Using Persuasive Refutation Texts to Prompt Attitudinal and Conceptual Change

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Abstract

We investigated knowledge and attitudes before and after reading refutation texts augmented by different kinds of persuasive information and how emotions mediated the process of knowledge and attitude change. Undergraduates (N = 424) enrolled in four universities from three countries read a refutation text on genetically modified foods (GMFs) and were then randomly assigned to receive additional information about advantages of GMFs, disadvantages of GMFs, or both. After studying, students reading about advantages of GMFs had significantly more positive attitudes than students who read about disadvantages. There was also a significant reduction in misconceptions; participants in the positive-oriented text condition showed the largest learning gains, particularly those who held more positive initial attitudes. Epistemic emotions of curiosity, frustration, hope, and enjoyment mediated attitude change while confusion mediated relations between pre-reading attitudes and post-reading knowledge. In addition, the direct relationship between prior attitudes and surprise was moderated by type of text. When reading about both advantages and disadvantages of GMFs, participants reported significantly less surprise when compared with those who read about either advantages or disadvantages of GMFs. To foster conceptual change when learning about complex topics, refutation texts may be paired with persuasive information that is aligned with accurate conceptions.

Keywords: conceptual change, epistemic emotion, attitude, refutation text, persuasive text

Educational Impact and Implications Statement

This study advances the idea that learning processes involve attitudes and emotions. We presented text to undergraduate students intended to correct misconceptions about genetically modified foods (GMFs) and paired it with information about the advantages of GMFs, the disadvantages, or both advantages and disadvantages. We found that participants who read text paired with information about the advantages of GMFs had fewer misconceptions and more positive attitudes towards the topic compared with those who read about the disadvantages. We also found that some emotions (i.e., hope, enjoyment, confusion, and frustration) elicited through reading the text mediate relations between pre- and post-reading attitudes and knowledge, while others did not (i.e., surprise, boredom, hopelessness, anger, anxiety, and curiosity). These findings suggest that the greatest learning occurs when text is crafted to shift both knowledge and attitudes and it may be the case that refutation texts can be paired with persuasive information to do so.

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In an era of online misinformation of questionable content being widely dispersed online and through social media, it is no surprise that many people hold misconceptions about various topics. This is especially true for controversial science topics—vaccinations, stem cell research, climate change, or genetically modified foods (GMFs)[1]—where a large portion of information found on the Internet is inaccurate (e.g., Kortum, Edwards, & Richard-Kortum, 2008; Scheufele, & Krause, 2019)—and topics regarding health issues (Allcott, Gentzkow, & Yu, 2019; Kata, 2012). Exposure to misinformation can result in large discrepancies between scientifically valid accounts and citizens' views; for example, a common misconception that genetic modification involves cloning and hormone injection (Varzakas, Arvanitoyannis, & Baltas, 2007) may explain why 88% of scientists believe GMFs are safe to consume yet only 37% of citizens share this belief (Funk & Kennedy, 2016). Misunderstandings and inconsistencies of this sort can lead the public to question the legitimacy of scientific viewpoints (Skogstad, 2003) and adopt negative attitudes.

Attitudes are positive or negative evaluations of a person, object, or event (Eagly & Chaiken, 1993) and can shape the approach people take towards engaging with a topic and influence how they construct an understanding from diverse sources (e.g., Heddy, Danielson, Sinatra, & Graham, 2017; Sinatra & Seyranian, 2016). Research has shown that misconceptions are often linked to negative attitudes which can make correcting misconceptions challenging (Broughton, Sinatra, Nussbaum, 2011; Heddy et al., 2017) because people with negative attitudes may resist engaging thoughtfully with new ideas (see Sinatra & Seyranian, 2016).

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[1] We use the term genetically modified food (GMF) rather than genetically modified organism (GMO) to discern between organisms specifically modified for human consumption. We make this distinction because individuals may hold more negative attitudes and beliefs regarding organisms modified to be consumed as food compared with organisms that are modified for other purposes (e.g., genetically modified cotton used for clothing fabric).

Attitudes that people hold are also linked to the emotions that they feel after engaging with novel information (Eagly & Chaiken, 1993), and both attitudes and emotions are linked to knowledge about controversial science topics like GMFs (Heddy et al., 2017). This invites research on how interventions designed to overcome learners' misconceptions could take account of prior conceptions, emotions, and attitudes.

Fortunately, several approaches exist that can productively shift learners' misconceptions and attitudes. One approach that specifically targets misconceptions, called refutation texts (Sinatra & Broughton, 2011), explicitly state misconceptions, provide direct refutation of those misconceptions, and explain the scientifically valid position (Kendeou, Walsh, Smith, & O'Brien, 2014; Kendeou & van den Broek, 2007). Another approach that specifically targets attitudes, called persuasive texts, are designed to persuade readers (but are not necessarily refutational) and can be crafted to guide readers towards adopting positive or negative attitudes by emphasizing the "pros" or "cons" of a given controversial subject (Murphy, 2001; Sinatra, Kardash, Taasoobshirazi, & Lombardi, 2012). Though studies have examined the impact of refutation or persuasive text on knowledge and attitude change (Heddy et al., 2017; Sinatra et al., 2012) none have investigated whether persuasive information might be crafted in ways to shift attitudes in various ways and whether these attitude manipulations might better support learners as they reflect on, and correct their own misconceptions while reading a refutation text.

As such, the purpose of this study was to extend previous theoretical (Sinatra & Seyranian, 2016) and empirical work by examining the relationship between knowledge, attitudes, and emotions when learning from different persuasive refutation texts. Specifically, we investigate how refutation texts paired with different types of persuasive information might differently impact attitudes, emotions, and knowledge outcomes. We set the stage for our specific research questions and hypotheses by first reviewing relevant theoretical and empirical work.

Theoretical Frameworks and Prior Research

Attitudinal and Conceptual Change

A long tradition of research has investigated factors impacting conceptual change (Dole & Sinatra, 1998; Pintrich, Marx, & Boyle, 1993; Posner, Strike, Hewson, & Gertzog, 1982) and attitude change (Eagly & Chaiken, 1993; McGuire, 1985; Petty, Cacioppo, & Goldman, 1981). Until recently, researchers studied conceptual and attitudinal change independent of one another (e.g., Chi,1992; Woloschuck, Harasym, & Temple, 2004). In the following sections, we summarize research on attitudinal change, conceptual change and recent research that has begun to investigate relationships between the two.

Attitudes and attitude change. Attitude research is foundational in the field of social psychology (Allport, 1935; McGuire, 1985; Maio & Haddock; 2010). Although there is no consensus on how to define the construct of attitude, many researchers consider attitudes to be the valenced (e.g., positive or negative) evaluation of an object or entity which is expressed by beliefs, affects, and behaviors (Eagly & Chaiken, 1993; Sinatra & Seyranian, 2016). For example, attitude theorists might argue that individuals who refuse to purchase corn because it has been genetically modified express a negative evaluation of GMFs, as demonstrated in their beliefs (e.g., that GMFs are dangerous), affect (e.g., anxiety or fear), and behavior (e.g., a boycott).

Attitude change occurs when an individual's evaluation of an object, person, or event changes in valence to become more or less positive or negative (Maio & Haddock, 2010). There has been a great deal of research on facilitating attitudinal change (Eagly & Chaiken, 1993; Petty et al., 1981; Sinatra & Seyranian, 2016). The Elaboration Likelihood Model posits that, if individuals are highly motivated and have requisite abilities to succeed on a given task, they will be more likely to engage in more thorough processing and experience attitude change (Petty et al., 1981). That is, if people process information to overcome misconceptions (e.g., conceptual change), they are more likely to also experience attitude change.

Misconceptions and conceptual change. Conceptual change researchers explore factors involved in resolving misconceptions between prior knowledge and scientific information (Dole & Sinatra, 1998; Vosniadou, 2013). Students' prior knowledge and experiences sometimes conflict with normative scientific perspectives (Dole & Sinatra, 1998; Vosniadou, 2013). If students hold scientifically inaccurate ideas or have insufficient knowledge, traditional conceptual change frameworks suggest misconceptions can be corrected by revising their existing mental models. That process is called conceptual change (Dole & Sinatra, 1998; Posner, Strike, Hewson, & Gertzog, 1982; Vosniadou, 2013).

Traditional models of conceptual change were framed in terms of cognitive factors that bring about conceptual change with little attention to contextual or attitudinal constructs (e.g., Posner et al., 1982). More recently, conceptual change has been recognized as a process of restructuring knowledge that is influenced by sociocultural, motivational, and affective factors (Pintrich, Marx, & Boyle, 1993; Sinatra, 2005; Sinatra & Mason, 2013). These recent frameworks for conceptual change have motivated empirical investigations of refutation texts to shift attitudes and misconceptions (e.g., Heddy et al., 2017). Understanding the role attitudes play in learning about controversial topics like GMFs is important for understanding conditions necessary for change.

Relation between attitudinal and conceptual change. Sinatra and Seyranian (2016) described a 2 x 2 matrix representing four different stances an individual might have when learning about controversial science topics. Briefly, these four combinations are *pro-justified* (favorable attitude and accurate knowledge), *pro-unjustified* (favorable attitude and inaccurate knowledge), *con-justified* (negative attitude and accurate knowledge) and *con-unjustified* (negative attitude and inaccurate knowledge; Sinatra & Seyranian, 2016). In general, Sinatra and Seyranian (2016) posit that attitudes, in addition to misconceptions, can obstruct learning of any topic, particularly controversial ones; and because learners' attitudes may be related to their misconception, changing the misconception may impact the valence or the strength of their attitude.[2] Heddy and colleagues (2017) investigated relations between attitude change and conceptual change in undergraduate students as they engaged with a text designed to correct misconceptions about GMFs. Those students who held negative attitudes had misconceptions about GMFs (con-unjustified), who read the refutation text shifted attitudes positively towards the topic and overcame misconceptions. Similarly, students who held a positive attitude and misconceptions about GMFs (pro-unjustified) maintained their positive attitude while correcting misconceptions after reading the refutation text.

Though this study suggests that correcting misconceptions can shift attitudes about GMFs, there is currently no research that manipulates attitudes to investigate the relationship between attitudes and conceptual change. According to Sinatra and Seyranian's (2016) framework, we hypothesize that providing learners with a text that targets their attitudes and misconceptions about a controversial topic (e.g., by providing them with a persuasive refutation text) will lead to greater attitude change and conceptual change. Yet, while Sinatra and Seyranian

[2] It is important to note that it may be possible that a learner's negative attitude could be associated with accurate conceptions. For example, an individual might be expected to have more negative attitudes towards smoking if they have an accurate knowledge of the associated health risks. For this study, however, we focus on the case of GMFs where positively shifting attitudes are expected to correspond with more accurate conceptions.

(2016) posit that conceptions and attitudes are closely related, the authors do not specify the direction of this relationship. Heddy and colleagues (2017) tested a particular relationship between knowledge and attitudes, though alternate relationships have not been explored empirically. As such, we tested various hypotheses regarding the directional relationships of attitudes and knowledge that extend from Sinatra and Seyranian's framework (2016; see Supplemental Material).

Impact of refutation and persuasive texts on attitudinal and conceptual change. A large body of research has investigated the use of refutation and persuasive texts and their influence on conceptual and attitudinal change outcomes (Alexander, Fives, Buehl, & Mulhern, 2002; Broughton et al., 2011; Murphy, 2001; Sinatra & Broughton, 2011; Sinatra et al., 2012; Tippet, 2010). Most of this research examines the impact of refutation texts (Kendeou, Walsh, Smith, & O'Brien, 2014; Kendeou & van den Broek, 2007; Sinatra & Broughton, 2011) or persuasive texts (Chambliss & Garner, 1996; Murphy, 2001) on conceptual change outcomes, and there is little, if any, research that investigates the influence of refutation texts paired with persuasive information as a means of testing the impact of on both attitudes and knowledge change. In the sections below, we review research that details the influence of refutation texts and persuasive texts on conceptual and attitude change about controversial topics in science, and argue that they might be paired for greater conceptual change.

Refutation texts. One way of shifting learners' attitudes and conceptions is with refutation texts. As noted, refutation texts are designed to prompt conceptual change by having readers attend to conflicts between their own conceptions and those in a text (Broughton et al., 2011; Sinatra & Broughton, 2011, Tippet, 2010). They have been typically used by researchers to shift scientifically inconsistent conceptions by explicitly stating misconceptions, directly refuting them, and then explaining the scientifically accepted position (Kendeou, Walsh, Smith, & O'Brien, 2014; Kendeou & van den Broek, 2007; Sinatra & Broughton, 2011). For example, a text may state, "Some people think that climate change is due to natural causes alone" (a common misconception), "however, this is not the case" (direct refutation). "There is considerable evidence that humans are contributing to the warming effect through increased CO_2 emissions" (explanation). Refutation texts have been shown to be effective in shifting individuals misconceptions about a variety of controversial topics (e.g., Pluto's demotion to dwarf planetary status, Broughton et al., 2011; GMFs, Heddy et al., 2017), non-controversial topics (e.g., seasonal change, Cordova, Sinatra, Jones, Taasoobshirazi, & Lombardi, 2014), as well as non-scientific topics (e.g., Aguilar, Polikoff, & Sinatra, 2019).

Research has shown that the effectiveness of refutation texts can be improved by various augmentations such as by providing graphics explaining the text (Danielson, Sinatra, & Kendeou, 2016). Refutation texts are not necessarily designed to be persuasive (i.e., designed to shift attitudes and beliefs), but they have been shown to influence attitudes (Heddy et al., 2017). However, little research has explored whether augmenting a refutation text with persuasive information (i.e., information about the advantages, disadvantages, or both advantages and disadvantages of a topic) would improve its effectiveness, leading to more attitudinal and conceptual change.

Persuasive texts. Research on persuasive texts also informs our study (Alexander, Fives, Buehl, & Mulhern, 2002; Murphy, 2001; Sinatra et al., 2012). Compared with traditional texts that are created to provide information to the reader, persuasive texts acknowledge that learners have prior attitudes and conceptions and are designed to leverage social/cultural, motivational, and cognitive information to evoke a change in a reader's conceptions and attitudes (Chambliss

& Garner, 1996; Murphy, 2001). A text is considered persuasive “if it is structured to counter the current beliefs of a typical reader as well as to present new ones by capitalizing on a reader’s existing knowledge and beliefs” (Chambliss & Garner, 1996, p. 294) and is expected to change attitudes because these properties call for more thoughtful processing of the message (Petty & Briñol, 2010). Persuasive texts often use provocative language to assert the “pros” or “cons” of a given topic, but do not typically use refutations. For example, a positively oriented persuasive text about GMFs might emphasize the advantages of harvesting genetically modified crops (e.g., foods can be engineered to withstand droughts or to contain additional vitamins and minerals). A negatively oriented persuasive text might emphasize the disadvantages of harvesting genetically modified crops (e.g., there is a possibility that insects will eventually become resistant to genetically modified pesticides or that humans will eventually develop allergies to GMFs), while a text that provides both the pros and cons might present a reader with a combination of advantages and disadvantages[3] (e.g., GMFs can withstand droughts, insects may become resistant to genetically modified pesticides).

Evidence suggests that persuasive texts can shift attitudes; Sinatra et al. (2011) crafted a persuasive text asserting that human activity comprises “the driving force” behind climate change, but did not target misconceptions. The text improved undergraduate students’ attitudes towards climate change as well as their expressed willingness to take action to mitigate the effects of climate change (Sinatra et al., 2012). Other studies have shown persuasive texts can be crafted to shift attitudes regarding other controversial topics in science (Alexander et al., 2002;

[3] Such “two-sided” persuasive texts are expected to be perceived by the learner as more credible and balanced than one-sided texts, though the direction of persuasion and attitude shift is not guaranteed given that attitude shifts depend on learners’ prior knowledge, motivation, attitudes, and ability to detect subtle bias (Hynd, 2001; Petty & Briñol, 2010; Stiff, 1994). As such, findings on the persuasiveness of two-sided texts compared with one-sided texts have been mixed (e.g., Buehl, Alexander, Murphy, & Sperl 2001).

Chambliss, 1995; Hynd, 2003; Kardash & Scholes, 1995).

As mentioned, persuasive texts are designed to shift attitudes because their compelling messages can elicit more thoughtful processing of relevant information (Chambliss & Garner, 1996**;** Petty & Briñol, 2010), while refutation texts are designed to shift knowledge by guiding people to reflect on and resolve conflicts between their prior misconceptions and those presented in a text (Tippet, 2010). Supplementing refutation text with persuasive information (which we refer to hereafter as “persuasive refutation text”) should thus have the combined effect of shifting both knowledge and attitudes—shifts that are expected to be dependent on one another (Sinatra & Seyranian, 2016). Namely, we posit refutation texts can be crafted to positively shift attitudes by including persuasive information that present advantages of a controversial science topic, negatively shift attitudes by presenting disadvantages, or yield mixed attitude shifts when presented with both advantages and disadvantages (see e.g., Petty & Briñol, 2010). Therefore, we hypothesized that persuasive information could lead to attitude shifts, as well as conceptual shifts due to the connected nature of attitudes and misconceptions (Sinatra & Seyranian, 2016). No prior research has experimentally verified whether persuasive augmentations to refutation texts can shift attitudes and misconceptions. In addition to this research gap, little research has examined the role of emotions in conceptual change from refutation and persuasive texts (e.g., Heddy et al., 2017; Sinatra, Broughton, & Lombardi, 2014). In the next section we discuss current theoretical models of emotion in conceptual and attitudinal change research as further extensions to Sinatra and Seyranian’s (2016) framework.

Emotions

Emotions that students experience permeate academic settings and are recognized as critical factors affecting student learning, conceptual change, and attitude change (Pekrun, 2006;

Pekrun & Linnenbrink-Garcia, 2014; Rosenberg, 1998; Scherer, 2000). Academic emotions are emotions that occur in academic settings and are multifaceted phenomena that include affective, cognitive, motivational, physiological, and expressive processes (Scherer, 2000). For example, the confusion learners may experience upon reading information that conflicts with their current conception may be associated with feelings of uneasiness (affective), worry about resolving conflicting conceptions (cognitive), a desire to quit the reading task (motivational), an increased heart rate (physiological), and a confused facial expression (expressive; Muis, Chevrier, & Singh, 2018).

Emotions can facilitate or constrain conceptual change (e.g., Fielder, 2001; Gregoire, 2003; Linnenbrink & Pintrich, 2002; Sinatra et al., 2014). Of particular relevance, when individuals are presented with information that conflicts with prior knowledge or recently processed information, this likely triggers epistemic emotions (emotions that arise during knowledge construction, such as curiosity; D'Mello & Grasser, 2012; Muis, Chevrier, & Singh, 2018). For example, cognitive incongruity between an individual's misconception and the correct conception can result in the epistemic emotion of surprise, which draws attention to what caused the surprise (Peters, 2006). Increased attention drawn to the surprising information can result in better memory and more intense processing of that information (Foster & Keane, 2015; Muis, Chevrier, & Singh, 2018; Vogl, Pekrun, Murayama, & Loderer, 2019), which may further the conceptual change process (Broughton, Sinatra, & Reynolds, 2010) and lead to changes in attitudes (Petty et al., 1981). As such, epistemic emotions are considered to mediate changes in attitudes and knowledge about controversial topics (Muis, Chevrier, & Singh, 2018) as has been supported empirically (Heddy et al., 2017; Broughton et al., 2011; Muis et al., 2015; Muis, Sinatra, et al., 2018). For example, Heddy and colleagues (2017) found epistemic emotions were significant mediating variables in attitudinal and conceptual change when learners read information intended to correct misconceptions about GMFs. In particular, undergraduate students with more negative attitudes towards GMFs reported significantly more surprise and curiosity upon reading a text designed to correct misconceptions. This led to more positive attitudes and greater improvements in developing correct conceptions of the topic.

In the current study, we consider epistemic emotions that arise during learning and assume that reading persuasive refutation texts prompts these emotions which influence conceptual change. Particularly, we predicted that emotions would mediate relations between pre- and post-attitudes as well as pre- and post-knowledge after reading a persuasive refutation text. We also hypothesized that prior attitudes would positively predict emotions, (e.g., joy, happiness, and curiosity) and that epistemic emotions would in turn positively predict post-reading attitudes; and that negative epistemic emotions (frustration, confusion, anger, and boredom) would mediate the positive relationship between pre- and post-reading attitudes (Muis, Chevrier, & Singh, 2018; Pekrun, 2006; Pekrun, Muis, Frenzel, & Goetz, 2017). Moreover, given our hypothesis regarding the moderation of attitudes, and the connection between attitudes and emotions, we hypothesized the impact of prior attitudes and prior knowledge on emotions would be moderated by the persuasive orientation of a refutation text (pro, con, or both pro-and-con; see Figure 1).

Current Study

This study examined the effects of persuasive refutation texts on conceptual and attitudinal change, and the mediating role of epistemic emotions. Specifically we examined whether prior attitudes and knowledge served as important antecedents to emotions, and whether the type of text—pro-GMF, con-GMF, or both pro-and-con-GMF text—moderated relations between prior attitudes, emotions and final attitudes, and conceptual change. We include the "pro-GMF" text condition to positively influence attitudes, the "con-GMF" text to negatively influence attitudes, and "both pro-and-con-GMF" text conditions (pro-con and con-pro orderings) to present individuals with a more realistic situation because controversial topics on the Internet are likely to present both pro and con persuasive information.[4] We asked the following research questions:

1. Does reading a refutation text about GMFs augmented with persuasive information change attitudes in the direction of the persuasive information?
2. Does reading a refutation text augmented with positive persuasive information about advantages of GMFs improve knowledge and reduce misconceptions when compared with reading the same text augmented with information about disadvantages or augmented with both types of information?
3. Which model drawn from Sinatra and Seyranian (2016) best describes associations between pre- and post-reading attitudes and pre- and post-reading knowledge and misconceptions (i.e., attitudinal and conceptual change)? (See Supplemental Material for more detail.)
4. Do epistemic emotions mediate relations between pre- and post-reading attitudes and/or pre- and post-reading knowledge and misconceptions?
5. Does type of text augmentation (pro, con, both) moderate indirect effects of pre- and post-reading attitudes and knowledge/misconceptions on post-reading attitudes and knowledge/misconceptions as mediated by epistemic emotions? In other words, does text

[4] It should also be mentioned that accurate conceptions of GMFs were previously found to be associated with positive attitudes toward GMFs (Heddy et al., 2017), and so we were mostly interested in using persuasive texts to positively shift attitudes compared with negatively oriented texts and both-positive-and-negative texts, while holding information intended to shift misconceptions constant.

type moderate the mediation by epistemic emotions?

Methods

Participants

Participants were 424 university students from multiple disciplines recruited from the USA (27%), Canada (36%), and Germany (37%). We chose to collect data from three countries in order to increase the generalizability of our results. We coordinated between researchers to obtain relatively equivalent sample sizes from Germany, Canada, and the United States. We examined whether there were differences across countries for all variables in the model, and ICCs were calculated. All ICCs' were less than .05, which suggests there were no multi-level effects. Moreover, no mean differences were found on any of the variables with the exception of prior attitudes, wherein students from the American university espoused less positive attitudes toward GMFs compared to students from the other universities ($p < .01$). In terms of year of study, 24%, 26%, 19%, 18%, and 7% were in their first, second, third, fourth, and fifth year, respectively, and 6% reported "other year." In the sample, 62% self-reported as female, 56% Asian, 32% White, 3% Black or African American, 7% multiple races, and 2% as other race. The mean reported age was 22.0 years ($SD = 4.5$).

Materials

Experimental texts. Four texts were adapted from material published by the Canadian Standards Association (Whitman, 2000; 1230-1345 words; see Table 1). All four texts began with an identical refutation text adapted from Heddy and colleagues (2017; 614 words; Flesch Kincaid score of 43.2). This common portion of the experimental texts was presented in a typical refutation format where the text identified four common misconceptions, refuted them, and then provided a scientific explanation why the misconception was incorrect. The four misconceptions addressed by the refutation text were (a) that genetic modification and cloning involve the same process, (b) genetic modification involves hormone injection, (c) genetic modification occurs only in laboratories conducted by scientists, and that (d) genetic modification is a recent phenomenon. For example, the first of the four refutation statements read, "You may think that genetically modifying foods is the same process as cloning. This belief is not correct. Cloning involves making an exact genetic copy of an organism. All of the genetic information is identical between those two organisms. In contrast, the process of genetically modifying food can be done using gene cloning methods; however, the protein in the genetically modified organism has been modified somewhat."

The refutation text was then followed by one section describing advantages of GMFs (pro), disadvantages of GMFs (con), or both (in pro-con order or con-pro order). For example, the pro text stated "Nutrition:…If rice could be genetically engineered to contain additional vitamins and minerals, nutrient deficiencies could be alleviated," while the con text stated, "Unknown effects on human health: There is a growing concern that introducing foreign genes into food plants may have an unexpected and negative impact on human health." The pro-con and con-pro texts contained both of these sections in different order. For these texts, the pro and con sections were shortened without loss of meaning to equate length to the pro only and the con only texts. As such, the pro, con, and both pro-and-con-GMF texts were similar in length (612, 721, and 678 words respectively) and in reading ease (Flesch Kincaid score of 40.4, 44.7, and 45.1 respectively). Given that we found no statistically significant differences in knowledge, emotion, or attitude at pre- or post-test between the pro-con and con-pro conditions, participants in these two conditions were merged to form one single group hereafter referred to as both pro-and-con. All persuasive information was intended to shift only attitudes and contained no information that pertained to the four misconceptions addressed in refutation text and knowledge assessments.

Knowledge assessments. One knowledge test was used to assess students' prior knowledge and post-reading knowledge. We used the same knowledge scale both pre- and post-intervention to measure whether the same misconceptions had changed over the course of the intervention. The test consisted of 10 multiple-choice questions about genetic modification definitions and processes (e.g., "[How many years ago] were processes used to modify a plant's or animal's DNA developed?") with four possible responses. One of the four options represented a correct conception about GMFs, whereas the other three represented common misconceptions, thus a greater number of correct responses correspond with both greater knowledge of correct conceptions and fewer misconceptions about GMFs. For each item, participants received a score of 1 for a correct response or zero for an incorrect response. The sum of scores indicated greater knowledge and fewer misconceptions, ranging from 0 to 10. A confirmatory factor analysis revealed that all but two items loaded onto the same construct in both pretest and posttest (see Supplemental Material for details). After dropping these two items from analysis, Cronbach's reliability coefficients for the eight items were acceptable at pretest, $\alpha = .79$, and posttest, $\alpha = .85$. Moreover, test-retest reliability was high, $\alpha = .86$.

Attitude surveys. Attitudes about GMFs were measured using two questionnaires adapted from Heddy and colleagues (2017). The first attitude survey was administered before reading the experimental text and consisted of four items reflecting attitudes towards GMFs ("Genetically modified foods are OK with me," "Genetically modified foods are beneficial to society," "I approve of genetically modified foods," and "I would eat food that has been genetically modified"). Responses were made on a 5-point Likert scale ranging from 1 (*strongly* *disagree*) to 5 (*strongly agree*; Cronbach's α = .91). The second survey consisted of the Feeling Thermometer that was administered after reading. The Feeling Thermometer is a single item adapted from Liu and Wang (2015): "What is your feeling towards genetically modified foods?" Responses were made on an 11-point scale from -5 (negative attitudes towards GMFs) to +5 (positive attitudes towards GMFs). Zero was considered neutral. Scores were recoded to range from 1 (negative) to 11 (positive) prior to analysis. We used a different scale to gauge post-attitudes rather than re-administering the same premeasure to prevent retest effects, such as participants reporting changed attitudes simply because they may have believed we expected them to do so (see Supplemental Material for more justification for the inclusion of this scale).

Epistemic Emotions. Epistemic emotions were measured post-reading using the Epistemic Emotions Scales (EES; Pekrun, Vogl, Muis, & Sinatra, 2017), a self-report questionnaire consisting of 21 items, three for each of seven emotions: surprise, curiosity, joy, confusion, anxiety, frustration, and boredom. We added to the EES seven emotion items representing hope, hopelessness, and anger given that participants have reported these emotions during learning about GMFs in previous research (Trevors, Muis, Pekrun, Sinatra, & Winne, 2016). Each item consisted of a single word (e.g., "Excited") and students reported the intensity of the emotion they experienced during learning using a Likert scale ranging from "Not at all" (1) to "Very strong" (5). Instructions for the scale stated, "We are interested in the emotions you experienced when learning about genetically modified foods from the text you just read. For each emotion, please indicate the strength of that emotion by clicking the number that best describes the intensity of your emotional response during learning." The Cronbach's alpha reliabilities for epistemic emotions were: surprise, α =.83; curiosity, α = .80; joy α = .84; confusion, α = .80; frustrated, α = .81; anxiety, α = .78; bored, α = .81; anger, α = .88; hope, α =

.85; hopelessness, α = .77. We also examined item statistics and ran CFA analyses to establish discriminant validity of our emotion scales (see Supplemental Material). These analyses demonstrate discriminant validity for emotions by contrasting 1-factor versus multiple-factor CFAs and support that the ten emotions included in the emotions scale are distinct.

Procedure

The procedures consisted of five steps. Step 1, participants first were invited to indicate informed consent to participate. Step 2, participants then completed the prior knowledge test assessing misconceptions about GMFs followed by attitudes towards about GMFs. Step 3, participants were randomly assigned to read one of four refutation texts augmented with persuasive information: (1) refutation plus advantages of GMFs; (2) refutation plus disadvantages of GMFs; (3) refutation plus advantages and disadvantages of GMFs, or (4) refutation plus disadvantages and advantages of GMFs. The latter two conditions were identical except for the order of the persuasive content (to allow testing for order effects). Step 4, after reading the text, participants reported their epistemic emotions using the EES (Pekrun, Vogl, et al., 2017) and attitudes towards GMFs using the Feeling Thermometer. Step 5, participants completed the same knowledge test and then completed a demographics questionnaire to conclude the study. The average time to complete the entire study was 48.5 min (SD = 15.2 min). At the end of the study, participants were awarded course credit or another incentive, $15 cash or a $10 gift card for their time, depending on the location of the study.

Results

Preliminary analyses. All variables were examined for skewness and kurtosis. The range for skewness values was -0.93 to 1.67 and for kurtosis was -1.37 to 2.36. Both are acceptable (Tabachnick & Fidell, 2013). Second, differences in prior knowledge and pre-reading attitudes were compared between groups to investigate equivalence at pretest. No statistically significant differences were found ($p > .12$ for all variables). Raw means and standard deviations by condition and overall for all variables are shown in Table 2. Correlations among variables in the hypothesized models are shown in Table 3.

Differences in Knowledge Gains and Attitude as a Function of Text Type

Research question 1. *Does reading a refutation text about GMFs augmented with persuasive information change attitudes in the direction of the persuasive information?* After finding no significant interaction between prior-attitude and condition on final attitudes, we computed a one-way analysis of covariance (ANCOVA) with text condition as the between subjects factor and prior attitudes as the covariate. Results revealed a statistically significant main effect of condition on attitude, $F(2, 420) = 23.55$, $p < .0001$, partial $\eta^2 = .10$. Consistent with our hypothesis, follow-up post hoc analyses using LSD[5] tests indicated that individuals in the pro-GMF condition held more positive attitudes towards GMFs at posttest compared to the con-GMFs condition ($p < .0001$) and both pro-and-con-GMF condition ($p < .0001$). Moreover, individuals in the both pro-and-con-GMF condition held more positive attitudes towards GMFs compared to individuals in the con condition.

Research question 2. *Does reading a refutation text augmented with positive persuasive information about advantages of GMFs improve knowledge and reduce misconceptions when compared with reading the same text augmented with information about disadvantages or augmented with both types of information?* After finding no significant interaction between prior-knowledge and condition on final knowledge, we computed a one-way ANCOVA with text condition as the between subjects factor and prior knowledge as the covariate. Results revealed a

[5] We used Fisher's Least Significant Difference (LSD) method in this case because it controls for the family-wise error rate if there are exactly three groups (Wilcox, 2011).

statistically significant main effect of knowledge by condition, $F(2, 420) = 3.16$, $p = .043$, partial $\eta^2 = .02$. Consistent with our hypothesis, follow-up post hoc analyses using LSD indicated that individuals in the pro-GMF condition had significantly fewer post-test misconceptions compared to the con-GMF condition ($p = .03$). Moreover, individuals in the both pro-and-con-GMF condition had fewer post-test misconceptions compared to the con-GMF condition ($p = .049$). Contrary to our hypothesis, no significant differences were found between the pro and both pro-and-con-GMF conditions. In sum, participants in the pro-GMF and pro-and-con-GMF conditions held more positive final attitudes and fewer misconceptions than participants in the con-GMF condition.

Attitudinal and Conceptual Change

Research questions 3-5. Beginning with Question 3: *Which model best describes associations between pre- and post-reading attitudes and pre- and post-reading knowledge and misconceptions (i.e., attitudinal and conceptual change)?*[6] We constructed path models on Mplus Version 7.11 (Muthén & Muthén, 2012) to compare four hypothesized models drawn from Sinatra and Seyranian (2016) to assess which model was better supported. Details regarding model comparisons and modifications can be found in the Supplemental Material. Ultimately, the best fitting model supported that prior knowledge predicts prior attitudes, and that final knowledge and attitudes were best modeled simultaneously (see Figure 2); this model resulted in an excellent fit, $\chi^2 = 679.03$, $df = 28$, $p < .0001$, CFI = .98 and RMSEA = .05.

Moderated Mediation Analysis

To explore relations between prior knowledge, pre-reading attitudes, emotions, post-reading attitudes, and post-reading knowledge, and to assess whether type of text moderated

[6] In these analyses, we operationalize conceptual and attitude change as direct and indirect associations between prior- and post-reading knowledge and attitudes.

these relations in answering research questions 3 and 4, we conducted a moderated mediation analysis using bootstrap sampling.[7] Dummy coding was used for text condition, and variables were centered for the interaction terms. As hypothesized, results revealed that prior knowledge significantly predicted individuals' prior attitudes about GMFs ($\beta = .27$, $SE = .05$, $p = .0001$). That is, the more that individuals knew about GMFs, the more positive their attitudes towards GMFs.

Pre-reading attitudes subsequently significantly directly predicted all emotions, with the exception of curiosity. That is, pre-reading attitudes positively predicted joy ($\beta = .20$, $SE = .04$, $p < .0001$) and hope ($\beta = .28$, $p < .0001$, $SE = .04$), and negatively predicted surprise ($\beta = -.13$, $SE = .04$, $p < .0001$), confusion ($\beta = -.40$, $SE = .04$, $p < .0001$), frustration ($\beta = -.48$, $SE = .04$, $p < .0001$), anxiety ($\beta = -.35$, $SE = .04$, $p < .0001$), boredom ($\beta = -.16$, $SE = .04$, $p = .001$), hopelessness ($\beta = -.36$, $SE = .04$, $p < .0001$), and anger ($\beta = -.34$, $SE = .04$, $p < .0001$).

For surprise, as predicted, text condition significantly moderated relations between attitudes and surprise, ($t = 2.59$, $p = .01$). Specifically, attitudes significantly and negatively predicted surprise ($\beta = -.22$, $SE = .04$) in the pro-and-con-GMF persuasive condition ($t = -3.16$, $p = .001$, CI = -.34 to -.08) but were not significant in the other two conditions ($\beta = -.15$, $p = .10$ for the pro-GMF and $\beta = .10$, $p = .33$ for the con-GMF condition). Surprise did not, however, mediate relations between pre-reading attitudes and post-reading attitudes. As such, only a moderated effect was found. To explain this moderation, a post hoc ANCOVA (with prior attitudes as the covariate) further revealed that individuals in the both pro-and-con-GMF condition reported significantly less surprise compared to the positive persuasive text condition

[7] Simulation studies support that our model is sufficiently powered for moderated mediation. For example, Preacher, Rucker, and Hayes (2007) show that moderated mediation models with bootstrapped estimates are sufficiently powered for samples near 500 for standardized coefficients exceeding .14 (see their results regarding "Model 2").

(p = .01), who experienced the most surprise.

Analyses further revealed that curiosity significantly and negatively predicted post-reading attitudes (β = -.17, SE = .04, p < .0001), as did frustration (β = -.31, SE = .04, p < .0001), whereas joy (β = .26, SE = .06, p < .0001) and hope (β = .37, SE = .06, p < .0001) significantly and positively predicted post-reading attitudes. Moreover, joy, hope, and frustration significantly mediated relations between pre- and post-reading attitudes (joy: *effects* / *ab* = .08, .12, .11, 95% CIs from .01 to .17, .03 to .23, and .02 to .21, respectively; hope: *effects* = .12, .19, .19, CIs from .04 to .21, .08 to .32, and .08 to .35, respectively; frustration: *effects* = .18, .16, .17, CIs from .01 to .36, .01 to .33, and .01 to .37, respectively).

For knowledge at posttest, results revealed that hope positively predicted post-reading knowledge (a proxy for conceptual change) (β = .24, SE = .04, p < .0001) whereas joy (β = .19, SE = .04, p = .005) and confusion (β = -.29, SE = .04, p < .0001) negatively predicted post-reading knowledge. Moreover, confusion significantly mediated relations between prior attitudes and post-reading knowledge (*effect* = .04, 95% CI from .0004 to .04).[8]

Given that the mediation effects (i.e., indirect effects) were consistent for all three emotions (joy, hope, frustration) across the three groups, no moderated mediation was found for any of the mediated relations between emotions and post-reading attitudes or between emotions and conceptual change (as indicated by post-reading knowledge scores). However, type of text significantly moderated relations between pre-reading attitudes and post-reading attitudes, wherein pre-reading attitudes more strongly positively predicted post-reading attitudes in the negative persuasive content condition (*effect* = .66, t = 3.97, p = .0001) compared to the pro-and-

[8] Mediation effect estimates and confidence intervals were obtained using bootstrapped estimation methods with replacement (see Hayes, 2003).

con-GMF condition (*effect* = .63, $t = 5.30$, $p < .0001$) and the positive persuasive content condition (*effect* = .51, $t = 3.24$, $p = .001$). Finally, text type did not moderate direct relations between prior knowledge and conceptual change (i.e., post-reading knowledge; all *p*s greater than .05). In contrast, a significant moderation occurred between prior attitudes and conceptual change wherein individuals with more positive prior attitudes in the pro-GMF and both pro-and-con GMF conditions significantly changed more misconceptions ($\beta = .21$, $SE = .04$, $t = 2.93$, $p = .003$, and $\beta = .25$, $SE = .04$, $t = 2.62$, $p = .009$) whereas individuals with more positive attitudes in the con-GMF condition maintained their misconceptions ($\beta = -.05$, $SE = .04$, $t = -.54$, $p = .59$).

Discussion

We examined the influence of pro-GMF, con-GMF, and both pro-and-con-GMF refutation text on emotions, attitudes, and conceptual change. Though there is research on each of these constructs separately, there are very few studies that bring all three into a single study (e.g., Heddy et al., 2017), and none that investigated the role of persuasive content in influencing emotions, attitudes, and knowledge. Generally, we found that students who read a pro-GMF refutation text had more positive attitudes and fewer misconceptions after reading than those who read a con-GMF text, and that emotions (curiosity, frustration, joy, hope) mediated changes in attitude and misconceptions. That is, refutation texts supplemented with persuasive information have the potential to substantially impact both readers' final attitudes and knowledge towards the subject. This has important implications for research on refutation texts, conceptual change, attitudes, and educational practice.

Attitudes can be shifted. Our results showed that learning from a refutation text paired with positive persuasive information led to more positive attitudes than those who read a refutation text paired with negative or both positive-and-negative persuasive information. This suggests that refutation texts can be coupled with persuasive information to shift attitudes about controversial subjects. This is important. Despite evidence that attitudes about science topics can be shifted with persuasive text (Alexander et al., 2002; Chambliss, 1995; Hynd, 2003; Kardash & Scholes, 1995; Sinatra et al., 2012), no previous research has experimentally verified whether text augmentations promote a shift of attitude. Thus, our finding that final attitudes can be predicted by persuasive orientation of text has implications for public understanding of science topics because, when individuals go online to seek out information about a potentially controversial science subject, the persuasive orientation of the texts they encounter may contribute to their post-reading attitude, which may subsequently enable or constrain future learning (Chambliss & Garner, 1996; Sinatra & Seyranian, 2016). That is, mitigating negative attitudes about GMFs with refutation texts infused with positive persuasive information may prompt positive attitude shifts and consequently improve learning outcomes.

Persuasive information supports conceptual change. Based on the framework provided by Sinatra and Seyranian (2016), we expected to find relationships between knowledge and attitudes. In our study, individuals who read a refutation text paired with positive persuasive information had fewer misconceptions compared with those who were given the same refutation text with negative persuasive information, consistent with Sinatra and Seyranian’s (2016) hypothesis. Further, our findings show that a text crafted to shift both learners’ attitudes and misconceptions in a way that complemented each other (i.e., a refutation text containing positive persuasive information to mitigate misconceptions that are grounded in negative attitudes) led to more positive final attitudes *and* fewer misconceptions compared to texts in which the persuasive information did not complement the information mitigating misconceptions (i.e., refutation text containing negative persuasive information). It may therefore be the case that refutation text supplemented with persuasive information aligned with the correct conception will cultivate the greatest conceptual change. However, given that we did not include a neutral text with neither positive nor negative attitudinal information, conclusions should be tempered.

We also found small but significant attitude and knowledge gains overall. Given that participants in all conditions read the same refutation text, this improvement in knowledge was expected. Most prior studies have shown that refutation texts reduce misconceptions and increase knowledge (for a review, see Tippet, 2010) and at least one has shown a shift in attitudes (Heddy et al., 2017). Our study adds to the growing literature demonstrating that various characteristics of refutation texts can be put in place to increase their effectiveness, for example, by supplementing them with graphics or metaphors (Danielson et al., 2016). Specifically, our findings suggest persuasive information is an important moderator of the effectiveness of refutation texts in predicting final attitudes and misconceptions. Future refutation text studies that investigate additional moderators should therefore consider persuasive orientation of the text.

Attitudes and knowledge shift simultaneously. After comparing the fit of four competing models, we found that the best fitting model supported prior knowledge predicting prior attitudes, but that final knowledge and attitudes were best modeled simultaneously. This finding supports Sinatra and Seyranian’s (2016) hypothesis that attitudes and knowledge are related, and shift in a related manner. Although previous evidence suggests that knowledge changes occur prior to attitude changes (Heddy et al., 2017), our data show simultaneous shifts in attitudes and knowledge which are likely due to the fact that in our study, unlike prior research, the experimental text that participants engaged with targeted both attitudes and misconceptions in the same text.

Emotions mediate conceptual change processes. Although emotions did not mediate relations between prior and final knowledge, results supported our hypothesis that epistemic emotions would mediate relationships between prior and final attitudes. Specifically, we found frustration negatively mediated relationships between prior and final attitudes while joy and hope were positive mediators of prior and final attitudes. These findings are consistent with previous results that, after reading a refutation text on GMFs, undergraduate students' positive emotions (e.g., hope and joy) were associated with attitude changes in the positive direction and that negative emotions (e.g., frustration) were associated with attitude changes in the negative direction (Heddy et al., 2017). We found that confusion negatively mediated relations between prior attitudes and final knowledge. This suggests that epistemic emotions may be an important mechanism underlying the association between attitudes and knowledge. We also found that curiosity negatively predicted post-reading knowledge, in contrast with previous findings (see Jirout & Klahr, 2012 and Muis, Chevrier, & Singh, 2018 for reviews).[9] In all, these findings suggests that conceptual change involves more than just the correction of misconceptions. Rather, attitudes, emotions, and prior knowledge should all be taken into account.

Type of text moderates relations between prior attitude and surprise as well as attitude and post-reading knowledge. Moderated mediation analyses revealed the type of text that participants received led to different emotional responses based on their prior attitudes. Surprise, in particular, was related to the type of text that individuals read. More specifically, participants with more negative attitudes reading the both pro-and-con GMF text were less surprised than students in the other groups. This is likely because participants reading the pro-

[9] One explanation for this discrepancy may be that attentional resources are reallocated upon experiencing positive emotions such as curiosity (Morton, 2010). Positive emotions can draw attention away from learning, resulting in a decrease in learning outcomes (Ellis et al., 1995; Meinhardt & Pekrun, 2013).

con text found parts of the text consistent with their negative attitude; therefore, they had less reason to be surprised. In other words, we found the persuasive orientation of a refutation text differentially influenced levels of surprise among our participants.

Furthermore, moderated mediation analyses revealed that the persuasive content of our refutation text moderated the relationship between prior attitudes and final knowledge. Participants who initially held a positive attitude towards GMFs and were assigned to read a pro-GMF text or both pro-and-con-GMF text demonstrated significantly fewer misconceptions than those with positive attitudes that were assigned to read a con-GMF text. In other words, participants with more positive attitudes who were assigned texts that were aligned with those attitudes demonstrated more learning. This suggests that individuals who have incorrect conceptions but hold positive attitudes (i.e., pro-unjustified learners; Sinatra & Seyranian, 2016) may be more open to learning incongruous information given that their attitudes already align with the correct conception. As such, it may be the case that pro-unjustified learners benefit from instructional interventions targeting their misconceptions.[10]

Implications for Practice

To foster greater conceptual change, refutation texts might be paired with information designed to attenuate negative emotions and negative attitudes, particularly when the topic is complex and may arouse negative emotions. Not all complex scientific topics naturally engender positive emotions and positive attitudes. Indeed, climate change, vaccinations, and GMFs are topics that can provoke many negative emotions and attitudes. Refutation texts designed to confront misconceptions could be paired with information about positive actions or steps

[10] Also worth noting is that learners with negative attitudes who received con-GMF text that agreed with their attitudes did not experience greater learning outcomes. This suggests that attitudinal agreement with persuasive text may not be sufficient to support conceptual change, but that attitudes be aligned with *correct* conceptions.

individuals can take to mitigate negative environmental or health impacts. Such content should help readers feel more empowered and less negative. Texts created for conceptual change should therefore be designed to target the multiple known factors moderating and mediating conceptual change—attitudes, emotions, and knowledge. Specifically, text geared towards shifting attitudes and knowledge and that have surprising information might more strongly promote conceptual change.

Moreover, when individuals are interested in a scientific topic, they are likely to encounter attitudinally-charged perspectives as they conduct research online. While prior research has shown a relation among multiple shifting constructs of knowledge, attitudes, and emotions (e.g., Heddy et al., 2017a), the directionality of these relations has not been precisely tested. Our results highlight the crucial role attitudes and emotions play in mediating attitude change and knowledge reconstruction. Specifically, emotions of hope, joy, confusion, and frustration were particularly important mediators of changes in conceptions and attitudes regarding genetically modified foods. As such, instructors, media specialists, science communicators, and textbook authors crafting messages about the science of GMFs might present the information in ways that are sensitive emotions. The most prudent course of action is to facilitate the emotions of hope and joy and mitigate confusion and frustration for the greatest conceptual and attitudinal changes on emotionally and attitudinally charge science topics.

Limitations and Future Directions

We acknowledge several limitations and issues. First, all participants engaged with a refutation text, so we cannot say whether our refutation texts incited more conceptual or attitudinal change compared to non-refutational types of texts. Our comparisons describe only refutation texts augmented with persuasive information. Future studies might compare various refutation texts of various persuasive orientations to other forms of texts with and without persuasive augmentations, for example, by including control groups that read only refutation or only persuasive text. Second, to reduce retest effects, our post-reading assessment of participants' GMF attitude consisted of a single-item; we acknowledge that this is a limitation (see Supplemental Materials for an extended discussion and further analyses of this measure). Third, our study was conducted in a lab setting, a more controlled environment compared to real-world online research and reading settings. Texts individuals encounter in the "real world" are likely more complicated than presenting only the "pros" or the "cons." A single search of GMFs on Google brings up several million hits with texts that include graphics, multiple arguments, different forms of justification, and various levels of credibility. To simulate only a bit of the complexity of real Internet searches of controversial topics, we included a "both pro-and-con" condition. Future studies might investigate wider ranges of text factors. Fourth, our sample was composed of college students from competitive universities in Western countries. This limits generalization. Researchers might involve more diverse samples reading about more diverse topics to better understand how to best promote conceptual change more broadly. Fifth, our findings are based on a topic where positive attitudes correspond with accurate conceptions. Future studies might investigate the impact of topics where negative attitudes are expected to correspond with more accurate conceptions, such as negative attitudes toward smoking associated with correct knowledge about associated health risks. As such, researchers can investigate whether our findings are replicable with topics where positive attitudes are inversely related to knowledge. Finally, our study concentrated on a single controversial topic, one that we believed would be sensitive to persuasive information. Future studies might consider studying a wider range of topics for which people hold a wider range of misconceptions that may interact differently with their existing attitudes.

Conclusion

Knowledge, emotions, and attitudes are important factors to consider when teaching about controversial scientific topics. Specifically, the role of attitude shifts in knowledge construction should not be ignored. However, we have a limited understanding of how these constructs interact, and how attitudes impact emotions and knowledge construction. Our results suggest that when individuals hold negative attitudes and misconceptions, providing a refutation text with positively-oriented persuasive information can foster positive emotions, shift towards more positive attitudes, and improve knowledge outcomes. Providing persuasive kinds of information can direct and ease conceptual change, especially for attitudinally-charged topics that may conflict with learners’ initial beliefs and attitudes.

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Table 1. *Refutation Text Paired with Persuasive Information (Persuasive Refutation Texts) Used in the Study. Text Blocks Appear in the Order that Participants Encountered them.*

Text Type		
All Participants		
Refutation Text	You may think that genetically modifying foods is the same process as cloning. This belief is not correct. Cloning involves making an exact genetic copy of an organism…	
Additional Persuasive Texts (Experimental Conditions)	Text Block 1	Text Block 2
Pro GMF text (pro-pro)	Drought tolerance/salinity tolerance: As the world population grows and more land is utilized for housing instead of food production, farmers will need to grow crops in locations previously unsuited for plant cultivation.	Nutrition: … If rice could be genetically engineered to contain additional vitamins and minerals, nutrient deficiencies could be alleviated.
Con GMF text (con-con)	Unknown effects on human health: There is a growing concern that introducing foreign genes into food plants may have an unexpected and negative impact on human health...	Unintended harm to other organisms. In 2013, a laboratory study was published in Nature showing that pollen from B.t. corn caused high mortality rates in monarch butterfly caterpillars.
Both pro-and-con GMF text (pro-con)	Nutrition: … If rice could be genetically engineered to contain additional vitamins and minerals, nutrient deficiencies could be alleviated.	Unintended harm to other organisms. In 2013, a laboratory study was published in Nature showing that pollen from B.t. corn caused high mortality rates in monarch butterfly caterpillars.
Both pro-and-con GMF text (con-pro)	Unintended harm to other organisms. In 2013, a laboratory study was published in Nature showing that pollen from B.t. corn caused high mortality rates in monarch butterfly caterpillars.	Nutrition: … If rice could be genetically engineered to contain additional vitamins and minerals, nutrient deficiencies could be alleviated.

Note. In all four experimental conditions, participants read the refutation text followed by persuasive information. Persuasive information was either all pro GMF (pro-pro), all con GMF (con-con), half pro followed by half con GMF (pro-con), or half con followed by half pro GMF information (con-pro).

Table 2

Means and standard deviations (SD) for all variables overall and by text condition (N=424).

Variable	Overall *M (SD)*	Pro-GMF Text *M (SD)*	Con-GMF Text *M (SD)*	Both pro-and-con-GMF Text *M (SD)*
Knowledge assessments				
Knowledge Score pretest (percent)	53.61 (23.34)	55.15 (23.32)	51.65 (25.06)	54.20 (20.16)
Knowledge Score posttest (percent)	80.34 (20.70)	83.65 (17.09)	77.71 (21.04)	79.13 (21.16)
Attitudes toward GMFs				
Prior attitudes	3.82 (1.25)	3.76 (1.29)	3.99 (1.21)	3.77 (1.24)
Final attitudes	6.68 (2.74)	7.66 (2.37)	5.86 (2.78)	6.58 (2.75)
Self-reported epistemic emotions about GMFs after reading text				
Surprise	2.37 (0.96)	2.58 (1.03)	2.32 (0.88)	2.29 (0.94)
Curiosity	3.35 (0.91)	3.38 (0.90)	3.50 (0.88)	3.25 (0.93)
Joy	2.00 (0.90)	2.26 (0.94)	1.92 (0.88)	1.90 (0.88)
Confusion	1.73 (0.74)	1.78 (0.72)	1.81 (0.83)	1.67 (0.69)
Frustration	1.73 (0.86)	1.68 (0.79)	1.83 (0.85)	1.71 (0.89)
Anxiety	1.89 (0.82)	1.74 (0.78)	1.99 (0.84)	1.92 (0.83)
Boredom	1.72 (0.79)	1.76 (0.86)	1.74 (0.77)	1.70 (0.77)
Anger	1.58 (0.85)	1.49 (0.74)	1.73 (0.92)	1.56 (0.86)
Hope	2.50 (0.98)	2.83 (0.96)	2.37 (1.02)	2.39 (0.94)
Hopelessness	1.55 (0.71)	1.48 (0.67)	1.57 (0.74)	1.57 (0.71)
n	424	107	106	211

Note. Larger Knowledge Scores correspond with fewer misconceptions.

Table 3

Correlations Among Variables in Moderated Mediation Model

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10	11.	12.	13.	14.
1.	Pre Knowledge	1													
2.	Post Knowledge	.48***	1												
3.	Pre Attitude	.26***	.19**	1											
4.	Post Attitude	.17*	.08	.49***	1										
5.	Surprise	-.20***	-.14**	-.13*	.09	1									
6.	Curiosity	.02	.08	-.04	-.02	.48***	1								
7.	Joy	.06	-.06	.20***	.44***	.50***	.40***	1							
8.	Confusion	-.17**	-.28***	-.37***	-.17***	.43***	.21***	.17***	1						
9.	Frustration	-.10*	-.16**	-.43***	-.42***	.15*	.16*	-.04	.53***	1					
10.	Boredom	-.08	-.19**	-.35***	-.30***	.36***	.32***	.10	.62***	.68***	1				
11.	Anxiety	-.07	-.15**	-.16*	-.05	-.02	-.29***	.00	.32***	.31***	.16***	1			
12.	Anger	.07	-.17**	-.34***	-.35***	.14*	.12	.01	.51***	.87***	.65***	.39***	1		
13.	Hope	.14*	.06	.28***	.48***	.42***	.41***	.77***	.12	-.06	.09	-.01	.00	1	
14.	Hopelessness	-.11*	-.20***	-.36***	-.32***	.22***	.13*	.02	.56***	.72***	.64***	.39***	.73***	.01	1

Note. * p < .05. ** p < .01. *** p < .001

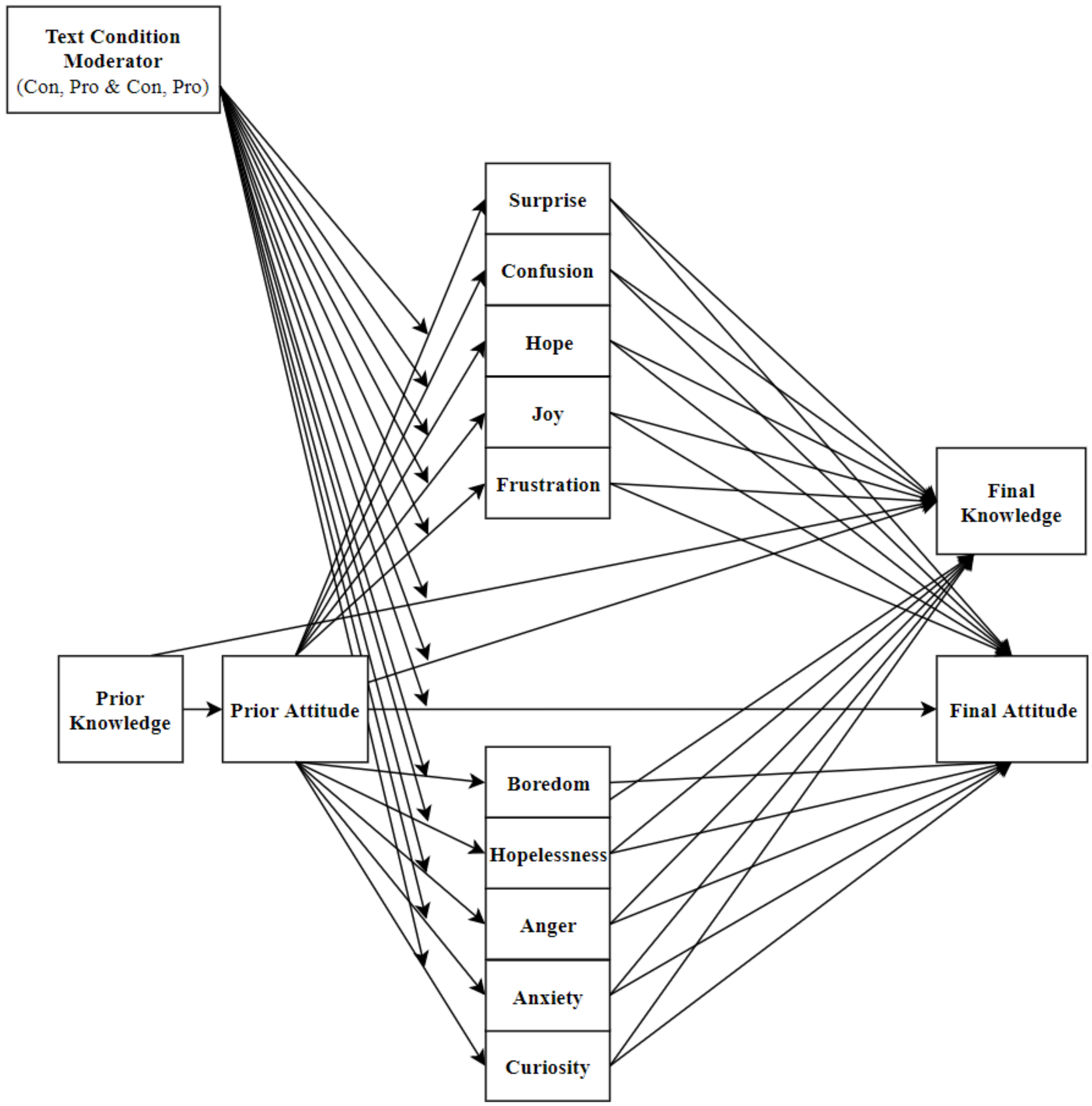

Figure 1. Hypothesized model. Model includes correlation paths between all emotions (not shown).

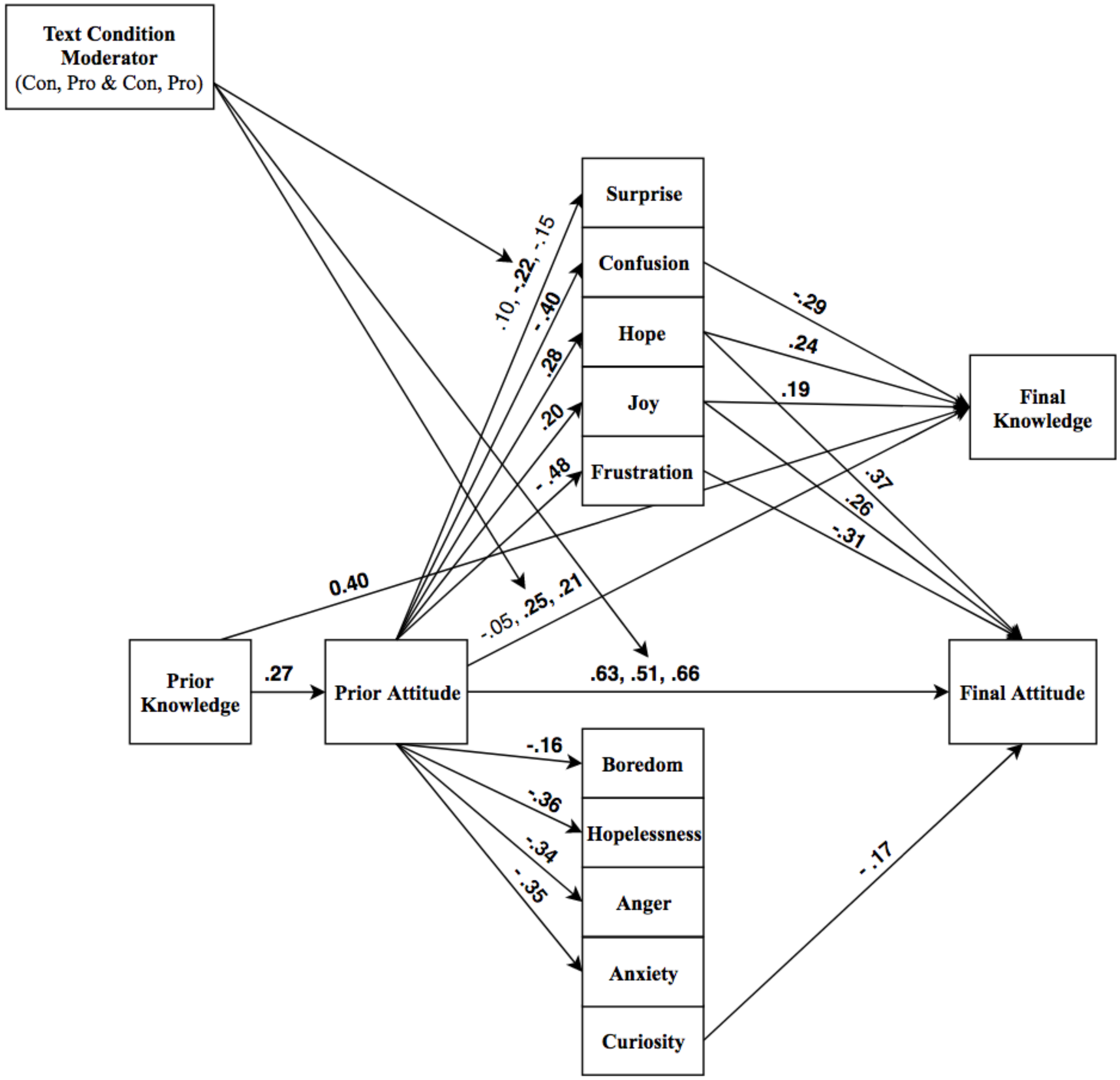

Figure 2. Final model. Values represent standardized beta coefficients. Paths for insignificant coefficients at the $p < .05$ level are not included. Bold moderation coefficients represent significant relationships at $p < .05$. Model includes correlation paths between all emotions (not shown).