

Epistemic Beliefs Moderate Mediations Among Attitudes, Prior Misconceptions, and Conceptual Change

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ABSTRACT

We investigated the mediating and moderating roles of attitudes and epistemic beliefs in conceptual change during learning about genetically modified foods (GMFs). One hundred twenty undergraduate students participated. To measure misconceptions about GMFs, students first completed a prior knowledge test. Students then completed self-report inventories to measure their attitudes and topic-specific epistemic beliefs regarding GMFs. Students were then randomly assigned to read a refutation or expository text about GMFs. Following reading, students completed a test to assess conceptual change. Results of a repeated measures ANOVA revealed participants who read a refutation text changed more misconceptions at post-test than participants who read an expository text. A moderation mediation analysis revealed attitudes toward GMFs significantly mediated the relationship between prior misconceptions and conceptual change, and that this relationship was moderated by learners' beliefs regarding the source and justification of GMFs knowledge. Theoretical and educational implications are discussed.

Keywords: attitudes; epistemic beliefs; conceptual change; genetically modified foods

INTRODUCTION

The public's increasing mistrust in science has become a particularly challenging problem for learning and science education. An example is the recent increase in measles outbreaks in America and Europe (World Health Organization, 2018) due to misconceptions that the measles, mumps, and rubella vaccine (MMR) causes autism (Kata, 2012). The vaccine-autism misconception can be traced back to a fraudulent study by Wakefield et al. (1998), published in the *Lancet* medical journal, wherein they asserted that a temporal association exists between administration of the MMR vaccine and the onset of autism. Despite its retraction and substantial research evidence to the contrary, many individuals continue to hold misconceptions about vaccines, and consequently, have been increasingly refusing to get vaccinated.

Misconceptions represent inaccurate knowledge, understanding, or faulty reasoning that departs from scientific knowledge or understanding of a topic (Heddy, Danielson, Sinatra, & Graham, 2017). Such errors in reasoning are typically acquired during previous learning and can negatively predict new learning (Krause, Kelly, Corkins, Tasooji, & Purzer, 2009). Misconceptions can be counterproductive for learning when individuals are unable to recognize and revise their misconceptions and discriminate between information based on evidence and information derived from opinion, including knowledge that has been contorted to meet social, political, and/or economic gains (Ecker, Hogan, & Lewandowsky, 2017; Sinatra & Seyranian, 2016).

Many individuals hold misconceptions about a variety of complex socioscientific topics, including vaccines, climate change, stem cell research, and genetically modified foods (GMFs). Indeed, due to a lack of accurate knowledge (i.e., misconceptions), many individuals believe GMFs are unsafe for human consumption and, as a result, hold negative attitudes towards them (Heddy et al., 2017). In addition to negative attitudes, individuals' epistemic beliefs (i.e., beliefs about the nature of knowledge and knowing) may lead them to reject scientifically accurate information about GMFs if they believe their own knowledge or understanding to be just as valid as those of experts. Taken together, attitudes and epistemic beliefs may play a role in terms of how individuals process, interpret, and evaluate various sources of knowledge related to a variety of complex socio-scientific topics of global significance.

Attitudes refer to positive or negative evaluations of objects, people, or events that predispose individuals to respond to attitudinal objects in preferential ways (Eagly & Chaiken, 1993; Fishbein & Ick, 1975). Epistemic beliefs, on the other hand, refer to personal theories (or individual doxastic assumptions) related to the nature of knowledge (structure and certainty) and the nature of knowing (i.e., source and justification; Hofer & Pintrich, 1997). Attitudes predict the types of information individuals are likely to select, perceive, process, and encode (Maio & Haddock, 2010), whereas epistemic beliefs play a role in how individuals interpret and evaluate knowledge claims. In other words, beliefs are the building blocks of attitudes (Dole & Sinatra, 1998). Indeed, an individual's attitude toward an object includes an evaluative component ("I don't like GMFs...") that is tied to a cognitive component that may be an unjustified belief (i.e., a misconception, "because they are not safe to eat") or a justified true belief (i.e., a correct conception [Sinatra & Syranian, 2016]). Changing individuals' misconceptions about a topic requires shifting an unjustified belief to a justified true belief where justification is the central mechanism by which this occurs (Authors, 2012).

However, individuals tend to seek out information that is congruent with their attitudes while ignoring attitude-incongruent information (Maio & Haddock, 2010). Similarly, individuals are likely to interpret and evaluate discrepant knowledge claims within the context of their own personal systems of epistemic beliefs, and subsequently, to reject information that does not conform to their own understanding or topical knowledge. As such, systems of beliefs (and emergent attitudes) can reflect judgements of fact or processes of evaluation that may be derivative of conjecture (Rockeach, 1968). Given this link, individuals' epistemic beliefs may interact with their attitudes to predict whether conceptual change occurs. That is, misconceptions may be less amenable to change when tied to individuals' negative attitudes about that topic (Sinatra & Seyranian, 2016). To date, researchers have not explored the possibility that attitudes and epistemic beliefs may interact to predict conceptual change. Additionally, few studies have investigated whether individual learner

characteristics such as attitudes and epistemic beliefs interact with the quality of a message (i.e., message characteristics of an assigned text) to predict conceptual change. Therefore, we included two types of texts as a treatment measure in our study: a refutation and an expository text. The refutation text was used as an instructional approach to support conceptual change by directly confronting a misconception using causal explanations to refute incorrect knowledge. The expository text served as a control and included the same content as the refutation text, but without the refutation content. Decades of research in the conceptual change literature has shown refutation texts to be an effective strategy for supporting conceptual change (see Tippet, 2010 for a full review). As such, we examined whether conceptual change would vary as a function of learners' attitudes and epistemic beliefs (i.e., learner characteristics) and type of instructional text (i.e., message characteristics).

In a post-truth era when public distrust in science has led to the proliferation of misinformation, fake news, and erroneous knowledge, expounding a working model of the roles of attitudes and epistemic beliefs in learning and conceptual change is imperative to understanding how these factors can be leveraged to enhance learning outcomes for individuals who hold inaccurate conceptions, negative attitudes, and limited epistemic strategies for interpreting and evaluating knowledge and knowing related to complex scientific issues (see WHO, 2018 for example). Therefore, the present study examined the direct, indirect, and conditional indirect effects of prior misconceptions on conceptual change via learners' attitudes and epistemic beliefs when learning about GMFs from refutation and expository texts. Prior to delineating our research questions and hypotheses, we present relevant theoretical and empirical work.

THEORETICAL FRAMEWORKS

Conceptual Change

Conceptual change involves revising misconceptions and updating inaccurate knowledge to reflect more accurate representations of knowledge regarding a topic (Kendeou & O'Brien, 2014). Typically, conceptual change is provoked when a state of cognitive conflict arises between misconceived prior knowledge and the learning of new, discrepant information (Chan, Burtis, & Bereiter, 1997). When incorrect prior knowledge comes into conflict with newly acquired, accurate conceptions of a topic, the ensuing incongruity leads to attempts to reconstruct inaccurate knowledge to reflect more accurate configurations within a conceptual network (Chan et al., 1997; Chi, 2008; Lombardi, Nussbaum, & Sinatra, 2016).

Regarding science learning, the notion of conceptual change implies that individuals have pre-existing misconceptions—inaccurate mental representations of a topic—that contradict scientific understanding of that topic (Lombardi et al., 2016). Science misconceptions are often quite enduring, resistant to change, and can have particularly deleterious effects on learning and decision-making behaviors (Ecker, Hogan & Lewandowsky, 2017; Vosniadou, 1994). To change science misconceptions, conceptual change is necessary.

Refutation texts are one method used by researchers to investigate and support conceptual change. Refutation texts help learners reconcile cognitive conflict regarding a topic by directing metacognitive awareness away from inaccurate knowledge and toward more accurate conceptions of a topic via the structured presentation of causal explanations to refute incorrect knowledge. Although effective, research examining the processes involved in conceptual change has shown that

successful revision of misconceptions is not merely a product of refuting inaccurate knowledge (i.e., simply stating knowledge to be incorrect) (Ecker et al., 2017; Kendeou & O'Brien, 2014). Rather, successful conceptual change depends in large part on an interaction between individual learner characteristics (i.e., prior knowledge, attitudes, beliefs, motivation) *and* message characteristics (i.e., comprehensibility, coherence, plausibility, and rhetorical structure of a message) (Dole & Sinatra, 1998). The dynamic and interdependent relations among learner and message characteristics in conceptual change are delineated in Dole and Sinatra's (1998) Cognitive Reconstruction of Knowledge Model (CRKM).

Cognitive Reconstruction of Knowledge Model (CRKM)

According to Dole and Sinatra (1998), individuals differ in the quantity and quality of their prior knowledge (i.e., misconceptions), and this prior knowledge can interfere with learning and the interpretation and evaluation of new information (see also Krause et al., 2009; Sinatra et al., 2008). In their Cognitive Reconstruction of Knowledge Model (CRKM), Dole and Sinatra (1998) described how interactions between learner characteristics (i.e., existing knowledge, attitudes, beliefs, and motivation) and message characteristics (i.e., comprehensibility, plausibility, coherence, and rhetorical structure) determine the likelihood individuals will cognitively reconstruct or revise previously acquired, inaccurate knowledge.

Individual learner characteristics, such as the strength and coherence of previously acquired information (i.e., the richness and explanatory power of a conception), as well as an individual's commitment to their existing knowledge (i.e., an individual's attitudes and beliefs regarding the value of a conception) determine the likelihood individuals will change pre-existing (mis)conceptions. The stronger and more conceptually coherent an individual's prior conceptions, as well as the degree of commitment an individual has toward previously acquired conceptions, the less likely conceptual change is to occur (Dole & Sinatra, 1998).

Regarding message characteristics, several factors are also likely to affect whether an individual will revise their existing knowledge, including (1) the comprehensibility and plausibility of a message; that is, whether the message is conceptually palpable and individuals view the message as credible (source evaluations), (2) the coherence of the message and whether the message has explanatory power and effectively links back to larger conceptual structures (elaborative complexity), and (3) whether the message is rhetorically compelling; that is, whether the message's structure, sources of information, and justification of arguments are sufficiently persuasive. In short, a message that is elusive, ambiguous, incoherent, or disconnected will not likely facilitate conceptual change.

Conceptual change is an iterative process involving dynamic interactions between both learner characteristics and message characteristics. For example, a comprehensible and plausible message may be personally relevant for one individual but not another. Additionally, an individual may have a strong, coherent prior conception to which he or she is strongly committed despite a plausible and rhetorically compelling counter message. Further, an individual may be dissatisfied with a previously acquired conception but not find a new message sufficiently plausible or coherent to warrant replacement of the existing conception. Finally, a message may be considered rhetorically compelling, but perceived as implausible. As previously noted, one method researchers have found to be effective in facilitating conceptual change and promoting deeper engagement while processing a message is via the use of refutation texts, which are described next.

Refutation Texts

Refutation texts are rhetorical devices designed to target misconceptions and facilitate conceptual change (Kendeou et al., 2014). Numerous studies have shown use of refutation texts to be an effective method for changing misconceptions related to a variety controversial socio-scientific topics including GMFs (Heddy et al., 2017; Heddy & Sinatra, 2013; Trevors et al., 2017a; Authors, 2016). Unlike expository texts that present information in a descriptive manner, refutation texts integrate elements of argumentation to draw metacognitive awareness towards misconceptions or inaccurate beliefs (Tippet, 2010). According to Kendeou et al. (2013, 2014), a refutation text must include the following three components to be effective. First, it must directly confront a misconception (i.e., draw metacognitive awareness toward inaccurate knowledge). Second, it must explicitly state the falseness of the misconception (i.e., create disequilibrium). Third, it must provide causal explanations based on empirical evidence to refute the misconception (i.e., to make the message more plausible; Kendeou et al., 2013, 2014). Causal explanations in refutations represent to-be-learned information and are intended to create a rich tapestry of information to help reduce cognitive conflict and the activation of previously acquired, incorrect information to aid in the reconfiguration of inaccurate knowledge structures within a conceptual network (Kendeou et al., 2013, 2014).

Although refutation texts are designed to be comprehensible, coherent, plausible, and rhetorically compelling, an individual's motivation to revise previously acquired misconceptions significantly determines their relative depth of engagement with a message (Dole & Sinatra, 1998). At the highest level of engagement, individuals are more likely to critically evaluate the content of a message to assess the validity of the knowledge claims as well as the quality of its source. At the lowest level of engagement, individuals are likely to process only that information that is congruent with their prevailing attitudes or underlying beliefs (Dole & Sinatra, 1998). In other words, learner characteristics such as attitudes and epistemic beliefs also predict the probability that learners will conceptually change and revise previously acquired misconceptions.

Attitudes

Attitudes refer to positive or negative evaluations of people, events, or ideas that lead individuals to respond with some degree of favor or disfavor (Eagly & Chaiken, 1993; Fishbein & Icek, 1975; Heddy et al., 2017). In lieu of the oft cited tripartite model of attitudes, which presupposes attitudes to be made up of orthogonally distinct cognitive, affective, and conative components, attitudes herein are construed as distinct entities existing separately from cognitive, affective, and behavioral elements, and specifically, to serve an evaluative function in the appraisal of information derived from these distinct factors (Fabrigar, Macdonald, & Wegener, 2005). In this way, attitudes are described in terms of simple object-evaluation associations that are typically embedded within larger semantic networks of associated knowledge structures (i.e., beliefs, affective states, and representative behavioral schemas).

The structural view of attitudes as simple object-evaluation associations can be concisely described as follows: an attitudinal object (say, GMFs) represents one node within a semantic network, the evaluation of the object (say, beliefs about GMFs) represents the other node, and the link between the two nodes represents the relative strength of the association (Fabrigar, et al., 2005). For example, GMFs (the object of evaluation) could be evaluated based on a set of beliefs that GMFs are

unsafe for human consumptions (attributes of the object), and the strength of these beliefs associated with the topic of GMFs could result in an overall negative attitudinal appraisal of GMFs. As previously mentioned, attitudes are commonly embedded (or linked) to larger networks of associated knowledge structures (Eagly & Chaiken, 1993; Fabrigar et al., 2005). For example, specific attributes associated with the representational nature of an object (e.g., cognitive, affective, or conative properties) are also associated with local evaluations of these representational features in addition to the overall (global) appraisal of the attitudinal object. In other words, the structure of an attitude comprises not only object-evaluation associations, but also interconnected knowledge structures (such as systems of epistemic beliefs), that vary as a function of the strength and pattern of associative links between the attitude and related structures (Fabrigar et al., 2005). Thus, attitudes are shaped by both general (global) evaluations of a focal object, and more specific (local) appraisals of an object's attributes (or interconnected knowledge structures) that situate the attitudinal object within a larger semantic network, as shown in Figure 1. In theory, any changes in knowledge (or conditions under which an object of knowledge and knowing is evaluated) at either the global or local level should lead to changes in the overall object-evaluation association, and subsequently, to changes in the representational nature of knowledge for which an attitude has been formed.

Attitudes serve an evaluative function in the processing of information related to a topic. For example, evaluations related to the credibility of a scientific claim (attributes of the object) could be biased by pre-existing attitudes (and associated beliefs), and thus, individuals may ignore evidence that contradicts their own understanding or conceptions (Sinatra, Kienhues, & Hofer, 2014). Consequently, attitudes can interfere with new learning, including individuals' interpretations of information (i.e., perceptions of certainty or complexity), evaluations of source credibility, and judgements regarding the veracity of scientific information (Sinatra et al., 2014). In other words, attitudes are likely related to an individuals' epistemic beliefs. Moreover, research has shown that epistemic beliefs predict individuals' understanding, learning, achievement, and conceptual change (Stathopoulou & Vosniadou, 2007).

Epistemic Beliefs

Epistemic beliefs reflect individuals' beliefs about knowledge and knowing, are relatively stable over time, and include doxastic assumptions regarding the nature of knowledge and knowing (Hofer & Pintrich, 1997; Authors, 2007, 2018; Schommer, 1990; Sinatra & Hofer, 2016). Whether explicit or implicit, epistemic beliefs play a central role in how individuals reason about knowledge and knowing (Chinn, Buckland, Samarapungavan, 2011; Sinatra et al., 2014), including evaluations and judgments regarding the veracity of information obtained from multiple sources (Greene, Yu, & Copeland, 2014), and are predictive of both learning processes and achievement outcomes (Chinn et al., 2011; Hofer, 2000; Authors, 2004, 2007).

Based on the work of Hofer and Pintrich (1997), epistemic beliefs are defined as personal theories related to beliefs about the structure of knowledge, certainty of knowledge, source of knowledge, and justification for knowing. The first two dimensions (structure and certainty) concern beliefs about the properties of knowledge, and the second two dimensions (source and justification) concern beliefs regarding processes of knowing. Beliefs regarding the structure of knowledge concern whether knowledge is believed to be made up of discrete (simple) facts, or whether knowledge is multifaceted and composed of highly complex and interrelated concepts. For the

certainty of knowledge, individuals may view knowledge as static and unchanging (steady state knowledge) or evolving and perpetually changing (entropic knowledge states). For the source of knowledge, individuals may believe knowledge is generated and disseminated via authority figures (externally generated), or personally constructed via reason and logic (internally generated). Finally, beliefs regarding the justification for knowing refer to whether individuals view knowledge as justified by expert authority, subjective experience, or via multiple sources of information (Hofer & Pintrich, 1997; Trevors et al., 2017b).

Research has shown that more constructivist epistemic beliefs (i.e., knowledge is complex, highly interrelated, uncertain, derived and justified via multiple sources of information) are correlated with various facets of learning and achievement (Franco, et al, 2012; Stathopoulou & Vosniadou, 2007), including self-regulated learning (see; Authors, 2007, 2010, 2018), conceptual change (Mason & Gava, 2007; Mason, Gava, & Boldrin, 2008), emotions (Authors, 2015, 2016), complex problem-solving (Authors, 2008), and digital literacy (Greene et al., 2014). In terms of conceptual change, numerous studies have found that individuals who hold more constructivist epistemic beliefs change more misconceptions after reading refutation texts than individuals who hold less constructivist epistemic beliefs (i.e., knowledge is simple, certain, derived and justified via authority or personal judgement; see Franco et al., 2012; Authors, 2011; Mason & Gava, 2007; Mason et al., 2008; Murphy & Alexander, 2016; Trevors et al., 2017).

Epistemic beliefs serve as a focal lens for understanding scientific topics and play an integral role in how individuals interpret and evaluate scientific knowledge, including discrepant knowledge claims (Sinatra et al. 2014), and predict the ways in which individuals engage in scientific inquiry, evaluate theories against evidence, interpret explanatory models of theoretical constructs, and develop understanding of complex science topics in relation to multiple, often discrepant sources of information (Stathopoulou & Vosniadou, 2007). Given the important role of epistemic beliefs in learning and understanding of scientific knowledge (Stathopoulou & Vosniadou, 2007), including the role attitudes play in how individuals select, interpret, process and encode information (Maoi & Haddock, 2010), more research is needed to examine how, in what ways, and for whom epistemic beliefs and attitudes work together to predict conceptual change. Such understanding could provide deeper knowledge of the structural and functional links between individuals' underlying systems of epistemic beliefs and the emergent attitudes by which they appraise objects of knowledge and knowing. The relationship between attitudes and epistemic beliefs in conceptual change is discussed next.

Theoretical Relationship Between Attitudes and Epistemic Beliefs

Common assumptions in the research on attitudes is that beliefs (i.e., cognitions and related knowledge structures) and attitudes are functionally consistent with one another. For example, a belief that GMFs are harmful for human consumption typically elicits a negative attitude, and changes to inaccurate beliefs (or misconceptions) can lead to a concomitant shift in the valence of attitudes (see Heddy et al., 2017 and Sinatra & Seyranian, 2016). According to Ajzen (1989), however, attitudes and beliefs are not merely consistent with one another; rather, attitudes systematically vary as a function of individuals' beliefs such that individuals' beliefs have a direct or causal effect on attitudes. In other words, attitudes are conditional upon individuals' beliefs.

While beliefs are typically tacit in exerting their effects on learning and behavior (Ajzen, 1989), attitudes tend to remain highly accessible to readily guide learning and decision-making behaviors (Ajzen & Fishbein, 2005). For example, previously formed attitudes regarding GMFs (the object of evaluation) are automatically activated during encounters with knowledge claims about GMFs (attributes of the object), and these readily available object-evaluation associations mitigate the need for individuals to metacognitively process all attributes of an argument vis-a-vis their predominant underlying epistemic beliefs each time they encounter a knowledge claim about GMFs. In this way, beliefs moderate attitudinal processing of information during learning and conceptual change, whereas attitudes serve a heuristic function for learning by enabling individuals to quickly process topical knowledge and to make quick decisions regarding whether to accept or reject knowledge claims related to a focal topic.

Although individuals' beliefs might not necessarily be veridical (i.e., beliefs may be biased or inaccurate), once an individual has developed a system of beliefs, these beliefs provide the cognitive substrate from which congruent attitudes are cultivated in a consistent fashion (Ajzen & Fishbein, 2005). Once an attitude is shaped, it can work backwards and influence the development of new systems of beliefs, or provoke a revision to incompatible systems. In other words, the information processing qualities of attitudes and epistemic beliefs result in recurring and reciprocal processes during conceptual change that create feedback loops to enable learners to metacognitively monitor, adapt, target and revise inaccurate knowledge structures during conceptual change.

THE CURRENT STUDY

Attitudes and epistemic beliefs predict how individuals process, interpret, and evaluate scientific information, and therefore, play a significant role in learning and conceptual change. Fulmer (2014), for example, found that students' attitudes toward science predicted their epistemic beliefs pertaining to the uncertainty of scientific knowledge, including their subsequent evaluations of sources of scientific knowledge. Additionally, Kapucu and Bahçivan (2015) found that students' epistemic beliefs about science positively correlated with their attitudes towards learning physics, and that students who held more constructivist epistemic beliefs regarding scientific knowledge tended to self-report more positive attitudes. Although these studies (and others; see Broughton et al., 2013; Franco et al., 2012) have revealed predictive and directional relationships between attitudes and epistemic beliefs in science education, few studies have directly investigated how, in what ways, and for whom these factors function to facilitate or constrain conceptual change while learning about complex science topics from refutation or expository texts. As previously noted, the unique rhetorical structure of refutation texts (i.e., message characteristics) has been shown to effectively support conceptual change (Tippet, 2010). Therefore, we used refutation and expository texts to examine whether text type (i.e., message characteristics) would interact with individual learners' characteristics (i.e., attitudes and beliefs) to predict conceptual change.

Examining relations between attitudes and epistemic beliefs in conceptual change can provide invaluable insights into how these factors predict socio-scientific reasoning and public understanding of science, especially regarding whether attitudes systematically vary as a function of individuals' epistemic beliefs, and in turn, whether attitudes predict the processing of scientific information during conceptual change vis-a-vis the evaluative function of learners' underlying epistemic beliefs. The current study thus examines potential mediating and moderating effects of

attitudes and epistemic beliefs in conceptual change while learning about GMFs, a complex socio-scientific topic.

Based on theoretical and empirical considerations, the following hypotheses were generated: (H1) Participants who read a refutation text will change more misconceptions at post-test than participants who read an expository text, and (H2) learners' attitudes towards GMFs will mediate between their prior misconceptions regarding GMFs and post-test conceptual change, but this effect will be conditional upon text condition and learners' epistemic beliefs such that participants with less constructivist epistemic beliefs will report more negative attitudes toward GMFs, and in turn, revise fewer misconceptions at post-test than learners with more constructivist epistemic beliefs and more positive attitudes toward GMFs. However, learners with less constructivist beliefs in the refutation condition should change more misconceptions than individuals with less constructivist beliefs in the expository condition. See Figure 2 for the hypothesized model.

METHODS

Participants

One hundred twenty undergraduate students participated in the study ($n = 32$ males) with a mean age of 21.29 years ($SD = 3.83$). Nineteen were in their first year of university, 24 were in their second year, 37 were in their third year, and 40 were in their fourth year. Students were drawn from an eclectic range of majors. Participants were recruited from a public university using an advertisement posted to the university's online classifieds.

Materials

Demographics Survey

A brief demographics survey was administered to capture participants' background information including gender, age, degree major/minor, cumulative GPA, first and second languages spoken and written, political affiliation.

Prior Knowledge Test

The prior knowledge measure included a 10-item multiple-choice test about GMFs (adapted from Heddy et al., 2017) and was used to assess participants' misconceptions related to GMFs. Participants were required to select the correct answer from a multiple-choice list of four possible answer choices. The three incorrect options were common misconceptions about GMFs. An example item included: "Processes used by scientists to modify the genetic makeup of plants and animals include which of the following?" One point was awarded for each correct answer, and zero points were awarded for incorrect answers. Participants' scores were summed, and an overall average score was calculated. The reliability index for the prior knowledge measure was moderately low (Cronbach's $\alpha = .60$; see Nunnally, 1978), yet this level of reliability is expected when participants' level of prior knowledge is also low, or when the topic being tested is sufficiently complex, as is the case with the topic of GMFs.

Attitudes Toward GMFs

The attitudes measure included four Likert-type items (adapted from Heddy et al., 2017) and was used to assess attitudes toward GMFs. An example item included, "I approve of genetically modified foods." Participants self-reported their attitudes toward GMFs on a scale ranging from "1 = strongly

disagree” to “5 = strongly agree.” The attitudes measure showed very good reliability (Cronbach’s $\alpha = .92$).

Topic-Specific Epistemic Beliefs Questionnaire

A modified version of the Topic-Specific Epistemic Beliefs Questionnaire (TSEBQ; Strømsø, Bråten, & Samuelstuen, 2008) was used to assess participants’ epistemic beliefs related to GMFs. The TSEBQ includes 24 items organized along four belief dimensions including the certainty of knowledge (6 items), complexity of knowledge (6 items), source of knowledge (5 items), and justification for knowing (7 items). Participants rated each item on a 10-point Likert scale ranging from “1 = strongly disagree” to “10 = strongly agree.” Psychometric analyses of the TSEBQ revealed low to moderate reliability estimates for each factor, including certainty (Cronbach’s $\alpha = 0.68$), complexity (Cronbach’s $\alpha = 0.48$), source (Cronbach’s $\alpha = 0.62$), and justification (Cronbach’s $\alpha = 0.71$).

Experimental Texts

The experimental texts presented information regarding GMFs and included one expository and one refutation text (Heddy et al., 2017). Both texts were comparatively equivalent in length (617 vs. 624 words, respectively). In terms of ease of readability, each text obtained Flesch-Kincaid ease of reading scores of 42.1 and 42.2, respectively (Flesch, 1948). Both the refutation and expository texts included the same information, but the refutation text presented information by directly identifying a common misconception and refuting it using three empirically validated causal explanations. An example refutation included the following: “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.” The expository text presented the same information as the refutation text, but without the refutation content. For example: “The production of genetically modified foods does not involve injecting hormones into a plant or animal. 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.” The refutation text presented participants with a total of four refutations that targeted common misconceptions related to GMFs.

Post-knowledge Test

To assess post-test learning (i.e., conceptual change), participants completed the same prior knowledge test. Psychometric reliability for the post-test measure was modest (Cronbach’s $\alpha = .71$).

Procedure

Participants first provided informed consent and subsequently received instructions on how to complete the study. Next, participants completed the GMFs prior knowledge test, the attitudes toward GMFs survey, and an adapted version of the TSEBQ (Strømsø et al., 2008). Following this, participants were randomly assigned to a refutation ($n = 62$) or expository ($n = 58$) text condition. After reading, participants completed the same GMFs prior knowledge test to assess conceptual change. Finally, participants completed a demographics survey to obtain basic background

information. At the end of the session, participants were thanked for their participation and compensated \$10 for their time.

RESULTS

Preliminary Analysis

Each continuous variable was inspected for skewness and kurtosis. Analyses revealed the GMFs knowledge post-test to be negatively skewed (-4.88). Given the post-test assessment included a true 0-value (answers were tabulated as being either correct or incorrect), no transformation was applied to normalize the distribution. No issues were observed regarding kurtosis. Descriptive statistics for all variables can be found in Table 1. Inspection of the data revealed univariate outliers for the following variables: attitudes ($n = 3, z = -2.53$), uncertainty of knowledge ($n = 2, z = -2.69$), complexity of knowledge ($n = 1, z = -2.55$), and the post-test knowledge assessment ($n = 3, z = -3.29$). In lieu of deletion, all cases were kept given the values were not extreme and equated to less than 2% of n (Cohen, Cohen, West, & Aiken, 2003). There were no multivariate outliers in the data, and examination of the Pearson correlation matrix revealed no issues of multicollinearity among variables of interest. See Table 2.

Repeated Measures Analysis of Variance (ANOVA)

A repeated-measures ANOVA was conducted to assess whether there were any significant group differences in conceptual change from pretest to posttest between learners who read a refutation text versus learners who read an expository text (H1). Time was used as a within-subjects factor (2 levels, pretest and post-test) and text condition (refutation and expository) as the between-subjects factor. Results revealed a significant Time by condition interaction, indicating that learners in the refutation text condition changed significantly more of their misconceptions at post-test than learners in the expository text condition, Wilks' Lambda = .850, $F(1,118) = 20.76, p < .001, \eta^2 = .15$. Post hoc analyses revealed a significant mean difference ($M = .17, SD = .04$) in post-test conceptual change between conditions, $t(118) = 4.56, p < .001$. Overall, 15% of the variance in post-test conceptual change was accounted for by text condition whereby learners who read a refutation text changed significantly more misconceptions regarding GMFs at post-test than learners who read an expository text.

Moderated Mediation Analyses

To examine whether attitudes mediated between prior misconceptions and post-test conceptual change and, in turn, whether this relationship was moderated by text type and learners' epistemic beliefs (H2), moderation mediation analyses were conducted using Hayes and Preachers' (2014) PROCESS macro for SPSS. See Figure 2 for the hypothesized model, and Figure 3 for the final model with standardized effects.

Results revealed a significant regression of prior misconceptions on attitudes towards GMFs ($\beta = .38, t(118) = 4.47, p < .001$). Findings also revealed a significant regression of prior misconceptions on post-test conceptual change ($\beta = .20, t(115) = 2.10, p = .04$). There was also a statistically significant regression of attitudes towards GMFs on post-test conceptual change, $\beta = .27, t(115) = 3.08, p = .003$. The overall model was significant, $F(4,115) = 10.41, p < .001, R^2 = .27$, with a medium effect size showing that 27% of the variance in post-test conceptual change could be accounted for by both the variables in the model.

With regard to the moderated mediation analyses, no statistically significant moderated mediation was detected for type of text. However, results revealed a statistically detectable conditional indirect effect (*Index* = -.06, with 95% bootstrap *CI*s from -.14 to -.01) of prior misconceptions on post-test conceptual change via learners' attitudes toward GMFs that varied as a function of their epistemic beliefs regarding the source of GMFs knowledge at levels of the mean (*effect* = .12, with 95% bootstrap *CI*s from .04 to .25) and 1SD below the mean (*effect* = .18, with 95% bootstrap *CI*s from .06 to .36). Overall, findings show that the more learners believed GMFs knowledge to be internally generated and derived via subjective experience, the less positive their attitudes towards GMFs, and in turn, the less misconceptions they revised at post-test.

Results also revealed a statistically detectable conditional indirect effect (*Index* = -.11, with 95% bootstrap *CI*s from -.23 to -.02) of prior misconceptions on post-test conceptual change via learners' attitudes that varied as a function of their beliefs regarding the justification of GMFs knowledge at levels of the mean (*effect* = .15, with 95% bootstrap *CI*s from .05 to .26) and 1SD below the mean (*effect* = .26, with 95% bootstrap *CI*s from .09 to .47). Overall, findings showed the more learners believed GMFs knowledge to be justified via personal judgement, the less positive their attitudes, and in turn, the less misconceptions they revised at post-test. Implications, future directions, and limitations of these findings are discussed next.

DISCUSSION

The purpose of our study was to advance knowledge about the roles of attitudes and epistemic beliefs in conceptual change while learning about GMFs. Based on Dole and Sinatra's (1998) CRKM of conceptual change, as well as our hypothesized conceptual model of relations among attitudes and epistemic beliefs, we examined whether attitudes mediated between prior misconceptions and post-test conceptual change, and in turn, whether this relationship was moderated by learners' epistemic beliefs. Additionally, we examined whether refutation texts were an effective intervention for facilitating conceptual change. The results supported our hypotheses, which have theoretical implications for understanding how individuals interpret, evaluate, and make sense of complex socio-scientific information.

Refutation Texts and Conceptual Change (Message Characteristics)

Although some findings in the extant literature have shown refutation texts can inadvertently strengthen learners' misconceptions (i.e., backfire; Hart & Nisbet, 2012; Nyhan, Reifler, & Ubel, 2013), the clear majority of research indicates that refutation texts are an effective strategy for facilitating conceptual change (Tippett, 2010). Refutation texts support conceptual change by directly targeting misconceptions and presenting a rich network of causal explanations based on scientific evidence to refute inaccurate knowledge (Kendeou et al., 2013, 2014). The causal explanations in refutation texts compete with previously-acquired misconceptions and begin to dominate the conceptual network by reducing (or suppressing) activation of previously-acquired misconceptions, thus facilitating a change in knowledge within a conceptual network. In our study, we hypothesized (H1) that learners who read a refutation text would change more misconceptions at posttest than learners who read an expository text. Our results supported this hypothesis, and provided support for previous studies that have shown refutation texts to be effective rhetorical devices for facilitating conceptual change (Heddy et al., 2017; Heddy & Sinatra, 2013; Kendeou et al., 2014; Trevors et al., 2016, 2017b).

Additionally, our findings provided added support for Dole and Sinatra's (1998) CRKM by highlighting the importance of message characteristics for aiding in conceptual change (Dole & Sinatra, 1998). Building from this, we argue that learner characteristics such as attitudes and epistemic beliefs serve as focal lenses through which causal explanations in refutation texts are processed, interpreted, and evaluated during conceptual change. As such, future studies should augment and organize refutation texts with the goal of scaffolding both attitudinal change and learners' development of epistemic strategies for critically evaluating information regarding complex scientific topics.

Moderating and Mediating Roles of Attitudes and Epistemic Beliefs in Conceptual Change (Learner Characteristics)

Based on theoretical considerations and previous research, we additionally hypothesized (H2) that attitudes would play a significant (mediating) role in learners' processing of socio-scientific information and while learning about GMFs from refutation texts and, in turn, that epistemic beliefs would moderate the interceding effects of attitudes on post-test conceptual change. Our findings supported this hypothesis. Specifically, our findings revealed a learning differential from pre-test to post-test that was mediated by participants' attitudes towards GMFs, and this relationship was moderated by learners' epistemic beliefs regarding the source and justification of GMFs knowledge. Accordingly, learners in our study who self-reported more positive attitudes towards GMFs and who believed GMFs knowledge to be derived and justified via empirical evidence and multiple sources of information revised more misconceptions at post-test than learners with negative attitudes who believed GMFs knowledge to be derived and justified via personal judgement, opinion and anecdotal evidence. Although no effects were observed for beliefs about the complexity or certainty of GMFs knowledge in our study, it is possible that learners in our study with positive attitudes and who possessed the skills necessary to critically evaluate and judge the veracity of diverse sources of information inherently viewed scientific knowledge as sufficiently complex and uncertain, despite our null results. Whatever the case, our findings nonetheless lend support for the structural and functional roles of attitudes and epistemic beliefs as vital factors involved in the processing socio-scientific information, and highlight the importance of both learner and message characteristics as vital factors in the reconstruction of knowledge.

Educational Implications

Our results underline the importance of considering the role of differential attitude structures in relation to specific dimensions of epistemic beliefs (rather than general systems) in conceptual change research. Results from our study show that individuals who believe GMFs knowledge to be derived and justified via empirical evidence and multiple sources of information also tend to express more positive attitudes toward GMFs and, in turn, experience greater learning gains in terms of conceptual change. Our findings suggest that designing refutation texts with persuasive attitudinal and epistemically-related content (i.e., content designed to change attitudes and improve epistemic evaluations and judgements regarding the veracity of information) could help equip learners with more robust strategies for learning and understanding complex socio-scientific topics. Although attitudes have important implications for how individuals select, perceive, interpret, encode and retrieve information related to complex science topics, epistemic beliefs play an important role in how individuals evaluate and judge sources of knowledge. Overall, changing attitudes (object-evaluation associations) reciprocally influences changes in underlying systems of

beliefs (evaluative knowledge structures), and the reciprocal interaction between these factors predict learning and conceptual change.

Therefore, developing interventions to foster the development of more positive attitudes, as well as more constructivist epistemic beliefs, has the potential to positively predict learning in relation to negatively charged, controversial socio-scientific topics that otherwise tend to elicit negative attitudes and conflict with individuals' personal, doxastic beliefs. In short, targeting individuals' sourcing and justification beliefs related to complex socio-scientific topics has the potential for endowing learners with the skills to critically evaluate and judge the veridicality of complex scientific information instantiated in diverse media and obtained from multiple sources. Understanding knowledge and knowing to be comprised of uncertain and complex processes, learners may better appreciate the diversity of methods for justifying scientific claims, and thus, become more open to discrepant sources of knowledge and information and, in turn, be more receptive to revising inaccurate knowledge.

LIMITATIONS AND FUTURE DIRECTIONS

Several caveats should be considered while interpreting the results of our study. First, we used self-report inventories to measure attitudes and epistemic beliefs. Although self-reports of attitudes are generally reliable indicators of individuals' attitudes, they can be somewhat unreliable indicators of epistemic beliefs (Greene et al., 2014). Indeed, for this sample, reliability estimates for epistemic beliefs were not particularly high. That said, the low to modest reliabilities for the epistemic beliefs measure could potentially reflect the relative diversity of participants' epistemic beliefs regarding GMFs. Alternatively, utilizing think aloud protocols (TAPs) could have provided richer, more reliable data from which to generalize findings regarding the attitudinal and epistemic processes at play during conceptual change as TAPs are particularly effective for observing emergent cognitive and metacognitive processes that arise during learning without interfering with the focal learning task (Chi, 1997).

Next, no measures of emotions towards GMFs were included in this study. The preponderance of research in the conceptual change literature has shifted focus away from examining exclusively 'cold' cognitive constructs of conceptual change (i.e., information processing) to investigations that additionally include 'hot' constructs, such as emotions and motivation (Broughton et al., 2013; Pintrich et al., 1993; Sinatra & Seyranian, 2016; Heddy et al., 2017). Although attitudes (a lukewarm construct) were a primary variable of interest in the present study, the roles of emotions (a hot topic) and their relationship to attitudes was not included in this research. Including measures of emotions, however, could have otherwise provided more explanatory power regarding the processes at play during conceptual change, especially considering that affect serves an evaluative function in the appraisal of information related to an attitudinal object.

Finally, we did not measure values toward GMFs in the present study. According to Rockeach (1968), values are an important factor to consider when examining relationships among attitudes and beliefs because value systems inevitably inform individuals' systems of beliefs and, in turn, the emergent attitudes that influence and shape individuals' processing of information and decision-making behaviors. Arguably, circumventing value systems and their relations to beliefs and attitudes provides a rather myopic focus on problems of persuasion at the expense of larger issues related 'education and re-education' (Rockeach, 1968). As such, findings from the present study

provide only a limited account of the potential multivariate factors that may influence conceptual change. Future research should address this issue by seeking to uncover how and for whom values predict epistemic beliefs, and in what ways these value-laden belief systems most profoundly predict subsequent attitudinal appraisals of complex socio-scientific topics. In closing, future research should focus more explicitly on the dynamic, functional and structural relations among emotions, values, attitudes, and epistemic beliefs to obtain a more inclusive understanding of how these factors operate to predict learning, conceptual change, and the processing of socio-scientific information.

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TABLES

Table 1: Descriptive Statistics for all Variables

	<i>Mean</i>	<i>SD</i>	<i>Skewness</i>	<i>Kurtosis</i>
Prior knowledge	.44	.20	2.30	.32
Post-test knowledge	.77	.20	-4.88	3.08
Attitudes	4.48	1.37	-2.09	.06
Complexity of knowledge	4.12	.70	.42	-0.68
Uncertainty of knowledge	4.71	.82	-1.13	.71
Source of knowledge	4.17	.86	.40	-.13
Justification for knowing	5.36	.70	-1.56	-.47

Note. Prior knowledge and post-test knowledge are reported as proportion of correct conceptions.

Table 2: Correlations Among All Variables (N = 120)

Variables	1	2	3	4	5	6	7
1. Attitudes	—	.215*	.131	.076	.138	.380**	.389**
2. Structure of Knowledge	.215*	—	-.005	.506**	.341**	.427**	.358**
3. Certainty of Knowledge	.131	-.005	—	.011	.247**	.097	.155
4. Source of Knowledge	.076	.506**	.011	—	.350**	.351**	.108
5. Justification for Knowing	.138	.341**	.247**	.350**	—	.344**	.248**
6. Prior Knowledge	.380**	.427**	.097	.351**	.344**	—	.391**
7. Post-test Knowledge	.389**	.358**	.155	.108	.248**	.391**	—

*p < .05. **p < .01. Two-tailed.

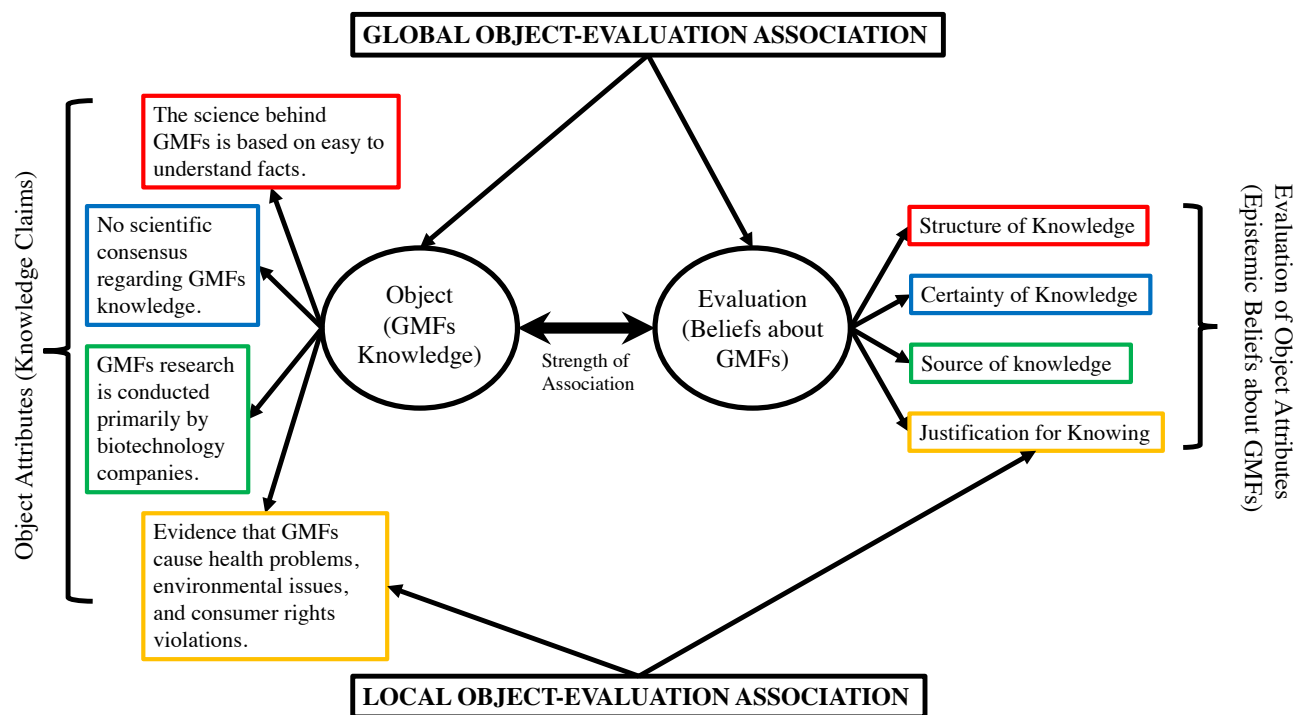


Figure 1. Object-evaluation association embedded in a semantic network.

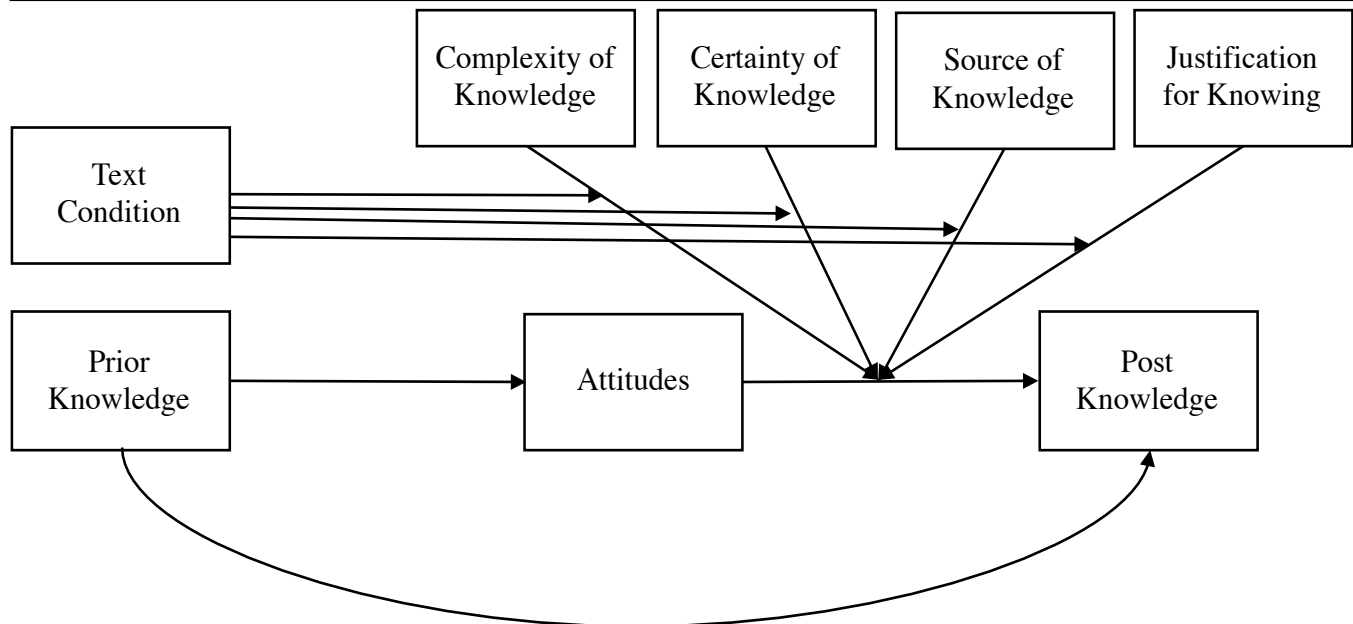


Figure 2. Hypothesized moderation mediation model.

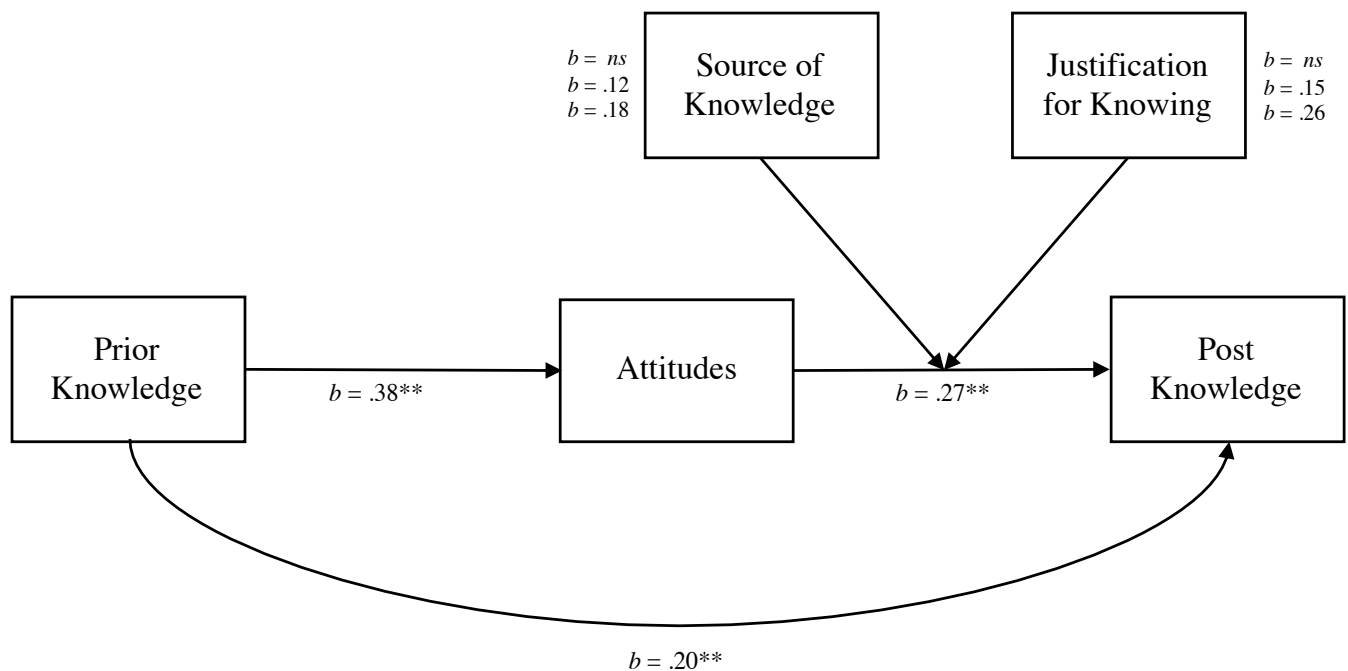


Figure 3. Final moderation mediation model.

Note: All values represent standardized coefficients. Coefficients labelled at the top for the moderators represent 1SD below the mean, coefficients in the middle represent the mean, and coefficients at the bottom for the moderators represent 1SD above the mean.

** $p < .001$ * $p < .05$.