Undergraduates' Attitudes toward Science and Their Epistemological Beliefs: Positive Effects of Certainty and Authority Beliefs

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Abstract

Attitudes toward science are an important aspect of students' persistence in school science and interest in pursuing future science careers, but students' attitudes typically decline over the course of formal schooling. This study examines relationships of students' attitudes toward science with their perceptions of science as inclusive or non-religious, and their epistemological beliefs about epistemic authority and certainty. Data were collected using an online survey system among undergraduates at a large, public U.S. university (n=582). Data were prepared using a Rasch rating scale model, and then analyzed using multiple regression. Gender and number of science and mathematics courses were included as control variables, followed by perceptions of science, then epistemological beliefs. Findings show that respondents have more positive attitudes when they perceive science to be inclusive of women and minorities, and when they perceive science to be incompatible with religion. Respondents also have more positive attitudes toward science when they believe scientific knowledge is uncertain, and when they believe knowledge derives from authority. Interpretations of these findings and implications for future research are discussed.

Keywords: science education; attitudes; epistemology; lay epistemic theory; Rasch measurement

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Attitudes toward science are an important aspect of students' persistence in school science and interest in pursuing science careers (Osborne, Simon, and Collins 2003). Unfortunately, prior research has shown that students' attitudes toward science generally decline over the middle and high school years (George 2000), and that female students have traditionally had less positive attitudes toward science than did male counterparts (Weinburgh 1995). Therefore, helping to bolster students' attitudes toward science is an important goal of science education, as it can help contribute to the broadening of scientific literacy for more students.

As part of achieving this goal, it is essential that the field explore the various factors that may influence students' attitudes toward science, thus uncovering the factors that may prove tractable or intractable as a lever for affecting science attitudes. Prior research on students' attitudes toward science has explored the ways that attitudes toward science are linked to students' experiences with science in school (e.g., Basl 2011; Maltese & Tai 2011) and out of school (e.g., Hazari, Tai, & Sadler 2007; Maltese & Tai 2010), and their perceptions of science as difficult, useful, and having a potential match with one's self (e.g., Aschbacher, Li, & Roth 2010; Buck, Cook, Quigley, Eastwood, & Lucas 2009; Deacon & Hajek 2011; Hazari, et al. 2007; Masnick, Valenti, Cox, & Osman 2010; Taconis & Kessels 2009).

Despite this wealth of research, little research has explored the extent to which students' attitudes toward science are affected by their epistemological beliefs, despite the noted importance of epistemology in the development of a scientifically literate citizen (Kolsto 2001; Sandoval 2005). Students' epistemological beliefs involve their core views about the forms and sources of knowledge. Furthermore, epistemological beliefs may be related to students' willingness to accept uncertainty, to question or accept knowledgeable authority, and their openness to new ideas. Indeed, prior research on epistemic beliefs has demonstrated that they can influence political and economic viewpoints and actions (Calogero, Bardi, & Sutton 2009; Chirumbolo, Areni, & Sensales 2004), as well as reasoning about scientific phenomena (e.g., Author 2011; Hogan & Maglienti 2001; Zeineddin & Abd-El-Khalick 2010). Other prior research has explored the relationship of understanding basic epistemological aspects of science to students' explanations of scientific phenomena (Schauble, Glaser, Duschl, Schulze, & John 1995), as well as the role of epistemological belief in students' understanding of authority and uncertainty (Lin, Hong, & Huang 2012). However, there has been scant attention to epistemological beliefs and their relationship with students' attitudes toward the subject matter. This dearth of attention belies the potentially influential role that beliefs about knowledge and knowledge-building may influence students' attitudes toward science.

The present study seeks to bridge this gap between the literature on epistemological beliefs and students' attitudes toward science through a large-scale survey study of undergraduate students. It examines epistemological beliefs and perceptions of science as predictors of attitudes toward science, after controlling for students' gender and prior course-taking. In so doing, the study may contribute to the broader effort to understand the factors that can support or hinder raising students' attitudes toward science.

Literature Review

This study builds on the literature in science education on individuals' perceptions and attitudes and on their epistemological beliefs. This section begins with presentation of the theoretical framework of lay epistemic theory (Kruglanski 1989). It then moves on to discussion of individual's attitudes toward and perceptions of science, before continuing to a review of epistemological beliefs.

Theoretical Framework

This study is based on lay epistemic theory (Kruglanski 1989; Kruglanski, Dechesne, Orehek, & Pierro 2009), which posits that knowledge is itself a form of belief, and that one's knowledge develops continually through an ongoing cycle of calls to evidence and subsequent conclusion-making. *Evidence* may be factual statements, experiences of natural phenomena, social interactions, views of oneself, and prior beliefs. An individual does not necessarily have to accept a belief to know it: one may know about the concept of a flat earth by believing *that* ancients believed *in* it in the past. Among the prior beliefs upon which an individual may call to judge evidence are his or her epistemological frames, attitudes, and cognitive needs.

Lay epistemic theory draws upon common psychological bases with persuasion (Petty & Cacioppo 1986a, 1986b) as both concepts are developed from prior work on individuals' need for cognition (Kruglanski 1989). The lay epistemic theory is, in a sense, an overarching theory that incorporates the elements of persuasive communications, cognitive dissonance, attitude, and self-concept through the lens of belief-assessment and decision-making (Kruglanski 1989). Through this integration it can support models of attitude and behavior that seemed conflicted in previous research (Shrigley 1990), but which the lay epistemic theory considers as varied forms of belief—including beliefs about oneself, one's attitudes and interests, one's "typical" behaviors, and beliefs about the credibility and authority of others making a persuasive communication. Because it enables consideration of self-concepts, perceptions, attitudes, and knowledge statements, it has much potential as a framework through which to understand the interrelations among students' perceptions, beliefs, and attitudes toward science.

Under the lay epistemic theory, two important aspects of individuals' epistemological beliefs are their perceptions of epistemic authority and their need for certainty. Epistemic authority is the extent to which a source of information is considered authoritative on a particular topic (Kruglanski 1989). In educational settings, this could be a teacher, parent, other student, or oneself. Previous research on epistemic authority demonstrates that views of authority influence how students respond to instruction that either emphasizes external authority such as the teacher, or that emphasizes their own authority (e.g., Ellis & Kruglanski 1992; Quiamzade, Mugny, & Chatard 2009). Need for certainty focuses on the extent to which individuals are or are not willing to accept uncertainty about knowledge or about sources of knowledge (Kruglanski 1989), and shares similarities with the motivation for individuals to accept familiar explanations to escape the discomfort of uncertainty without considering evidence for or against the proposed explanation (e.g., House, Hanges, Javidan, Dorfman, & Gupta 2004). Previous research on lay epistemic theory has focused primarily on individual's reasoning about social situations such as their political beliefs, personal beliefs, and related propositional knowledge statements (e.g., Calogero, Bardi, & Sutton 2009; Chirumbolo, Areni, & Sensales 2004; Jost, Glaser, Kruglanski, & Sulloway 2003 ; Webster & Kruglanski 1994). The present study extends this framework by applying the lay epistemic theory to relationships among epistemological beliefs and attitudes toward science, focusing on the roles of certainty and authority.

Attitudes toward and Perceptions of Science

Attitudes toward science are the positive or negative opinions that individuals have about science, based on their perceptions of science—as a school subject, as an aspect of society, and as a human endeavor. In their review of attitudes toward science, Osborne, Simon, and Collins (2003) show that the attitude research consists of an amalgam of constructs that continue to be popular in recent literature, including: interests, such as preferences for science as a school subject or a career (e.g., Bøe 2012); motivation, such as the desire and/or ability to continue engaging in science (e.g., Glynn, Brickman, Armstrong, & Taasoobshirazi 2011); pleasure, such as enjoyment or other positive emotions when engaging in science (Lin, et al. 2012); and competence, such as a sense of ease in learning science, feeling a sense of achievement in science, or (conversely) fear of failure in doing science (e.g., Beghetto 2007). Other researchers have also considered behavioral aspects of attitudes, which are *intentions* to engage in behaviors (though not measures of behaviors themselves), such as spending time reading books or doing projects about a science (Cheung 2009; Eagly & Chaiken 1993). This constellation of related constructs contains a great deal of variation in definition and application, so measuring the entire set of interrelated constructs is a challenge.

Attitudes are related to students' performance in science and their retention in science majors. For example, Hazari and colleagues (2007) found that attitude has a positive relationship with students' performance in introductory physics courses. Yet as Shrigley (1990) and Shrigley and Koballa (1992) argue, the particular relationship among attitudes, intentions, and behavior can be complex, and either mediated or moderated by individual differences for students as well as contextual variables in the classroom and any other social situations. This calls for efforts to explore the connections between students' attitudes and their behaviors while accounting for such complexity. For example, Singh, Granville, and Dika (2002) report on analysis of the effects of interest and motivation on students' mathematics and science achievement. Their findings showed no direct effects of interest or of motivation on achievement, but did find that both attitude and motivation significantly predicted the amount of time that students spent on academic work, which yielded higher achievement. Likewise, Singh, Chang, and Dika (2005) identify a positive relationship between attitudes toward science and course-taking patterns. So, attitudes toward science may have indirect relationships with science achievement or other behaviors, with intermediary effects via their engagement and motivation or their persistence with academic study of science.

Corroborating this view of intermediary variables relating to attitudes, prior work indicates an important role of students' identity and experiences—both in school and out of school—in developing positive attitudes. Within school environments, Basl (2011) shows that students' experiences in school have an effect on their reported attitudes toward science. Likewise, undergraduate students who perceive science as a fit with their self-identify consider it one of their favorite subjects also have higher expectations of success and more positive self-concepts of their ability to engage in advanced academic studies (Enman & Lupart 2000). Outside of the school environment itself, students' early interests in science and perceptions of the usefulness of science are predictive of their future science studies (Maltese & Tai 2011). Students with a stronger sense of family support and expectations tend to perform better in science (Hazari, et al. 2007). Similarly, Aschbacher, Li, and Roth (2010) find that students benefited from science-related experiences with people and places outside of school time, and this helped them develop the idea of a science-related identity.

The development of instruments to measure attitudes toward science has, like the definitions of attitudes, drawn upon many different aspects of attitude. Many if not all previously-developed instruments have included items addressing individuals' perceptions of science. Blalock and colleagues (2008) reviewed the instrument validity and reliability data for 66 attitude instruments published between 1935 and 2005, finding that the great majority of instruments were used only in a single study, and that few of the instruments were reported with complete information on their validity and reliability. Among those that have been used in multiple studies, one of the more frequently used is Cobern's (2000) Thinking about Science Survey instrument (TSSI). The particular areas it addresses include: science-related emotions and aesthetics; perceptions of science's inclusiveness; economic, societal, and personal usefulness; and beliefs regarding science and religion. The TSSI has been recognized for its broad applicability (Heath, Lakshmanan, Perlmutter, & Davis 2010), and further validated in later studies by Cobern (e.g., Cobern & Loving 2002) and other researchers (e.g., Stewart, Dickerson, & Hotchkiss 2009).

Drawing upon the reviewed literature, it seems clear that having positive attitudes toward science—along with the host of related perceptions and experiences that go into such attitude—contributes to students' motivation for and persistence in school science. Thus, while direct and immediate outcomes of attitude may seem limited, attitude can have meaningful influences on students' intentions and behaviors over time, making it a worthwhile focus of study as a stepping stone to student performance in addition to being an outcome in its own right. Furthermore, previous findings indicate that students' perceptions of science can have important relationships with their attitudes toward science. Drawing on these findings, the present study will focus on measures of students' attitudes toward science, as well as the role of their perceptions of science as being inclusive or as being in conflict with religion.

Epistemological Beliefs

Epistemological beliefs have been the subject of much interest in cognitive science, educational psychology, and science education. The lay epistemic theory that undergirds the present study is one example of the broad interest in epistemological beliefs (Kruglanski 1989). For science education in particular, students' epistemological beliefs are an essential part of their gaining a deeper understanding of scientific inquiry, the scientific process, and the nature of science (Sandoval 2005). There have been a variety of ways that epistemology has been conceptualized and measured. Duell and Schommer-Aikins (2001) review the various conceptualizations of epistemological beliefs and their respective measures. They identify a progression in the theorization of epistemological belief from a simple, unidimensional construct toward a multidimensional model of related constructs. The multidimensional models vary in the specific aspects that are highlighted. In one example, Schommer (1990, cited in Duell & Schommer-Aikins 2001) includes views of knowledge structure, knowledge stability, and ability to learn. Another example comes from Kuhn, Cheney, and Weinstock (2000, cited in Duell & Schommer-Aikins 2001), which includes value judgment, views of facts about the social world, and views of facts about the physical world. One of the more commonly used multi-dimensional frameworks—and associated instrument—comes from Schraw, Bendixon, and Dunkle's (2002) Epistemic Belief Inventory (EBI) and its five subscales: Simple Knowledge, Certain Knowledge, Omniscient Authority, Quick Learning, and Fixed Ability.

Epistemological beliefs have also been the subject of study in relation to other constructs of interest in science education. In a study of the relationship between epistemology and reasoning about socio-scientific issues, Liu, Lin, and Tsai (2011) found that students with views of scientific knowledge as changing and tentative were more likely to have reservations about authority in the decision-making process. However, relatively little previous study has examined the relationships between science attitudes and epistemological bases. Some exceptions include Enman's and Lupart's (2000) study of undergraduates' achievement motivations, finding that students' for whom science is a favorite subject agree more strongly with the idea that individuals have fixed intellectual ability (a belief about the nature of one's ability to know), and science majors agree more strongly with the idea that knowledge is a simplistic set of distinct facts (a belief about the set of scientific knowledge).

Drawing upon the previous literature in science education on epistemological beliefs and the lay epistemic theory, the present study focuses on students' beliefs about epistemic authority and about knowledge certainty. The present hypothesis is that, after accounting for other factors—gender, prior coursework in science and mathematics, and perceptions of science as inclusive and non-religious—epistemological beliefs in authority and certainty will be negatively related to attitudes toward science.

Methods

The purpose of the study is to identify the role of epistemological beliefs in predicting students' attitudes toward science. To do so, it is first necessary to distinguish the attitudes toward science from the perceptions of science. This allows analysis of the effect of epistemological beliefs after controlling for perceptions of science, and for background demographic variables.

Participants and Setting

Data come from students at a large, public university in the eastern United States who participated in the study as part of a standard data collection system in exchange for extra credit. The university is the flagship campus for the state's university system but is not considered an "elite" school. Students completed a series of questionnaires on their attitudes, beliefs, and epistemologies. Complete data for 582 students was collected. The sample is 67% female, and 95% of respondents are between the ages of 18 and 21. The sample participants' ethnic backgrounds are 66% Caucasian, 12% Asian or Asian American, 10% Black or African American, and 5% Hispanic or Latino. These values are similar to the demographics for the student population overall, according to the Forbes online information service (2012), with Caucasian students only slightly overrepresented in the sample. The majority of students in the sample are psychology majors (55%); the next largest group is of students majoring in a science, technology, engineering, or mathematics (STEM) field (20%). The remaining 25% of students in the sample have majors in the humanities or other social sciences, or have not declared a major. The students in the sample had, on average, taken between 4 and 5 STEM-related courses at the university, with a range of 0 to 30 previous courses. Taken together, the sample is relatively well representative of undergraduates at the institution. Therefore, the sample provides insight into the perceptions, beliefs, and attitudes of undergraduate students including both those who have chosen to study a STEM field and those who have not.

Instruments and Data Preparation

Measures for the present study include the Epistemic Belief Inventory (EBI; Schraw, et al. 2002) and the Thinking about Science Survey instrument (TSSI; Cobern 2000). These instruments have been studied previously with participants of similar age to the current sample, making the instruments well-suited for the present study (Liu 2012). For both EBI and TSSI, the full instrument was used in data collection. After data collection, clusters of items, or *subscales*, were created from the participants' responses. The data is first prepared for analysis by identifying the subscales, then creating estimates of students' measures on these subscales using the Rasch measurement model (Liu 2010). Although some items adapted from the EBI were included in a Rasch analysis of epistemic beliefs (Van Strien, Bijker, Brand-Gruwel, & Boshuizen 2012), the present study is the first known work to examine both the EBI and TSSI using a Rasch measurement model. Fitting with the goals of the study, the subscales identified represented key areas of focus for the research—attitudes toward science, perceptions of science, and epistemological beliefs of authority and certainty. The estimates on these variables are then used for further analysis.

The Rasch model allows estimation of both item difficulty and student ability for a test, whether items are coded dichotomously or in a rating scale (Andrich 1978). Only scales that show acceptable model fit and reliability are retained. In Rasch modeling, items are compared by examining the degree of fit between the observed student response data and the values predicted by the model, using weighted statistics, or *infit*, and unweighted statistics, or *outfit* (Bond & Fox 2007). Items are generally considered to have acceptable fit if the *infit* and *outfit* have mean-square values within the range of 0.7 – 1.3, and if the respective z-scores for *infit* and *outfit* have magnitude less than 2 (that is, if $|z_{infit}|\leq 2$ and $|z_{outfit}|\leq 2$). The WINSTEPS software program (Linacre 2007) is used for all Rasch model estimation.

Rasch analysis of the TSSI and EBI instruments reveal that the overall scale was not unidimensional, but that items did cluster around functional dimensions as expected. Only subscales with acceptable item functionality are described and used for the remainder of the paper. Three subscales are developed from the TSSI. The first TSSI subscale includes items that were about positive attitudes toward science, such as, “There are many good things we can do today because of scientific knowledge.” This scale is labeled *science-positive*. This variable is a measure of students’ positive attitudes toward science. It is used as the dependent variable in later analyses. The second TSSI subscale includes items about the *inclusiveness* of science, such as, “African Americans and other minority people are just as welcome in the scientific community as are white people.” This variable is a measure of students’ perceptions of science as inclusive and open to minorities and to women. The third TSSI subscale includes items about the perceived discrepancy between scientific and religious knowledge, such as, “Science is a more important source of knowledge than religion;" so, it is called *non-religious*. This scale measures the extent to which individuals perceive science to be discrepant with religion or even at odds with it.

The EBI analyses result in 2 subscales with acceptable fit. The first EBI subscale focuses on the concept of *certainty*. It consists of items describing belief that scientific knowledge is certain and clear-cut, such as, "If two people are arguing about something, at least one of them must be wrong." The second EBI subscale focuses on the concept of *authority*. It consists of items such as, "Children should be allowed to question their parents' authority" (this item is reverse coded).

The instrument item reliabilities and average infit mean-square statistics are shown in Table 1. Though the reliabilities of the measures of persons are only moderate for some of the scales, the values indicate good fit between the measurement model and the students' responses. This supports the use of the Rasch model for scale preparation. The scale reliabilities may be improved in subsequent study by developing additional items for each scale, as more items generally increases reliability in measurement (Crocker & Algina 1986). Table 2 presents the descriptive statistics and correlations of the variables. The values for the Rasch-scaled measures (science-positive, certainty, authority, inclusiveness, and non-religious) are in logits, the log of the odds ratio for responses (Bond & Fox 2007). The logit values can range from negative infinity to positive infinity. Positive values indicate more of the measured trait, and negative values indicate less of the measured trait.

INSERT TABLE 1 ABOUT HERE

INSERT TABLE 2 ABOUT HERE

Data Analysis

After data preparation, the subscale scores are analyzed using multiple regression. The dependent variable is *science-positive* (TSSI-1), which is the extent to which students have positive attitudes toward science. The demographic independent variables are entered first: students' gender, and number of previous STEM courses. These are included as control variables, as previous literature has shown differences in attitude based on gender and course-taking patterns. The next independent variables entered are *inclusiveness* and *non-religious*. Finally, the two epistemological belief variables of *certainty* and *authority* are entered. Lastly, two-way interactions of *certainty* and *authority* with the other independent variables are entered. Non-significant interaction terms are not reported to conserve space.

Results

This study examines the effects of undergraduates' epistemological beliefs regarding certainty and authority on their attitudes toward science, after accounting for control variables. The results of the analysis for *science-positive* attitudes are presented in Table 3. Regarding the students' gender, the findings show that women have a significantly less positive attitude toward science than did men ($b = -0.610$, $p<.001$), which is consistent with previous research. There are no significant interactions between gender and the epistemic belief scales ($p>.05$), indicating that any observed effects for the epistemic belief scales are equivalent for male and female students. Regarding number of university STEM-related courses previously taken, there is not a significant effect ($b = 0.013$, $p>.05$), indicating no relationship between students' science and mathematics course experience and attitudes toward science.

INSERT TABLE 3 ABOUT HERE

Students’ perceptions of science are significantly related to their attitudes toward science. There is a significantly positive effect of perceiving science as inclusive ($b = 0.348$, $p<.01$). That is, students have more positive attitudes towards science when they perceive science as inclusive of women and minorities. Additionally, there is a significantly positive effect of perceiving science as non-religious ($b = 0.697$, $p<.001$). Thus, students have higher attitudes toward science when they perceive it as being non-religious or even as standing in opposition to religious belief.

After controlling for gender, previous courses, and perceptions of science, there remain significant relationships between attitude and epistemological beliefs. There is a statistically significant, positive effect for the belief that knowledge derives from authority ($b = 0.403$, $p<.001$). This indicates that students have greater attitudes toward science when they believe that knowledge can derive from authority. There was also a significantly negative effect of believing that scientific knowledge is certain on students’ attitudes toward science ($b= -0.269$, $p<.001$). There were no significant interaction terms between these epistemological beliefs and the control variables or perceptions of science ($p>.05$). This indicates that the main effects of authority and certainty are consistent for both male and female students, and are consistent regardless of perceptions of science.

Discussion

Overall, the findings demonstrate that there is a relationship between students’ attitudes toward science and their epistemological beliefs about certainty and authority, as proposed under the lay epistemic theory (Kruglanski, 1989). This supports the importance of measuring these epistemological variables as possible predictors of students’ attitudes toward science, above and beyond variables that have been the subject of prior study (e.g., Deacon & Hajek 2011; Weinburgh 1995). Consistent with previous research, men have higher overall attitudes toward science. Furthermore, both men and women have more positive attitudes when they perceive science as inclusive of women and minorities and scientific knowledge is more reliable than religious knowledge. After accounting for these factors, there is a statistically significant effect of epistemological beliefs: students have more positive attitude toward science when they believe that knowledge can derive from authority, and when they believe that knowledge is uncertain.

The finding that attitudes are positively related to *authority* and *non-religious*, but negatively related to *certainty*, requires some further consideration. At first glance, one may expect that certainty and religiosity should align with authority—considering the cultural role of religious institutions as sources of authority and seminal work that shows positive relationships between religiosity and acceptance of authority (e.g., Rigby & Densley 1985). However, as the present data are collected among university students, the referent for the respondents' views on epistemic authority may be their university faculty rather than epistemic authorities outside of the academic setting. In such a situation, university faculty may be perceived as deriving authority from their secular, academic accomplishments. Thus, students' attention to epistemic authorities in this case may support views that (1) knowledge can be uncertain and (2) scientific knowledge is incongruent with religious knowledge. Additional research is needed to pursue this conjecture further.

Contrary to expectation, there is not a significant effect of number of previous STEM courses on attitudes toward science. At face value this finding may seem somewhat conflicting, because one may typically assume that students' attitudes toward science should be correlated with their science and mathematics coursework. However, prior work has suggested that there are important contextual factors that may influence the effect of coursework on students' attitudes (Machina & Gokhale 2010). Furthermore, the perceptions of science and epistemological beliefs that are included in the present study may also serve as important alternative factors affecting attitudes, but that are not included in previous studies that have found an association between attitudes and course taking experiences (e.g., Singh, Chang, & Dika 2005).

Limitations and Implications for Future Research

The present study's findings point to the value of epistemological beliefs as a factor that may influence students' attitudes toward science. However, the study was limited as it consists of a single, large survey. Thus, it cannot establish a causal relationship between epistemological belief and attitudes—and which would be the cause or the effect. Additional work is needed to determine whether increasing understanding of scientific uncertainty leads to higher attitudes, whether higher attitudes leads to understanding of scientific uncertainty, or whether there are yet other variables that influence both.

The present study's findings also have implications for future research. Other extensions of the current study could examine the relationship of epistemological beliefs with other constructs of importance. For example, future studies could examine students' epistemological beliefs and their views of the nature of science (NOS; Lederman 1999). As one of the key aspects of NOS is that scientific knowledge is tentative, views of NOS will likely correlate with students' beliefs in knowledge certainty. Likewise, as another aspect of NOS is that science is a social endeavor, views of NOS may correlate with beliefs about epistemic authority.

Another direction for future study is to pursue the possible conflicts in the directionality of the relationships of attitudes with *authority*, *certainty*, and *non-religious*. Additional research is needed to examine qualitatively the varying aspects of students' perception of epistemic authority and its relationship to beliefs and attitudes toward science. Furthermore, future studies should pursue this question in a broader variety of settings, such as primary or secondary education, as well as among members of the public, to give a broader understanding of the extent to which epistemological beliefs relate to attitudes toward science.

Implications for the Teaching and Learning of Science

There is ongoing effort to increase students' attitudes toward science and interest and persistence in science in primary and secondary school, through university education, and into everyday life. The present findings at the undergraduate level suggest promising directions for development and testing of instructional materials that could raise students' attitudes toward science, although the causal relationships still need to be examined. For example, the findings suggest that helping students see science as inclusive could increase their positive attitudes toward science. Additionally, helping students understand the scientific process and the nature of uncertainty in scientific knowledge may also lead to more positive attitudes toward science. Thus, efforts to help students understand the scientific enterprise and the processes of creating and critiquing scientific knowledge may also raise their attitudes toward the subject overall.

Tables

Table 1

Rasch subscale names, source instrument, and measurement model information

Subscale Name	Instrument and Factor	N Items	Mean (MNSQ)		Reliabilities	
			Infit	Outfit	Item	Person
science-positive	TSSI - Factor 1	8	1.01	1.02	0.99	0.75
inclusiveness	TSSI - Factor 2	4	0.99	1.00	0.99	0.53
non-religious	TSSI - Factor 3	5	0.99	1.01	0.99	0.64
certainty	EBI - Factor 1	5	1.03	1.02	0.99	0.52
authority	EBI - Factor 2	5	0.99	1.01	0.99	0.54

Note. Reliabilities are based on the reliability of distinctions among items or persons, respectively. MNSQ is the mean-square fit statistic; ideally it should be about 1 for both infit and outfit.

Table 2

Correlations and descriptive statistics for study variables (n=582)

	Correlations						
Variable Name	1	2	3	4	5	6	7
Courses (1)	1.00						
gender (2)	0.03	1.00					
science-positive (3)	0.02	-0.20	1.00				
certainty (4)	-0.05	-0.03	-0.17	1.00			
authority (5)	-0.04	-0.02	0.21	0.07	1.00		
inclusiveness (6)	0.03	-0.10	0.22	0.15	0.27	1.00	
non-religious (7)	-0.07	-0.11	0.31	0.09	0.26	0.28	1.00
	Descriptive Statistics						
Mean	4.90	0.67	2.17	-1.68	0.27	0.31	0.22
SD	4.35	0.47	1.67	1.36	0.61	0.56	0.50

Note. Correlation coefficients greater than 0.15 are statistically significant at the $p<.01$ level, after Bonferroni correction. The values for Courses (variable 1) ranged from 0 to 30.

Table 3

Results of regression of demographic and epistemological variables on science-positive attitudes (n=582)

Source	Estimate	
Intercept	1.714	**
Courses	0.013	
gender	-0.610	**
certainty	-0.269	**
authority	0.403	**
inclusiveness	0.348	*
non-religious	0.697	**

* p<0.01; ** p<0.001

References

Author. (2011).

Andrich, D. (1978). A rating formulation for ordered response categories. *Psychometrika, 43*(4), 561-573. doi: 10.1007/bf02293814

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*(5), 564-582. doi: 10.1002/tea.20353

Basl, J. (2011). Effect of school on interest in natural sciences: A comparison of the Czech Republic, Germany, Finland, and Norway based on PISA 2006. *International Journal of Science Education, 33*(1), 145-157. doi: 10.1080/09500693.2010.518641

Beghetto, R. A. (2007). Factors associated with middle and secondary students' perceived science competence. *Journal of Research in Science Teaching, 44*(6), 800-814.

Blalock, C. L., Lichtenstein, M. J., Owen, S., Pruski, L., Marshall, C., & Toepperwein, M. (2008). In pursuit of validity: A comprehensive review of science attitude instruments 1935-2005. *International Journal of Science Education, 30*(7), 961-977. doi: 10.1080/09500690701344578

Bøe, M. V. (2012). Science choices in Norwegian upper secondary school: What matters? *Science Education*, *96*(1), 1-20. doi: 10.1002/sce.20461

Bond, T. G., & Fox, C. M. (2007). *Applying the Rasch Model: Fundamental Measurement in the Human Sciences* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates.

Buck, G., Cook, K., Quigley, C., Eastwood, J., & Lucas, Y. (2009). Profiles of urban, low SES, African American girls’ attitudes toward science: A sequential explanatory mixed methods study. *Journal of Mixed Methods Research, 3*(4), 386-410. doi: 10.1177/1558689809341797

Calogero, R. M., Bardi, A., & Sutton, R. M. (2009). A need basis for values: Associations between the need for cognitive closure and value priorities. *Personality & Individual Differences, 46*(2), 154-159. doi: 10.1016/j.paid.2008.09.019

Cheung, D. (2009). Developing a scale to measure students' attitudes toward chemistry lessons. *International Journal of Science Education, 31*(16), 2185-2203. doi: 10.1080/09500690802189799

Chirumbolo, A., Areni, A., & Sensales, G. (2004). Need for cognitive closure and politics: Voting, political attitudes and attributional style. *International Journal of Psychology, 39*(4), 245-253. doi: 10.1080/00207590444000005

Cobern, W. W. (2000). The Thinking about Science Survey Instrument (TSSI) – SLCSP 151. Kalamazoo, MI.

Cobern, W. W., & Loving, C. C. (2002). Investigation of preservice elementary teachers' thinking about science. *Journal of Research in Science Teaching, 39*(10), 1016-1031. doi: 10.1002/tea.10052

Crocker, L., & Algina, J. (1986). *Introduction to classical and modern test theory*. New York, NY, USA: CBS College Publishing.

Deacon, C., & Hajek, A. (2011). Student perceptions of the value of physics laboratories. *International Journal of Science Education, 33*(7), 943-977. doi: 10.1080/09500693.2010.481682

Duell, O. K., & Schommer-Aikins, M. (2001). Measures of people's beliefs about knowledge and learning. *Educational Psychology Review, 13*(4), 419-449. doi: 10.1023/a:1011969931594

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Fort Worth, TX: Harcourt Brace Jovanovich College Publishers.

Ellis, S., & Kruglanski, A. W. (1992). Self as an epistemic authority: Effects on experiential and instructional learning. *Social Cognition, 10*(4), 357-375.

Enman, M., & Lupart, J. (2000). Talented female students' resistance to science: An exploratory study of post-secondary achievement motivation, persistence, and epistemological characteristics. *High Ability Studies, 11*(2), 161-178. doi: 10.1080/13598130020001205

Forbes. (2012). *America's Top Colleges* (webpage). Retrieved 20 December 2012 from http://www.forbes.com/top-colleges/.

George, R. (2000). Measuring change in students' attitudes toward science over time: An application of latent variable growth modeling. *Journal of Science Education & Technology, 9*(3), 213-225.

Glynn, S. M., Brickman, P., Armstrong, N., & Taasoobshirazi, G. (2011). Science Motivation Questionnaire II: Validation with science majors and nonscience majors. *Journal of Research in Science Teaching, 48*(10), 1159-1176. doi: 10.1002/tea.20442

Hazari, Z., Tai, R. H., & Sadler, P. M. (2007). Gender differences in introductory university physics performance: The influence of high school physics preparation and affective factors. *Science Education, 91*(6), 847-876.

Heath, B., Lakshmanan, A., Perlmutter, A., & Davis, L. (2010). Measuring the impact of professional development on science teaching: A review of survey, observation and interview protocols. *International Journal of Research & Method in Education, 33*(1), 3-20. doi: 10.1080/17437270902947304

Hogan, K., & Maglienti, M. (2001). Comparing the epistemological underpinnings of students' and scientists' reasoning about conclusions. *Journal of Research in Science Teaching, 38*(6), 663-687.

House, R. J., Hanges, P. J., Javidan, M., Dorfman, P. W., & Gupta, V. (2004). *Culture, Leadership, and Organizations: The GLOBE Study of 62 Societies*. Thousand Oaks, CA: Sage.

Jost, J. T., Glaser, J., Kruglanski, A. W., & Sulloway, F. J. (2003). Political conservatism as motivated social cognition. *Psychological Bulletin, 129*(3), 339. doi: 10.1037/0033-2909.129.3.339

Kolsto, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education, 85*(3), 291-310.

Kruglanski, A. W. (1989). *Lay epistemics and human knowledge: Cognitive and motivational bases*. New York, NY: Plenum Press.

Kruglanski, A. W., Dechesne, M., Orehek, E., & Pierro, A. (2009). Three decades of lay epistemics: The why, how, and who of knowledge formation. *European Review of Social Psychology, 20*(1), 146-191. doi: 10.1080/10463280902860037

Lederman, N. G. (1999). Teachers' understanding of the Nature of Science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching, 36*(8), 916-929.

Lin, H.-s., Hong, Z.-R., & Huang, T.-C. (2012). The role of emotional factors in building public scientific literacy and engagement with science. *International Journal of Science Education, 34*(1), 25-42. doi: 10.1080/09500693.2010.551430

Linacre, J. M. (2007). WINSTEPS (Version 3.61.2). Chicago: Winsteps.com.

Liu, X. (2010). *Using and developing measurement instruments in science education*. Charlotte, NC: Information Age Publishing.

Liu, X. (2012). Developing measurement instruments for science education research. In B. J. Fraser, K. G. Tobin & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 651-665). Dordrecht, The Netherlands: Springer.

Machina, K., & Gokhale, A. (2010). Maintaining positive attitudes toward science and technology in first-year female undergraduates: Peril and promise. *International Journal of Science Education, 32*(4), 523-540. doi: 10.1080/09500690902792377

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the Fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669-685. doi: 10.1080/09500690902792385

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education, 95*(5), 877-907. doi: 10.1002/sce.20441

Masnick, A. M., Valenti, S. S., Cox, B. D., & Osman, C. J. (2010). A multidimensional scaling analysis of students' attitudes about science careers. *International Journal of Science Education, 32*(5), 653-667. doi: 10.1080/09500690902759053

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, *25*(9), 1049. doi: 10.1080/0950069032000032199

Petty, R. E., & Cacioppo, J. T. (1986a). *Communication and persuasion: Central and peripheral routes to attitude change*. New York: Springer.

Petty, R. E., & Cacioppo, J. T. (1986b). The elaboration likelihood model of persuasion. *Advances in Experimental Social Psychology, 19*, 123-205.

Quiamzade, A., Mugny, G., & Chatard, A. (2009). When teaching style matches students' epistemic (in)dependence: The moderating effect of perceived epistemic gap. *European Journal of Psychology of Education, 24*(3), 361-371. doi: 10.1007/bf03174766

Rigby, K., & Densley, T. R. (1985). Religiosity and attitude toward institutional authority among adolescents. *Journal Of Social Psychology*, *125*(6), 723.

Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education, 89*(4), 634-656. doi: 10.1002/sce.20065

Schauble, L., Glaser, R., Duschl, R. A., Schulze, S., & John, J. (1995). Students' understanding of the objectives and procedures of experimentation in the science classroom. *Journal of the Learning Sciences, 4*(2), 131-166. doi: 10.1207/s15327809jls0402_1

Schraw, G., Bendixen, L. D., & Dunkle, M. E. (2002). Development and validation of the Epistemic Belief Inventory (EBI). In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 261-275). Mahwah, NJ, US: Lawrence Erlbaum Associates.

Shrigley, R. L. (1990). Attitude and behavior are correlates. *Journal of Research in Science Teaching, 27*(2), 97-113.

Shrigley, R. L., & Koballa, T. R., Jr. (1992). A decade of attitude research based on Hovland's learning theory model. *Science Education, 76*(1), 17-42.

Singh, K., Chang, M., & Dika, S. (2005). Affective and motivational factors in engagement and achievement in science. *International Journal of Learning, 12*(6), 207-218.

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *Journal of Educational Research, 95*(6), 323.

Stewart, C. O., Dickerson, D. L., & Hotchkiss, R. (2009). Beliefs about science and news frames in audience evaluations of embryonic and adult stem cell research. *Science Communication, 30*(4), 427-452. doi: 10.1177/1075547008326931

Taconis, R., & Kessels, U. (2009). How choosing science depends on students' individual fit to 'Science Culture'. *International Journal of Science Education, 31*(8), 1115-1132. doi: 10.1080/09500690802050876

Van Strien, J., Bijker, M., Brand-Gruwel, S., & Boshuizen, E. (2012). *Measuring sophistication of epistemic beliefs using Rasch analysis.* Paper presented at the International Society of the Learning Sciences, Sydney, NSW, Australia.

Webster, D. M., & Kruglanski, A. W. (1994). Individual differences in need for cognitive closure. *Journal of Personality and Social Psychology, 67*(6), 1049-1062. doi: 10.1037/0022-3514.67.6.1049

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32*(4), 387-398. doi: 10.1002/tea.3660320407

Zeineddin, A., & Abd-El-Khalick, F. (2010). Scientific reasoning and epistemological commitments: Coordination of theory and evidence among college science students. *Journal of Research in Science Teaching, 47*(9), 1064-1093. doi: 10.1002/tea.20368

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Tables

Table 1

Rasch subscale names, source instrument and items, and measurement model information

Subscale Name	Source Instrument and Items	Mean (MNSQ)		Reliabilities	
		Infit	Outfit	Item	Person
science-positive	TSSI (8 items): 2, 4, 5, 7, 8, 10, 22, 23	1.01	1.02	0.99	0.75
inclusiveness	TSSI (4 items): 18, 19, 20, 21	0.99	1.00	0.99	0.53
non-religious	TSSI (5 items): 11, 12, 13, 15, 16	0.99	1.01	0.99	0.64
certainty	EBI (5 items): 2, 6, 23, 25, 31	1.03	1.02	0.99	0.52
authority	EBI (4 items): 4, 20, 27, 28	0.99	1.01	0.99	0.54

Note. Reliabilities are based on the reliability of distinctions among items or persons, respectively; item reliabilities are typically much higher. MNSQ is the mean-square fit statistic; ideally it should be about 1 for both infit and outfit.

Table 2

Correlations and descriptive statistics for study variables (n=582)

	Correlations						
Variable Name	1	2	3	4	5	6	7
Courses (1)	1.00						
gender (2)	0.03	1.00					
science-positive (3)	0.02	-0.20	1.00				
certainty (4)	-0.05	-0.03	-0.17	1.00			
authority (5)	-0.04	-0.02	0.21	0.07	1.00		
inclusiveness (6)	0.03	-0.10	0.22	0.15	0.27	1.00	
non-religious (7)	-0.07	-0.11	0.31	0.09	0.26	0.28	1.00
	Descriptive Statistics						
Mean	4.90	0.67	2.17	-1.68	0.27	0.31	0.22
SD	4.35	0.47	1.67	1.36	0.61	0.56	0.50

Note. Correlation coefficients greater than 0.15 are statistically significant at the $p<.01$ level, after Bonferroni correction. The values for Courses (variable 1) ranged from 0 to 30.

Table 3

Results of regression of demographic and epistemological variables on science-positive attitudes (n=582)

Source	Estimate	
Intercept	1.714	**
Courses	0.013	
gender	-0.610	**
certainty	-0.269	**
authority	0.403	**
inclusiveness	0.348	*
non-religious	0.697	**

* p<0.01; ** p<0.001