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LEARNING, INSTRUCTION, AND COGNITION

Modifying Knowledge, Emotions, and Attitudes Regarding Genetically Modified Foods

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\textbf{ABSTRACT}

The purpose of this study was to explore whether conceptual change predicted emotional and attitudinal change while learning about genetically modified foods (GMFs). Participants were 322 college students; half read a refutation text designed to shift conceptual knowledge, emotions, and attitudes, while the other half served as a control group. The results suggest that the refutation text effectively facilitated change in conceptual knowledge, emotions, and attitudes. The hypothesized relationship among the variables was explored using structural equation modeling. The analysis showed that when participants experienced knowledge change toward more scientifically accepted conceptions of GMFs, their emotions became more positive and less negative, which predicted a subsequent shift toward more-positive attitudes. The results suggest that change in emotions mediates the relationship between conceptual and attitudinal change. Several theoretical and practical implications are discussed including the impact that these findings may have on science education.

\textbf{KEYWORDS}

Attitude change; attitude; conceptual change; cognitive process; emotion; GMFs; GMOs; refutation text; science education

The change landscape

THERE HAS BEEN a multitude of research that explores factors that impact conceptual change (Dole \& Sinatra, 1998; Pintrich, Marx, \& Boyle, 1993; Posner, Strike, Hewson, \& Gertzog, 1982), emotional change (Broughton, Sinatra, \& Nussbaum, 2013; Lombardi \& Sinatra, 2013; Pekrun, Frenzel, Goetz, \& Perry, 2007), and attitudinal change (Eagly \& Chaiken, 1993; Mcguire, 1985; Petty \& Cacioppo, 1981; Sinatra \& Seyranian, 2016; Zimbardo \& Leippe, 1991). However, researchers have typically explored changes in concepts, emotions, and attitudes independent from one another (Chi, 1992; Williams, Cross, Hong, Aultman, Osbon, \& Schutz, 2008; Woloschuk, Harasym, \& Temple, 2004). A few studies have examined the intersections of two of these constructs (Gregoire, 2003; Heddy \& Sinatra, 2013; Murphy \& Mason, 2006), but only one that we know of has explored all three in the same study (Broughton et al., 2013).

Most research has examined variables that predict conceptual change (see e.g., Broughton et al., 2013; Lombardi, Nussbaum, \& Sinatra, 2016; Taasoobshirazi \& Sinatra, 2011); that is, previous research typically posits that emotions and attitudes precede and impact knowledge change with conceptual change as the outcome (Broughton et al., 2013; Dole \& Sinatra, 1998; Gregoire, 2003). To our knowledge, no research has been conducted on what happens \textit{after} conceptual change, especially on related variables such as emotional and attitudinal change. Some suggest that these affective variables may have a more dynamic relationship with cognitive and motivational variables, thus affect not only could precede conceptual change but could be impacted by conceptual change as well (Op’t Eynde &
Turner, 2006; Linnenbrink, 2007; Lombardi & Sinatra, 2013). This is important because engaging in conceptual change may in fact influence students’ emotions and attitudes and thus impact the learning process (e.g., by making students more open to learning in the future; Frey, 1986; Holbrook, Berent, Krosnick, Visser, & Boninger, 2005).

Knowledge, emotions, and attitudes influence learning in most domains (Maio & Haddock, 2010; Pekrun et al., 2007). However, this process may be particularly salient in the science domain given the perceived controversial nature of many concepts and the conceptual nature of science (Sinatra, Broughton, & Lombardi, 2014; Sinatra, Kienhues, & Hofer, 2014; Sinatra & Seyranian, 2016). In this study, we explore how engaging in conceptual change predicts emotional and attitudinal change and test a model examining how conceptual change modifies emotions and attitudes. To investigate this phenomenon, we chose a controversial topic that would likely elicit misconceptions, negative emotions, and negative attitudes: genetically modified foods (GMFs). Misconceptions regarding GMFs can generate strong emotions and attitudes. For instance, misconceiving cloning and hormone injection as GMFs (Varzakas, Arvanitoyannis, & Baltas, 2007) may conflict with worldviews (Evans, 2002), resulting in negative emotions and attitudes and, in turn, leading to a rejection of GMFs. Therefore, the topic of GMFs provides a means to explore the relationship between knowledge, emotion, and attitude change, all of which play an important role in so many science-learning tasks (Sinatra et al., 2014).

Building on prior research

Conceptual, emotional, and attitudinal change are each well-researched topics on their own; however, little research has explored the interactions among them. In the sections that follow, we present the literature regarding conceptual, emotional, and attitudinal change. Then, we hypothesize the relationship among these variables based on previous theoretical literature and empirical research. Finally, we discuss the motivation and goals for the current study.

Conceptual change

Although misconceptions and conceptual change can occur in most academic fields, we focus specifically on conceptual change within the domain of science. Thus, we operationalize conceptual change as the process of restructuring conceptual knowledge about a phenomenon from nonscientific views toward accepted scientific perspectives (Sinatra & Pintrich, 2003; Vosniadou, 2013b). We define a misconception as an understanding that is different from what is scientifically accepted (NRC, 2012), and the goal of conceptual change is to move students from a misconception to the scientifically accepted understanding. There are many different theoretical perspectives on conceptual change and the nature of misconceptions. Indeed, conceptual-change researchers have characterized ideas that conflict with scientific ideas as “misconceptions,” but terms such as alternative conceptions, alternative worldviews, naive conceptions, and lay conceptions are also used (for alternative views on conceptual change and differing views on characterizing prior conceptions, see Vosniadou, 2013a).

Traditionally, conceptual change examined cognitive structures and placed little emphasis on contextual factors, motivational factors, and affective constructs such as moods and emotions (Pintrich et al., 1993). Posner et al. (1982) argued that if students were dissatisfied with their current conception, found the new concept intelligible and plausible, and could apply the concept in fruitful ways, then these conditions would be sufficient to bring about conceptual change. Pintrich and his colleagues (Pintrich et al., 1993) described this as a “cold” view of conceptual change because it failed to account for “hot” constructs such as motivation, emotion, and attitude. Since that time, the field has placed an increasing emphasis on motivational and affective factors in both theoretical models of conceptual change and in empirical research. Sinatra has described this as the “warming trend,” in conceptual change research (2005, p. 109).

Several models of conceptual change now explicitly acknowledge the role of emotions, attitudes, and motivation in learning. In proposing the cognitive reconstruction of knowledge model (CRKM), Dole and Sinatra (1998) posited that conceptual change would be much more likely to occur when there
was a deep level of engagement with the content. The CRKM suggests that learner characteristics such as motivation and affect interact to influence a student’s level of engagement. Similarly, Gregoire (2003) proposed the cognitive-affective model of conceptual change (CAMCC). This model brought emotion and appraisal or evaluation into the conceptual change process. For example, emotions such as fear and anxiety may impact and/or be impacted by the conceptual change process. The CAMCC also includes appraisal and evaluation, which are both necessary for the formation of attitudes. We chose the CRKM as the theoretical framework for this study because of the centrality of the role of attitudes and emotions in conceptual change in science. Even with the emphasis in theory on “warm conceptual change,” few studies have explored the interaction and directionality among several hot constructs within the same study. Furthermore, it is important to note that the CRKM and the CAMCC posit that emotions and attitudes precede conceptual change but do not theorize about the possibility of conceptual change predicting change in emotions and attitudes. Therefore, we sought to extend the research on conceptual change by exploring the impact that conceptual change may have on other cognitive variables such as emotional change and attitudinal change.

**Emotions and emotional change**

Emotions have increasingly become an important aspect to investigate when exploring cognitive processing before, during, and after learning (Pekrun, 2006; Rosenberg, 1998). Emotions are described as psychophysiological responses to one’s environment that usually occur due to a person, object (topic), or event (Rosenberg, 1998). More recently, researchers have begun exploring academic emotions, or emotions that occur in achievement settings (Pekrun, 2010; Pekrun, Elliot, & Maier, 2006; Pekrun & Linnenbrink-Garcia, 2012). These emotions can be domain specific (e.g., science, math; Pekrun, 2006) or topic specific (e.g., science concepts including adaptation, diffusion, and genetic engineering; Pekrun & Stephens, 2012; Sinatra et al., 2014). We explore topic emotions related to learning about GMFs.

Pekrun (2006) hypothesizes that emotions can have a positive (enjoyment, hope) or negative (anger, hopelessness) valence. Furthermore, emotions can be activating or deactivating. Activating emotions cause physiological arousal (anger, enjoyment), whereas deactivating emotions lead to non-arousal (relief, hopelessness). Thus emotions can fall into one of four hypothesized categories including (1) positive/activating (enjoyment), (2) positive/deactivating (relief), (3) negative activating (anger), and (4) negative/deactivating (boredom). Based on the aforementioned categories, each emotion may have a differential impact on the change process. Most research related to conceptual change and emotions focuses on the differential impact of emotions on conceptual change (Fielder, 2001; Gregoire 2003; Linnenbrink & Pintrich, 2002; Sinatra et al., 2014). However, very little research has explored the impact of conceptual change on emotional change. Thus, although we recognize the nuanced nature of each individual emotion (for more information, see Sinatra et al., 2014) and the subsequent impact that emotions may have on attitude change, we focus only on the positive and negative valence of emotions. There are too few prior studies on emotions related to GMFs to propose differential hypotheses regarding each of the four emotions categories.

Researchers have begun to investigate how emotions change within learning situations (Broughton et al., 2013; Heddy & Sinatra, 2013; Muis et al., 2015; Pekrun et al., 2007). For instance, when learning about evolution, students experienced high levels of anxiety (Griffith & Brem, 2004). Anxiety has been shown to negatively impact learning (Pekrun, 1992; Rosenberg, 1998), and it would be beneficial to reduce this anxiety to improve future learning. Specific instructional practices can be developed to dampen negative emotions (Broughton et al., 2013), setting the stage for more successful learning outcomes. For example, Heddy and Sinatra (2013) facilitated conceptual change related to common evolution misconceptions using a teaching model that aims to facilitate transfer of classroom content to everyday experience. The teaching model successfully facilitated conceptual change and during the process increased student enjoyment when learning about biological evolution, a topic that is often accompanied by anxiety. The research mentioned above illustrates that when students engage in conceptual change, their emotions are subsequently impacted (Heddy & Sinatra, 2013).
Attitudes and attitude change

Attitudes are one of the most extensively researched topics within the field of social psychology (Allport, 1935; Maio & Haddock, 2010; McGuire, 1985; Prislin & Crano, 2008). Research on attitude change has many implications for learning, public understanding of science, and economic behaviors (Sinatra & Seyranian, 2016). Although there is some disagreement on the exact definition of an attitude, most social psychological researchers agree that an attitude includes an overall evaluation of an object, person, or event (Eagly & Chaiken, 1993; Maio & Haddock, 2010); that is, researchers generally agree that attitudes are described in terms of a valence such as the liking or disliking of an object (Frey, 1986; Holbrook et al., 2005). We define an attitude as a negatively to positively valenced evaluation of an object (topic), person, or event.

Attitude change occurs when an individual’s evaluation of an attitude object changes in valence to become more positive or more negative (Maio & Haddock, 2010). There has been a significant amount of research on methods for facilitating change in attitudes (Eagly & Chaiken, 1993; McGuire, 1985; Petty & Cacioppo, 1981; Sinatra & Seyranian, 2016; Zimbardo & Leippe, 1991). The elaboration likelihood model (ELM), posited by Petty and Cacioppo (1981), remains one of the most widely cited attitude-change models.

The ELM is grounded in social psychological theory related to persuasion and states that persuasion depends on an individual’s ability and motivation to process information. When individuals are highly motivated and have the requisite ability, they are more likely to engage in attitude change; that is, motivation and ability increase the probability that a message is elaborated on, allowing information to be processed more deeply and making attitude change more likely to occur. Therefore, according to ELM, if people process information more deeply (e.g., conceptual change) they are more likely to experience attitude change.

The relationship among conceptual, emotional, and attitudinal change

Most of the research conducted on conceptual, emotional, and attitudinal change has shown that emotions and attitudes precede and influence the conceptual change process (Broughton et al., 2013; Dole & Sinatra, 1998; Gregoire, 2003). More recently, scholars have shown that affective and cognitive processes (including emotion and attitude) may have a more dynamic relationship during learning (Op’t Eynde & Turner, 2006; Linnenbrink, 2007; Lombardi & Sinatra, 2013). For instance, Heddy and Sinatra (2013) demonstrated that when individuals engage in conceptual change, they are more likely to show emotional change as well; that is, they found that conceptual change is associated with a positive shift in emotions. However, they were investigating conceptual and emotional change with regard to the concept of evolution, which is considered a controversial scientific construct that often is associated with negative emotional reactions (e.g., anxiety). It is important to note that conceptual change could possibly lead to more negative emotions if the misconception was related to positive emotions and the scientifically accepted conception was less enjoyable to think about. For example, having a misconception that dinosaurs lived simultaneously with humans may be enjoyable and learning the scientifically accepted conception that dinosaurs were extinct before humans evolved could increase negative emotions and decrease positive emotions. Related, less affectively charged misconceptions could lead to a more nuanced change in emotions and attitudes. Regardless, we posit that engagement in conceptual change is related to a shift in emotions in many cases.

Researchers suggest that compared with attitudes, emotions are more visceral in nature and are a mechanism that can hinder or facilitate attitude change (Petty & Brinol, 2015). In a recent review by Petty and Brinol (2015), the authors theorize the impact that emotions can have on attitude change (persuasion) during high versus low elaboration. Specifically, they suggest that when elaboration is high, which occurs during conceptual change, emotions can serve as arguments for a position or bias cognition related to a message. In essence, Petty and Brinol argue that when individuals elaborate deeply on a persuasive message (such as when reading a refutation text), emotions impact the extent to which they experience attitude change. Therefore, we hypothesize that if individuals engage in conceptual change (deep elaboration), the emotions that are caused by this outcome should predict engagement in attitude change. Based on this prior research, we hypothesized that emotional change likely mediates the relationship between conceptual and attitudinal change.
Sinatra and Seyranian (2016, see also Sinatra et al., 2014) propose a $2 \times 2$ matrix of conceptual and attitudinal change that suggests that conceptual knowledge can be either accurate or inaccurate and that attitudes can be either pro or con. They argue that those individuals who fall in the inaccurate knowledge category would be more likely to have negative attitudes and those in the accurate knowledge category would have positive attitudes. Thus, moving from inaccurate to accurate knowledge would facilitate a shift from negative to positive attitudes. We sought to test this hypothesis. However, predictions about emotions are not specifically included within the Sinatra and Seyranian framework, which is an important motivation of the current study. Given the import of emotions for learning about controversial topics, we posited that emotions might mediate the hypothesized relationship between conceptual change and attitudinal change. Therefore, we wish to empirically examine and then extend the Sinatra and Seyranian (2016) proposed framework by including a test of conceptual, emotional, and attitudinal change in the same study.

We used a refutation text as the mechanism to facilitate change. Refutation texts are a specific type of text that presents misconceptions and directly refutes them, followed by an explanation of the scientifically accepted conception (Sinatra & Broughton, 2011). Our first question is essentially a conceptual replication of previous research in which we are attempting to generate conceptual, emotional, and attitudinal change to investigate via structural equation modeling the path through which the variables of concern are related. Therefore, we used a refutation text because such texts have been shown to be effective for facilitating conceptual, emotional, and attitudinal change in previous research (Braasch, Goldman, & Wiley, 2013; Kendeou & van den Brock, 2007; McCrudden & Kendeou, 2014; Muis et al., 2015). (For more information on refutation text effect please read Sinatra & Broughton, 2011; Tippett, 2010.)

**Research questions**

Based on prior research and our knowledge of the topics, we generated the following questions to guide our research:

- Would readers of a GMFs refutation text demonstrate greater conceptual, emotional, and attitudinal change than a control group?
- Would conceptual change predict attitudinal change?
- Would emotional change mediate the relationship between conceptual change and attitudinal change?

We predicted that reading a refutation text would promote greater conceptual, emotional, and attitudinal change in participants, which is in alignment with over a decade of research that illustrates the effectiveness of refutation texts to facilitate learning and motivation (Alvermann & Hague, 1989; Sinatra & Broughton, 2011; Tippett, 2010). For instance, Heddy and Sinatra (2013) found that although an experiential learning instructional intervention was more effective, refutation text significantly facilitated conceptual change and increased positive emotions. Therefore, we predicted that our study would affirm the findings of prior research, which suggests that refutation text can generate conceptual and affective change (see also Kendeau & van den Broek, 2005).

We predicted that change in conceptual knowledge would promote a change in attitude valence from more negative to more positive. This prediction is supported by recent studies that have found that when students engage in conceptual change, a subsequent positive impact on affect can occur (Hynd, 2001; Muis et al., 2015). Thus, we are extending previous research by providing evidence for the hypothesis that a dynamic relationship exists between cognitive processes and affect (Op’t Eynde & Turner, 2006; Linnenbrink, 2007; Lombardi & Sinatra, 2013). Specifically, we aim to show that conceptual change can be a driver of attitude change rather than just an outcome.

Finally, we predicted that emotional change would mediate the relationship between conceptual and attitudinal change. We posited this hypothesis based on our knowledge of the conceptual, emotional, and attitudinal change research and literature. Although the relationship between emotion change and attitude change has been theorized (Petty & Brinol, 2015), to our understanding this is the first study to seek empirical evidence of the meditational role of emotions between conceptual and attitudinal change. Previous research supports that instruction can bring about change in one or two of these
constructions in combination (Broughton, et al., 2013; Heddy & Sinatra, 2013; Hynd, 2001; Kardash & Scholes, 1996; Murphy, 2001; Murphy & Mason, 2006) but not all three. Our goal was to provide a testable model that predicts specific testable paths among change in all three constructs and to exhibit what occurs concerning emotions and attitudes after conceptual change.

Methods

Participants

Participants were 339 undergraduate students recruited from a psychology participant pool at a large southwestern university in the United States. In all, 17 participants were flagged and removed for completing the task in too short of time (less than 3 minutes), which left 322 total participants. The participants were given credit toward meeting their psychology courses research participation requirement. The participants ranged from age 18 to 40. Consistent with enrollment patterns nationally in psychology, 63% were female and 37% were male. Participants self-reported their ethnicities as Caucasian (47%), African American (5%), American Indian/Alaskan (1%), Mexican American/Chicano (5%), other Latino/a (5%), Asian (31%), Hawaiian/Pacific Islander (1%), Puerto Rican (.3%), and other (5%). On average, participants had completed four high school–level science courses and three college-level science courses with a reported GPA of 3.4. In terms of political affiliation, roughly 20% self-reported as “very” to “slightly” conservative, 14% as “moderate,” 44% as “slightly” to “very” liberal, and nearly 20% as “libertarian.” Political affiliation is important to note, given the politically charged nature of GMFs.

Materials

Refutation text

A refutation text refutes misconceptions of GMFs by confronting the misconceptions directly and then provides the scientific conception and explains why it is correct. We implemented a refutation text developed from one that had been used in prior research and had been reviewed by an expert on GMFs (Broughton, Pekrun, & Sinatra, 2012). The text addressed several misconceptions (ideas in conflict with scientific ideas) about GMFs including cloning and cross-pollination. For instance, many individuals assume that genetic cloning is a genetic modification (Gaskell, Bauer, Durant, & Allum, 1999). However, this belief is a misconception because the process of cloning generates a genetic replica of the original organism, whereas the goal of genetic modification is to alter the genes of an organism so that it expresses desired characteristics that are different from the original organism. A second common misconception is the view that injecting organisms with hormones or pesticides is genetic modification; this is also incorrect (Uzogara, 2000). Injecting organisms does not change their genetic makeup. A third misconception is that all genetic modifications are “unnatural” (Uzogara, 2000). The scientific conception of GMFs is that modifications can be made through several processes including artificial selection and natural processes such as cross-pollination. The text specifically targeted these particular misconceptions. The text contained 630 words and was determined to be at a 10th-grade–reading level according to Flesch-Kincaid. The refutation text was used as the intervention to facilitate conceptual, emotional, and attitudinal change in the participants.

Demographics

A demographics survey was administered to all participants after intervention. We administered the demographics survey after intervention so participants’ responses to the demographic questions (e.g., gender, ethnicity, age) would not impact their responses to the surveys, which could prime participants or serve as a type of stereotype threat (Steele & Aronson, 1995). The survey asked specific questions regarding participants’ age, ethnicity, and gender. Further, we asked participants about the number of biology and chemistry courses that they completed in high school and college. A question on the demographics survey asked for participants’ political identification using a 7-point scale anchored by strongly liberal and strongly conservative, with moderate at the center. The political identification question has been effectively used in prior research to distinguish between conservatives, liberals, and
moderates (Graham, Haidt, Nosek, 2009). Given that the topic of GMFs is politically charged, this question allowed us to control for political affiliation between conditions.

**Test of knowledge and conceptions of genetically modified food**

A quiz was implemented before and after intervention that assessed content knowledge and conceptions related to GMFs (see Appendix B). The GMF quiz was co-designed and reviewed by an expert on GMFs (Broughton et al., 2012); furthermore, the instrument has been shown to be valid and reliable in other research (see Trevors, Muis, Pekrun, Sinatra, & Winne, 2016). This instrument asked 10 multiple-choice questions regarding GMFs. As an example, one question asked, “What will happen to the genetic offspring of plants and animals that have been genetically modified?” Participants had the option to choose from four options that represent either a misconception view (three options) or the scientifically accepted perspective of genetic modification (the one correct option). Answering a question correctly indicates conceptions consistent with the scientific conception and was scored as a 1. Answering incorrectly indicates a misconception related to GMFs and was scored a −1. Therefore, if the mean score was in the positive range then the participant generally held the scientifically accepted conception, whereas if the mean score was in the negative range the participant generally held a misconception view of GMFs.

**Attitudes about GMFs survey**

An instrument that assessed explicit attitudes about GMFs was implemented to participants both before and after reading the refutation text (see Appendix C). We developed this instrument based on years of research suggesting that Likert scales can be effectively used to assess explicit attitudes toward topics (Likert, 1932; Maio & Haddock, 2010). The four items were modified from Poortinga and Pidg-eon’s (2006) study and were designed to assess the valence of attitudes with regard to four different aspects of attitude including general attitude, acceptability, behavioral intentions, and concern. This instrument contained four statements regarding genetically modified foods and then asked participants to respond to a 5-point Likert scale with the anchors strongly disagree and strongly agree, with unsure at the center. For example, the acceptability attitude statement was: “Genetically modified foods are okay with me.” Cronbach’s alpha was α = .84, which suggests that the instrument was highly reliable.

**Emotions survey**

An instrument based on prior work by Broughton and colleagues (Broughton et al., 2013) was used to assess participants’ positive and negative topic emotions related to GMFs (See Appendix D). Topic emotions are “those that are experienced by students in relation to a specific topic within a domain of study,” (Sinatra et al., 2014, p. 416). The questionnaire was altered to assess student emotions such as enjoyment, pride, boredom, and so forth regarding learning about GMFs. This instrument asked students to rate the intensity with which they were experiencing 13 emotions. Although several other emotions exist that may relate to this topic we chose these specific emotions by listing all of the emotions investigated in the topic emotions literature and then eliminating closely related emotions. For instance, we removed the emotion “irritated” due to its similarity to frustration and we removed “happiness” due to its similarity to enjoyment. Although there may be some limitations to this approach, the emotions that were included represent unique and relevant emotions with regard to learning in our particular context that have a basis in prior research. Participants rated the extent to which they felt an emotion about the topic on a 5-point Likert scale ranging from not at all (1) to very strong (5). The topic emotions survey was implemented before and after intervention. Cronbach’s alpha was α = .80, which suggests that the instrument was highly reliable.

**Procedures**

A description of the study was posted on the psychology department–participant pool website. Students who were interested in the study or were required to participate in research studies for course credit had the option to sign up to be a participant. The study was a pre-post design with treatment and control groups and pre and post surveys conducted within the same session.
After signing up for the study, participants were immediately directed to a set of online surveys (using the survey platform Qualtrics), which included a consent form, the genetically modified foods quiz, emotions survey, and the survey on attitudes about GMFs. We decided to have participants take the knowledge survey first in order to elicit emotions and attitudes related to GMFs and conversely so that emotions and attitudes provoked by their respective surveys did not impact the knowledge quiz. The emotions survey and attitudes survey were randomly counterbalanced at both pre- and postimplementation to be sure that the order in which participants received these two surveys did not differentially impact their responses. Next, the participants in the treatment condition received the online refutation text. Following the text, students were provided with the genetically modified foods quiz, emotions survey, the attitudes about GMFs survey, and the demographics survey. The participants in the control condition received the same materials excluding the refutation text. The entire session was to take a maximum of 60 minutes to complete; average completion time was approximately 15 minutes. The longest completion time was 56 minutes and 32 seconds, while the shortest completion time was 3 minutes (participants who took under three minutes were removed from further analysis). After completing the session, participants were debriefed on the purpose of the study, were granted credit, and were thanked for their time.

Results

Screening and descriptive statistics

Most data were analyzed using SPSS 21 to explore differences between participants within and between conditions. The SEM was conducted using STATA 12. Table 1 shows the means, standard deviations, skewness, and kurtosis for treatment and comparison conditions on the Knowledge Quiz (pre and post), Emotions Survey, positive items (pre and post), Emotions Survey, negative items (pre and post), and Attitudes Survey (pre and post). All skewness and kurtosis values were less than or equal to an absolute value of 3, indicating that normality in the remainder of the analyses could be assumed (Tabachnick & Fidell, 1996). Further, no outliers were found in any of the data (i.e., zs ≤ 3).

All subjects were randomly assigned to either the treatment or control condition. However, we found no significant differences between groups on any demographic measures (gender, ethnicity, high school science courses, college science courses, grade-point average, and political identity). Zero-order correlations were conducted to determine whether assumed relationships between experimental variables were present. Please see Table 2 for details.

Main results

All preintervention measures were subjected to a multivariate analysis of variance (MANOVA) to ensure that no preexisting differences existed between the treatment and the control groups on our experimental measures. No significant differences were found between the treatment and the

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge (pre)</td>
<td>-3.46</td>
<td>3.45</td>
<td>0.88</td>
<td>1.10</td>
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<tr>
<td>Knowledge (post)</td>
<td>-0.67</td>
<td>4.98</td>
<td>.230</td>
<td>-1.03</td>
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<tr>
<td>Attitudes (pre)</td>
<td>11.8</td>
<td>3.42</td>
<td>-0.56</td>
<td>-0.09</td>
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<tr>
<td>Attitudes (post)</td>
<td>12.55</td>
<td>3.64</td>
<td>-0.575</td>
<td>.082</td>
</tr>
<tr>
<td>Negative Emotions (pre)</td>
<td>16.35</td>
<td>5.36</td>
<td>0.09</td>
<td>-0.63</td>
</tr>
<tr>
<td>Negative Emotions (post)</td>
<td>15.11</td>
<td>5.52</td>
<td>.374</td>
<td>-0.677</td>
</tr>
<tr>
<td>Positive Emotions (pre)</td>
<td>13.93</td>
<td>4.15</td>
<td>0.12</td>
<td>-0.68</td>
</tr>
<tr>
<td>Positive Emotions (post)</td>
<td>14.32</td>
<td>4.54</td>
<td>.238</td>
<td>-0.505</td>
</tr>
</tbody>
</table>
The results revealed a significant interaction between time of testing and refutation condition—specifically, the refutation text group reported significantly greater positive emotion change than the control group, $F(1, 320) = 11.69, p < .001, \eta^2 = .03$, indicating a small effect size. While pretest scores did not differ between the two conditions (Treatment $M = 14.24, SD = 4.24$; Control $M = 13.63, SD = 4.05$), posttest scores were significantly higher for the treatment group (Treatment $M = 15.12, SD = 4.81$; Control $M = 13.47, SD = 4.10$). Further, the refutation text group reported significantly greater negative emotion change than the control group, $F(1, 320) = 45.41, p < .001, \eta^2 = .12$, which indicates a moderate effect size. While pretest scores did not differ between the two conditions (Treatment $M = 16.33, SD = 5.24$; Control $M = 16.37, SD = 5.49$), posttest scores were significantly lower for the treatment group (Treatment $M = 13.93, SD = 5.21$; Control $M = 16.25, SD = 5.58$) than the control group. Taken together, these results supported our hypothesis that reading a refutation text would increase positive emotions and decrease negative emotions regarding GMFs.

Finally, we found a significant interaction between time of testing and refutation condition—specifically, the refutation text group reported significantly greater attitude change compared to the control group, $F(1, 320) = 79.77, p < .001, \eta^2 = .20$, which indicates a large effect. Specifically, whereas pretest scores did not differ between the two conditions (Treatment $M = 11.97, SD = 3.40$; Control $M = 11.63, SD = 3.45$), posttest scores were significantly greater for the treatment group ($M = 13.91, SD = 3.23$) than for the control group ($M = 11.23, SD = 3.55$). These results show that implementation of the refutation text resulted in greater attitude change regarding GMFs in the treatment group than the control group. Taken together, these results support our hypothesis that reading a refutation text would result in change in conceptual knowledge, emotions, and attitudes. Again, the first question was a conceptual replication of previous findings to ensure that the intervention facilitated all three forms of change so that we could explore the hypothesized directionality of the variables.
To address the second question, *Would conceptual change predict attitudinal change?*, the data were submitted to a regression analysis. Specifically, prior knowledge, prior attitudes, treatment, and postknowledge were used to predict attitudes following intervention. Results revealed that the final model was statistically significant $F(6, 321) = 117.34, p < .001$, adjusted $R^2 = .686$. The results show that after controlling for prior knowledge and prior attitude, the addition of negative and positive emotion change, treatment, and postknowledge accounted for an additional 15% of the variance (see Table 3). The unstandardized regression coefficient for postintervention knowledge, $b = .106, t = 3.11, p < .05$, indicated that for every unit increase in knowledge change, the predicted attitude toward GMFs of participants increases by .106. Results indicate that all predictors in the model, except for prior knowledge, were significant at the $p < .05$ level. Taken together, these analyses suggest that exposure to refutation texts produced conceptual change, and moreover, that conceptual change predicts attitudinal change beyond prior knowledge and previous attitudes. However, these analyses do not take into account the sequential nature of this predictive model or the nuances between emotional variables. The goal of the regression analysis was to explore whether conceptual change predicted attitudinal change independently of emotional change, thus allowing us to explore emotional change as a mediatory variable in an SEM, described next.

To address the final question, *Would emotion change mediate the relationship between conceptual change and attitudinal change?*, data were entered into a structural equation model. The use of structural equation modeling (SEM) was employed because it provides three distinct advantages over more traditional models. First, SEM allows the researcher to create and confirm specific path models with much more flexibility than traditional methods (e.g., multiple regression) (Kline, 2011). In the present investigation, this allows us to confirm, empirically, the theoretically hypothesized model discussed above. Secondly, SEM allows the researcher to model latent, hypothesized constructs using data collected on discrete items. In the present investigation, this takes the form of empirically creating factors of emotions that would otherwise be combined theoretically as either positive or negative. Finally, traditional methods would require separate analyses to create and then incorporate these factors into predictive models—a two-step process whereby first emotions items would be entered into a factor analysis and then these composite factor scores would be entered into a path analysis. However, SEM allows a researcher to combine a traditional factor analysis with a path analysis into a single model. In the present investigation, this results in a more parsimonious model without a loss of information required by traditional factor analysis.

The relationships between conceptual change, emotional change, and attitudinal change were analyzed within an SEM. Paths were created based on theoretically meaningful relationships. Specifically, the model begins with all students. Then, we hypothesized that exposure to the treatment would predict conceptual change, but not all students who received the treatment would undergo conceptual change. Next, we expected that the extent to which individuals underwent conceptual change would predict the extent to which they would undergo positive and negative emotional change. Finally, we expected that positive and negative emotional change would differentially predict attitudinal change. The final model is shown in Figure 1.

Table 3. Results of regression analysis showing the predictive relationship between attitude change and conceptual change, positive emotion change, negative emotion change, and the treatment ($N = 322$).

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
</tr>
<tr>
<td>Constant</td>
<td>3.218</td>
<td>0.491</td>
</tr>
<tr>
<td>Pre Knowledge</td>
<td>0.021</td>
<td>0.038</td>
</tr>
<tr>
<td>Post Knowledge</td>
<td>0.106</td>
<td>0.034</td>
</tr>
<tr>
<td>Att Pre</td>
<td>0.728</td>
<td>0.035</td>
</tr>
<tr>
<td>Pos. Emotion Change</td>
<td>0.093</td>
<td>0.040</td>
</tr>
<tr>
<td>Neg. Emotion Change</td>
<td>-0.173</td>
<td>0.038</td>
</tr>
<tr>
<td>Treatment</td>
<td>1.302</td>
<td>0.296</td>
</tr>
</tbody>
</table>

Note. $R^2 = .692; p < .05$. 
All paths shown are standardized (for ease of interpretation) and are significant at the \( p < .05 \) level. The overall model fits the data relatively well: \( \chi^2 (N = 321) = 297.7, p < .05, \text{RMSEA} = .077, \text{CFI} = .75 \) and explains 36% of the variance in attitude change. As expected, those individuals who read the refutation text were significantly more likely to experience conceptual change (\( \beta = .58 \)). In turn, experiencing conceptual change predicted a significant increase in positive emotions (\( \beta = .29 \)) and a significant decrease in negative emotions (\( \beta = -.4 \)). Finally, increases in positive emotions (\( \beta = .33 \)) and a decrease in negative emotions (\( \beta = -.46 \)) each predicted an increase in positive attitudes. These findings are noteworthy for two reasons. First, while changes in emotions significantly predict changes in attitudes, a decrease in negative emotions exerts much more influence than an increase in positive emotions (as indicated by the standardized beta values). Second, we contrasted this final model with a baseline model that included a direct path between conceptual change and attitude change. However, after accounting for the variance associated with emotion change, the direct path between conceptual change and attitudinal change ceased to be significant (\( p = .057 \)). And while our final model is not significantly better than the baseline model (\( \text{lr} = 3.67, \text{CFI} = .752, \text{TLI} = .709, p = .056 \)), we posit that our final model is more parsimonious. This finding may indicate that while conceptual change influences attitudinal change, this effect is mediated by changes in emotions. However, although the path became nonsignificant, this was barely the case (\( p = .057 \)). This finding should be interpreted with caution—it is possible that there could still be a substantial relationship between conceptual change and attitudinal change, even with the addition of emotion change, if more participants were included. However, the opposite is possible as well; with the inclusion of more participants, the more parsimonious model may perform statistically better than the baseline model. Thus, due to the size of the sample and the amount of variance left unexplained (64%), this relationship warrants further exploration.

Figure 1. Model showing relationship between the intervention, conceptual, emotion, and attitude change.
Discussion

The goal of this study was to explore the relationship among three related constructs: conceptual change, emotional change, and attitudinal change. Although there is extensive research on these three forms of change, to our knowledge, this is the first study that was designed with the goal of shifting all three, what Sinatra et al. called "the hat trick of change" (2016, p. 132).

Our first research question was, Would the GMFs refutation text group demonstrate greater conceptual, emotional, and attitudinal change than the control group? Our results showed that learning through a refutation text not only facilitated conceptual change, replicating a wealth of previous research (for a review, see Sinatra & Broughton, 2011), but we also found that it was effective for generating more-positive emotions, while decreasing negative emotions and increasing positive attitudes when learning about GMFs. Thus, our first research question was essentially a conceptual replication of previous research findings (Broughton, et al., 2013). This was important to establish because some research has shown that reading a refutation text when you have the correct connection does not "backfire" (Braasch et al., 2013), others have suggested that there can be a backfire effect (Trevors et al., 2016; van Loon, Dunlosky, van Gog, van Merriënboer, & de Bruin, 2015). Our findings support those of prior research suggesting that refutation text does promote change and we saw no evidence of a backfire effect (see also Kendeou & van den Broek, 2007). Refutation texts and instruction are most impactful when they directly confront students' misconceptions and, more importantly, provide a clear, compelling, and plausible conception (Braasch et al., 2013), which we tried to do in our text.

Many individuals hold misconceptions about what constitutes GMFs (Varzakas, Arvanitoyannis, & Baltas, 2007). Our results show that, when people engage in conceptual change related to GMFs, their emotions and attitudes become more positive. This is important because it gives people a more in-depth understanding about the pros and cons of GMFs based on scientifically accepted understandings. Therefore, rather than just assuming that all GMFs are harmful, they may recognize that there are also some positive aspects of GMFs as well (such as increasing drought tolerance of edible plants). This can have potentially life-saving implications for populations in drought-prone regions of the world and for countries with large populations. GMFs have been shown to be an effective method for generating drought resistant and high yielding crops (Kasuga, Liu, Miura, Yamaguchi-Shinozaki, & Shinozaki, 1999). Also important to note, we are not suggesting that every aspect of GMFs is positive; however, having more positive attitudes can lead to a more nuanced perspective so decisions regarding the banning and/or labeling of GMFs can be more informed and not based on misinformation and/or negative affect.

Our second research question was, Would conceptual change predict attitudinal change? Based on the theoretical model proposed by Sinatra and Seyranian (2016), we hypothesized that conceptual change would predict attitudinal change. Our results showed attitudes towards GMFs shifted to become more positive in valence when a refutation text was used to overcome misconceptions about GMFs. This is the first study we know of to empirically test a potential powerful means of promoting attitude change—shifting misconceptions related to the attitude object (in this case, GMFs) as hypothesized by Sinatra and Seyranian (2016). We add emotions to their framework, which we discuss with regard to the third research question below.

Shifting attitudes is important because this could influence how individuals approach and acquire knowledge in the future. For instance, previous research suggests that our attitudes influence the type of information we are likely to process and seek out (Frey, 1986; Holbrook et al., 2005). Rather than perceiving the world as an objective observer, humans encode and interpret information based on their attitudes (Maio & Haddock, 2010). Further, studies have exhibited that attitudes influence the extent to which people remember different types of information (Eagly, Chen, Chaiken, & Shaw-Barnes, 1999). Based on this and other research, we argue that if individuals have negative attitudes toward and misconceptions about a topic and subsequently engage in conceptual change, their attitudes may become more positive, and thus, their new positive attitudes may lead them to seek out more information on the topic, remember related information, and be more open to learning the content in the future.

Our third research question was, Would emotional change mediate that relationship between conceptual change and attitudinal change? Our results supported our hypothesis that emotions would
meditate the relationship between conceptual change and attitudinal change. We believe this to be an important finding because it is the first research to demonstrate this relationship empirically. We supported Petty and Brinol’s (2015) predicted mediatory effect of emotions between knowledge and attitude change. Thus, in accordance with the newly modified ELM, it appears that when people read refutation texts, they elaborate deeply on the content, and engage in conceptual change; engaging in conceptual change elicits a change in emotions, and subsequently changes attitudes. Such elaboration and engagement with refutation text has been demonstrated in other studies (see for example, Kendeou & van den Broek, 2007; Lombardi, Danielson, & Young, 2016).

This finding has practical import because many controversial science topics are emotionally charged. First, we found that attitudes became more positive when positive emotions increased and negative emotions decreased. This lends support to research that suggests the fruitful role of positive emotions in education (Bless, 2000; Heddy & Sinatra, 2013; Linnenbrink & Pintrich, 2002; Lombardi & Sinatra, 2013). Although emotions are relevant in most learning situations, they are particularly impactful when learning about hot-button issues. Related, Sinatra and Seyranian (2016) suggested that changing attitudes would be more effective if misconceptions about the topic were overcome, but their framework did not take emotions into account. Our results suggest that emotions must be addressed as well because of their mediating role between conceptual knowledge and attitudes. Sinatra and colleagues refer to changing three constructs at once as the “hat trick of change” (Sinatra et al., 2014, p. 132) precisely because it is challenging to effect change in multiple constructs simultaneously. The results of the present study show that refutation text is one promising means by which to promote multiple forms of change in learners’ knowledge, emotions, and attitudes. Each of which is challenging to change on its own. Change in these three components may help overcome some of the barriers that have been identified in the public understanding of science (Sinatra et al., 2014).

**Instructional implications**

Our findings contribute to the research on the intersection of knowledge, emotions, and attitudes in instructional situations. Previous research on attitude change shows that holding a positive attitude about a topic allowed for better processing of the material (Frey, 1986; Holbrook et al., 2005). If this holds true, gaining knowledge and, subsequently, a more positive attitude may work reciprocally to improve the learning experience. Previous research on emotions in science learning has shown that students’ negative emotions can be dampened down, by overcoming misconceptions (Broughton, Sinatra, & Reynolds, 2010). Positive emotions have consistently shown a benefit for learning and for conceptual change (Broughton et al., 2010; Pekrun & Linnenbrink-Garcia, 2012). Taken together, the current study and prior research indicate that teaching for conceptual change related to negatively charged topics may provide a mechanism for increasing positive emotions, dampening negative emotions, and leading to more positively valenced attitudes. When teaching about controversial science topics such as GMFs, evolution, and climate change, conceptual change could be used to promote more-positive emotions and attitudes, not just shifts in knowledge.

**Directions for future research**

Our results have implications for teaching and learning about controversial topics, and for understanding the impact of conceptual change on emotional and attitudinal change. Our study also suggests several questions for future research. First, will our results extend to other controversial topics such as climate change or evolution? There may be significant variation among topics when considering conceptual, emotional, and attitudinal change. For example, climate change has been shown to evoke emotions such as anxiety and hopelessness (Lombardi & Sinatra, 2013). Learning about evolution has been shown to evoke anxiety but also enjoyment (Heddy & Sinatra, 2013). Relatedly, will similar results occur for affectively charged noncontroversial topics or topics that are not emotionally charged at all? We focused on a controversial topic, which generally elicits highly charged emotional and attitudinal reactions, which could provide features that moderated our findings. As an example of an affectively
charged noncontroversial topic, a student may really like learning about weather, which is noncontroversial, but the student’s affection for the topic could influence engagement in conceptual, emotional, and attitudinal change. The pattern of change may look different than the one we found because the affective charge unfolds in a different fashion. Thus topic emotions vary, and different emotions are likely to vary in their impact on shifts in attitudes and knowledge. Therefore, a fruitful area of investigation would involve several other emotions not included in the current study and exploring their differential impact on attitude change.

Second, what interventions can be developed to facilitate conceptual, emotional, and attitudinal change? Broughton et al. (2010) demonstrated limited change in all three through a text and discussion intervention, even though the goal of the study was to promote only conceptual and attitudinal change. The results show that leveraging conceptual change in order to facilitate emotional and attitudinal change is productive, so further research should explore the effectiveness of other conceptual change interventions for producing the “hat trick of change.” Related to this, we measured knowledge, emotion, and attitude at two time points. Future research should focus on assessing these variables at a third and potentially fourth time point. Such assessment would show whether the change had a lasting effect and growth curve analyses could be conducted to explore participants’ growth or decrease in the variables over time.

Third, will other methods for facilitating change lead to the same directional relationship between conceptual, emotional, and attitudinal change demonstrated here? For instance, future research should explore if other types of text facilitate all three types of change in the same fashion. Here, we used a refutation text as compared to a no-text condition intentionally to ensure that our treatment facilitated all three forms of change, so we could explore the relationship. However, researchers could examine a refutation text condition as compared to an expository text condition and explore whether the same relationship between conceptual, emotional, and attitudinal change persists or whether different texts elicit distinct reactions among participants. Also, doing so would allow researchers to investigate the power of refutation text as a tool to facilitate change. In the present study, emotions mediated the relationship between conceptual and attitudinal change but previous research showed that if emotions were overwhelmingly negative then the negative emotions were not associated with change (Broughton et al., 2010). This begs the question of whether in cases in which the topic elicits very negative emotions, emotions have to be directly addressed first, before they could play any mediating role between conceptual and attitudinal change?

**Limitations**

As with all studies, this study has limitations. First, because our control group did not participate in an intervention, we cannot say whether our intervention was more potent than any other change-promoting instruction. Relatedly, “no reading” as a control is problematic because participants, not only weren’t exposed to a text activating their misconceptions, they also were never exposed to accurate text. However, we included a control only to be sure that our treatment facilitated all three forms of change so that we could perform subsequent analyses and not necessarily to test the impact of refutation text. Second, the study was conducted entirely online, which limits the scope because behavior may be different in person. Other studies have shown the power of discussion in promoting change but that was not explored here. However, the topic of GMFs is not something that is typically learned in biology courses but rather is a topic that individuals learn and read about on their own, which we presume is often in online environments. Therefore, we choose to use an online-reading-only condition for reasons of ecological validity. So, while our methodology matched our goal, future research should explore the change process within classroom contexts. A third limitation was that, in the treatment condition only, the preintervention knowledge assessment was administered before the refutation text and in the same session as the postintervention knowledge assessment. This is a limitation because the preknowledge assessment may have acted as an “advanced organizer” for the treatment group by highlighting what to pay attention to in the text. One could argue that this “advanced organizer” could have driven the conceptual change results in the treatment group. Although we cannot deny that this could have been the case, the lack of change in the control group suggests that the knowledge pretest was insufficient to promote change on its own. In addition, our goal was to explore the relationship between conceptual, emotional, and attitudinal change, not the impact of refutation text on these variables.
Finally, our sample was a limitation in that it was composed of college students in the southwest, which has implications for generalization. Our sample was advantageous due to the liberal nature of students in our sample because a liberal political affiliation has been shown to be associated with negative emotions and attitudes toward GMFs and therefore exploring change with this population was a fruitful endeavor. In the future, exploring multiple forms of change using other topics and other populations who hold different points of view on different topics should prove fruitful for understanding how best to promote change.

**Conclusion**

Conceptual understanding, emotions, and attitudes are important in teaching or persuading others to think differently about scientific topics. However, we have a limited understanding of how these constructs are related and how change in one impacts change in the others. Our results suggest that when individuals hold misconceptions, negative emotions, and negative attitudes, conceptual change can facilitate shifts in attitudes, mediated by emotional change. This suggests that facilitating conceptual change may have a positive effect on changing more than students’ knowledge but also on their emotions and attitudes. This finding is especially important for topics that conflict with individuals’ beliefs and have strong emotional and attitudinal components that are often found in science.

**References**


Appendix A

Refutation text

Have you ever wondered just what it means when you hear the term “genetically modified foods”? Along those same lines, have you ever thought about how genetically modified foods are developed? Each of those questions are quite interesting to think about given that some of the foods we eat may...
have been genetically modified. In answer to the first question, genetically modified foods are those that have been modified via genetic engineering or other more traditional methods in order to produce heritable improvements in plants or animals for specific uses (U.S. Department of Agriculture, 2011). In other words, they are foods that have been modified at the gene level to produce a desired trait that would most likely not occur through natural processes. So, just what processes are involved in genetically modifying foods?

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, genetically modified food can be produced by gene cloning methods; however, the protein in the genetically modified organism has been modified somewhat so that the host (modified) organism will express the desired trait. Thus, the genetically modified organism is not necessarily an exact replica of the donor organism.

Instead of cloning you may think that injecting hormones into a plant or animal is involved in the production of genetically modified foods. This belief is also incorrect. Injecting hormones into a plant or animal can increase its growth rate or its size. However, injecting hormones does not modify the genetic makeup of the plant or animal. In contrast, genetically modified foods have had some of their characteristics changed at the gene level.

Now you know that genetically modified foods are those foods that have had some of their genetic information changed or new DNA added or suppressed. You may think that the development of genetically modified foods occurs only in laboratories by scientists. Not so! Genetic modifications may happen through natural processes. For example, one type of a natural process for genetic modification of plants is cross-pollination. Cross-pollination occurs when the pollen from one plant is crossed with the pollen of a second plant. Corn plants are often cross-pollinated through wind transport which occurs when the wind carries pollen from one corn crop to a separate corn crop in nearby fields. When corn plants of different varieties are cross-pollinated, the seeds they produce will be genetically different than the original corn plants. The corn produced by these cross-pollinated plants is a combination of the two varieties of corn. The corn seeds from the new cross-pollinated plant will carry the new genetic information. That new genetic information will continue to be a part of that plant’s offspring.

Since it is the case that genetically modified foods can occur through natural processes you may wonder just how long genetic modification of foods has been taking place. You may hold the belief that genetically modified foods are only a product of contemporary scientific research. This belief is not correct! Indeed, for many centuries farmers and gardeners have used cross-pollination of plants in an attempt to produce plants or flowers that would have particular qualities. For example, farmers have used selective pollination of plants in hopes of producing sweeter fruits or more colorful flowers. Even today, farmers and gardeners use cross-pollination in hopes of producing sweeter corn or more colorful decorative corn.

In summary, genetically modified foods are those foods that have had some of their genetic information changed. Some foods can be genetically modified through natural processes such as cross-pollination. Farmers have used the process of genetically modifying foods for centuries as they attempt to develop plants with desired characteristics.

Appendix B

Knowledge assessment items: Genetically modified foods

Directions: Below are statements about genetically modified foods. Please choose the answer that is the most consistent with your own knowledge.

1. Genetically modifying foods occurs through …
   a. natural processes.
   b. artificial processes.
   c. all of the above
   d. none of the above
2. Processes used by scientists to modify the genetic makeup of plants and animals include which of the following?
   a. Exact replica cloning
   b. Hormone injection
   c. Cross-pollination
   d. All of the above

3. When using gene cloning methods a genetically modified organism is …
   a. an exact replica of the donor organism.
   b. a bit different than the donor organism.
   c. in no way similar to the donor organism.
   d. Gene cloning methods cannot be used to genetically modify organisms.

4. Cross-pollination is considered to be a process through which plants can be …
   a. genetically modified.
   b. cloned.
   c. hormone injected.
   d. exactly replicated.

5. Which of the following can genetically modify plants or animals?
   a. Farmers/gardeners
   b. Scientists
   c. Animals
   d. All of the above

6. What will happen to the genetic offspring of plants and animals that have been genetically modified?
   a. The genes will be passed to the new offspring.
   b. The offspring’s genetic makeup will revert back to its original state.
   c. A genetic mutation will occur.
   d. They will be physically or mentally disabled.

7. Injecting hormones into a plant or animal may change what about that organism?
   a. the size of the plant or animal
   b. the genetic makeup of that plant or animal
   c. all of the above
   d. none of the above

8. Adding to or inhibiting a plant’s or animal’s DNA occurs only in …
   a. laboratories
   b. nature
   c. farms
   d. all of the above

9. When were processes used to modify a plant’s or animal’s DNA developed?
   a. In the past 10 years
   b. In the past 50 years
   c. In the past 100 years
   d. Longer than 100 years

10. Methods that are NOT used in producing genetically modified foods include which of the following?
    a. Gene cloning methods
    b. Hormone injection
    c. Cross-pollination
    d. Selective pollination
Appendix C

**Attitudes about genetically modified foods**

Please mark how strongly you agree or disagree with each of the statements listed below. Please select the number that best matches the strength of your attitude.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Unsure</th>
<th>Agree</th>
<th>Strongly agree</th>
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</thead>
<tbody>
<tr>
<td>Genetically modified foods are okay with me.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Genetically modified foods are beneficial to society.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I approve of genetically modified foods.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I would eat food that has been genetically modified.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Appendix D

**Emotions about genetically modified foods**

We are interested in the types of emotions you experience when thinking about genetically modified foods. For each emotion, please indicate the strength of that emotion by selecting the number that best describes the intensity of your emotional response.

<table>
<thead>
<tr>
<th>Emotion</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angry</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
</tr>
<tr>
<td>Hopeful</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
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<tr>
<td>Anxious</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
</tr>
<tr>
<td>Bored</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
</tr>
<tr>
<td>Curious</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
</tr>
<tr>
<td>Happy</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
</tr>
<tr>
<td>Fearful</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
</tr>
<tr>
<td>Confused</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
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<tr>
<td>Interested</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
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</table>

(Continued on next page)
(Continued).

<table>
<thead>
<tr>
<th>Emotion</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surprised</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
</tr>
<tr>
<td>Frustrated</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
</tr>
<tr>
<td>Hopeless</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>Not at all</td>
<td>Very little</td>
<td>Moderate</td>
<td>Strong</td>
<td>Very strong</td>
</tr>
</tbody>
</table>

Other (list multiple emotions if needed) ________________________________