Monsanto should be able to patent organisms or punish farmers if their 'product' is found growing on their land when they didn't plant it their [*sic*].

Thus, the views on the use of GMOs and the evidence oftentimes was not scientific at all – rather, political or cultural. While we have just scratched the surface of these socio-scientific issues, there were some indications that participants were resistant to this biotechnology because they were associated multi-national corporations and agribusiness. This association may have been a factor in their acceptance of evidence about GMOs.

Conclusions and future directions

The data presented here help us to build better theoretical models of views on contentious scientific issues in two major ways – changes in the processing of information may not be reflected in view complexity and that there is evidence that text type may play a specific role in how this processing takes place. Before turning to these two issues, it is important to contextualise the overall non-significant finding in the repeated measures ANOVA for change in view complexity. Rather than assuming that the non-significant finding indicates that change in view complexity was random, our interpretation of the quantitative and qualitative evidence is that there were actually specific patterns in the growth, decline, or stability of these scores that can be attributed in part to processing and the texts themselves. Individuals' processing and interaction with the texts are two possible reasons these different patterns in view complexity may change in these ways.

First, reader characteristics, such as epistemic beliefs may play an important role in how and whether information from the text will be integrated into their views. While epistemic beliefs have long been associated with changes in academic performance (e.g. Schommer, 1993) more generally and science performance more specifically (e.g. Chen & Pajares, 2010), the evidence points here to a change in view complexity as well – which is not often measured in studies that examine performance or achievement. Additionally, what those readers do in their everyday lives (i.e. their cultural activities related to food) also play a role (e.g. Brown & Crippen, 2016) as evidenced by the qualitative findings as well as indications in the quantitative data that there at least appears to be a small effect. Thus, theoretical models of scientific beliefs – and view complexity specifically – must account for these characteristics of the reader to better describe the influence of texts on readers' views.

Second, with regard to the text itself, there were indications in these data (both quantitative and qualitative) that the type of text (narrative, information, and persuasive) change the manner in which individuals process text. Although the sample is relatively small, the changes in view complexity in these three conditions had a moderate effect that was supported by the qualitative findings as well. While evidence has suggested that persuasive text might be best in changing individuals views (Hynd, 2001), the effects of the text on view complexity were contrary to these findings. In other words, one's views might change after reading a persuasive text, however, we have not achieved one of the major goals of science education which is to make use of available evidence to support a given conclusion.

These two major findings can help build more useful models of learning about socio-scientific issues. If the goal is to change individuals' views about a contentious scientific issue, persuasive text might well play a role in changing those views. However, if the goal is helping individuals understand the complexity of the problem at hand (GMOs in this case), narrative text may actually be more helpful – one interpretation being that narrative (or informational) text may not make the reader resistant to further processing and use of evidence (Slater & Rouner, 2002).

One limitation of the current study relates to the size of the sample, which was relatively small for large-scale statistical analyses. However, since our purpose as described in the data analysis section was to use these tests to build a more useful model about view complexity, we do not interpret significance values over .05 as meaning that these data would support the interpretation that epistemic beliefs or type of text matter, rather that the effect was smaller than we initially anticipated. Our hope is that these data will help build better theoretical models that can be used to frame future studies. Additionally, the collection and interpretation of qualitative data supported these interpretations – we did not interpret the data based on the quantitative analyses alone.

Future directions for research

The more exploratory nature of these findings opens up many avenues for further research. First, at least in terms of complexity, the net positive effect for narrative and expository text and the net negative effect for persuasive text from pre- to posttest should be further explored since this finding is contrary to many of the positive effects of persuasive texts more generally on beliefs (e.g. Buehl et al., 2001). The texts used in this study were manipulated in very small, controlled ways in order to keep the texts as parallel (and comparable) as possible in all other aspects (only manipulating a few sentences). It is quite possible that larger manipulations of text would lead to even larger differences in view complexity – such as a major restructuring of the text. Additionally, the effects of narrative text should also be investigated as a text structure that might afford the advantages of persuasive text in terms of more positive reading outcomes (e.g. metacognitive monitoring and control) with the narrative components lowering the cognitive resistance of reader, a particular effect seen in these data.

Second, the socio-cultural milieu of participants should be further considered in terms of how cultural beliefs or practices may interact with specific interventions. While Kahan et al. (2012) found that political views did shape individuals' views about science, these data support the notion that intervention, such as text, can change the relation between cultural activities and the complexity of their views. Extension of this research could examine how other types of intervention or activities (e.g. classroom instruction, scientific simulations) might mediate the relation between the socio-scientific and the nature of individuals' views about a contentious scientific issue.

Third, follow-up interviews using a more qualitative approach could add clarity about participants' views on scientific issues. While our coding for the short-answers about participants' views on GMOs yielded some useful context, a deeper discussion about these perspectives would add greater depth to this context. For example, participants indicated that they were uncertain about the evidence to support their views. Follow-up interviews might help get to the deeper causes of this uncertainty (e.g. conflicting studies they had read, mistrust in corporate-funded research, discussions with peers about safety reports). These data could add clarity to participants' senses of uncertainty, whether personal or in a more scientific sense.

Implications for practice

Due to the more exploratory nature of these findings, caution would be recommended at implementing these ideas in any systematic way. However, two specific recommendations may help teachers and instructors better understand students' changing viewpoints. First, the texts that teachers use in the classrooms tend to be rather expository (e.g. chemistry; Chiappetta, Sethna, & Fillman, 1991) and present science as a body of knowledge, rather than a way of thinking. More of a focus on text that allows readers to understand science from a particular point of view (such as narrative text) may provide benefits beyond simply the collection of knowledge. These texts may start to build students' complexity of knowledge if different narrative viewpoints are introduced throughout a course. For example, multiple narratives on climate change may present perspectives from those that propose different solutions to the issues, while acknowledging an issue exists. These solutions may include those that recommend a decrease in CO_2 in contrast to those that propose carbon capture. This may be a method to show uncertainty in science (for solutions) in a manner that captures a scientific consensus (that there is an issue).

Second, specific classroom activities to elicit and share students' cultural beliefs and activities should give teachers a better understanding of how these beliefs may influence their views on scientific topics in terms of both their beliefs about these issues and how complex they believe them to be. For example, in an environmental biology classroom, understanding students' experience with water may influence their initial views about conservation of water. Students who have lived in or through long periods of drought may have different views than those who have never thought much about the issue in the course of their daily lives. Children in California in the United States who lived through a water crisis in which there were water usage restrictions in place may have particular strong pre-existing views on the use of and conservation of water. Through the use of better theoretical models that take into account view complexity as well as changing beliefs, science educators can better adjust texts to meet the needs of the individual characteristics of the readers in their classrooms.

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