Conceptual and Methodological Issues in the Measurement of Attitudes Towards Science

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Abstract

This study argues for the need to clarify the attitude construct in science education. After positing a conceptual definition for attitudes derived from the social psychology and persuasion literature, this study makes a demarcation between science attitudes and attitudes towards science. Based on this conceptual clarity, the study offers a constructive critique of five commonly used measures of attitudes in science education and offers a theoretically grounded alternative. Data gathered to test the alternative measure's validity and reliability is in the main consistent with strong validity and reliability claims for the new measure. Implications for science education are discussed.

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Introduction

Several reports on science, technology, engineering, and mathematics (STEM) education put forth by industry, government, and education emphasize the declining participation of U.S's youth in science, technology, engineering, and mathematics (Business Roundtable, 2005; Domestic Policy Council, 2006; National Science Board, 2010; U.S. Department of Education, 2007). According to the National Science Board (2010) only 16% of U.S. undergraduates major in a STEM field compared to 47% in China and 38% in South Korea. These statistics reflect students' decreasing interest in science at the secondary school level. For instance, only 16 percent of high school seniors are interested in the STEM fields (U.S. Department of Education, 2012). A more concerning STEM statistic is about gender gap. According to Stem Connector (2012) female students' interest in STEM fields remains at 14.5% compared to 39.6% for their male counterparts.

In order to change this trend, science educators are increasingly interested in studying students' attitudes towards science, factors impacting their attitudes toward science, and the relationship between students' attitudes towards science and their engagement with science-related activities (i.e., taking advanced science courses or pursuing a science-related college degree). Consequently, there is a need to address conceptual and methodological issues related to the use of the attitude construct in science education and the accurate measurement of students' attitudes towards science. This study, therefore, aims to 1) identify and address problems related to the use of the attitude construct in science education in light of developments in educational and social psychology literature related to attitudes, and 2) design a new instrument that will measure students' attitudes towards science validly and reliably. These two goals will allow for the relationship between students' attitudes and behaviors as they relate to science to be understood in meaningful and scientifically sound ways.

This paper is organized in the following manner: a literature review, an argument for a new instrument, and development of an instrument. The literature review is set out with three parts. First, problems with the use of the attitude construct in science education literature are highlighted and a clear distinction between attitudes towards science and scientific attitudes is posited. Second, the theoretical frameworks used to study the relationship between students' attitudes towards science and their behaviors related to science are examined. Third, instruments designed to measure students' attitudes towards science are considered and their strengths and weaknesses are elaborated upon.

After the literature review, an argument for the need for developing a new instrument that can better measure the attitude construct is forwarded. Finally, an instrument designed to measure students' attitudes towards science is forwarded and its validity and reliability are tested.

Literature Review

Problem

Differentiating Attitudes, Attitudes Towards Science, and Scientific Attitudes. The attitude construct is central to understanding why some students participate in science and others do not. Therefore, science educators have spent a considerable effort into studying students' attitudes towards science (Koballa & Glynn, 2007). In spite of the apparent centrality of attitudes to students' participation in science learning, researchers have identified problems with the use of the attitude construct (Butler, 1999; Laforgia, 1988; Ray, 1991; Shrigley, Koballa & Simpson, 1988). Specifically, the attitude construct has been conceptualized in several ways by science education researchers (e.g., attitudes towards science versus scientific attitudes) but used interchangeably. The multiplicity of meaning that the term attitude bears in science education research has not only prevented the development of valid and reliable measures of attitudes towards science but it has also limited the interpretability of attitude studies in science education (Koballa & Glynn, 2007). Moreover, this problem has limited the ability for reviews to meaningfully synthesize across studies systematically (e.g., meta-analytic reviews). Thus, there is a need for researchers in the field of science education to explicate precisely the attitude construct (i.e., conceptual clarity) before they begin to collect data in studies on students' attitudes towards science (Rennie & Parker, 1987). In terms of conceptual clarity, there is a need to define what we mean by attitude, and recognize attitudes towards science and scientific attitudes as separate units of analysis. Making this distinction will both increase the methodological rigor by addressing validity and reliability issues when measuring students' attitudes towards science and enhance the predictive power of students' attitude for their future behavior.

Defining the Construct: Attitudes. The attitude construct arose in psychology literature as a way to account for regularities with respect to how people respond to objects in the environment. The specific responses in question were evaluative. Psychologists noticed that people had a tendency to evaluate objects in their environment positively or negatively with some degree of regularity across repeated exposures and that these evaluations seemed to impact behavior. Eagly and Chaiken (1993) define attitude as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (p. 1).

Eagly and Chaiken strategically chose to refer to attitudes as tendencies rather than dispositions to reflect the fact that although they are long lived and stable relative to fleeting thoughts, they are more malleable and temporary than a disposition like a personality trait. In fact, this component of the definition also performs the function of distinguishing attitudes from values. Whereas attitudes are tendencies, values are central components of a person's identity that serve as a guideline for a preferred state of existence (e.g., the lifelong pursuit of knowledge is important). Their definition also emphasizes the evaluative nature of attitudes to distinguish the construct from beliefs. For example, beliefs are opinions about the nature of an object (e.g., science is difficult) but without the evaluation that would be necessary for it to be considered an attitude (e.g., science is difficult and I do not like it). From this example it can be seen why attitudes are sometimes modeled quantitatively as, $A = \sum b_i e_i$, where attitudes (A) are composed of the sum of the product of all beliefs (b) and evaluations (e) about an attitude object (Fishbein, 1967a; 1967b). This definition captures the prevailing conceptualization of attitudes that exists within social psychology and persuasion literature.

The problem with the use of the construct attitude in science education, however, is that there has been a failure to recognize the distinction between attitudes towards science and scientific attitudes. Central to the attitude construct is evaluation and central to the attitude construct in science education research are evaluations of science as subject, science related careers, and the role of science in the advancement of personal and social life (Berkowitz, 1980; Mueller, 1986; Shrigley et al., 1988). The attitudinal research in science education, however, can be categorized under two main themes: attitudes towards science (Gardner, 1975; Schibeci, 1981; 1984) and scientific attitudes (Gauld & Hukins, 1980). Attitudes towards science deal with the evaluations of the domains of science learning (i.e., curriculum, science teaching, outcome expectancy, motivation). Scientific attitudes deal with evaluations of scientific meta-theory or the scientific habits of minds.

The distinction between attitudes towards science and scientific attitudes is shown by close examination of education researchers' conceptual definitions of attitudes. For example, Gardner (1975) offers an attitude definition consistent with an attitude towards science by stating that attitudes are "a learned disposition to evaluate in certain ways objects, people, actions, situations, or propositions involved in learning science" (p. 2). Laforgia (1988) defines attitudes similarly by stating that attitudes are, "learned disposition toward the content of science, that is, whether they regard science as boring and dull or associate it with being an interesting, exciting area” (p. 410). On the other hand Lee (1997) presents a definition of attitudes consistent with scientific attitudes stating that attitudes are, “characterized by the values and attitudes shared and practiced in the science community, such as empirical criteria, logical argumentation, questioning, and skepticism” (p. 220). In a consistent manner, Haney (1964) describes attitudes as curiosity, rationality, skepticism, open-mindedness, critical mindedness, objectivity and intellectual honesty, humility and reverence for life. In the main, however, researchers have not been able to use a language that effectively conveys the distinction between attitudes towards science and scientific attitudes.

Another concern that needs to be addressed is the process through which the students acquire attitudes and the ways in which their attitudes toward science may be changed. The argument presented in the following paragraphs focuses on this aspect of students’ attitudes towards science.

Understanding the Attitude-Behavior Relationship

Science educators who are interested in the study of the relationship between students’ attitudes towards science and their behavior related to science have, in the main, used the theory of reasoned action (Fishbein, 1967a) as a theoretical framework for their studies. The studies informed by this theory have advanced knowledge and understanding of students’ attitudes and attitude behavior consistency. However, this theory only applies to volitional behaviors, which are, behaviors where the students feel they have some level of control over their actions. More recently, the theory of planned behavior (Azjen, 1985) has gained some popularity of use to understand the relationship between attitudes and behavior in non-volitional settings. For example, in the science classroom where students might experience fear of science content leading them to perceive that they have very little control over their ability to successfully engage in science related behaviors.

The theory of planned behavior (Azjen, 1985) is based on a model that argues that the best predictor of behaviors are behavioral intentions and that the best predictor of behavioral intentions are the three constructs of attitudes, subjective norms, and perceived behavioral control. In the context of the current study, attitudes refer to students’ attitudes towards science, whereas subjective norms are the students’ beliefs about whether or not important others like friends, family, or respected teachers would want them to engage in science related behaviors. Perceived behavioral control deals with the students’ self-efficacy of completing science related behaviors (Ajzen, 2002). Critics of past theories argue that behavioral intentions are not the sole determinant of whether the individual performs a particular behavior or not when the individual does not have control over behavior. Therefore, they argue that by adding perceived behavioral control, the theory of planned behavior can explain the relationship between attitudes and behavior better than previous theories (Ajzen, 2002; Crawley & Koballa, 1990; Zimmerman, 2005). Ajzen (2002) defines perceived behavioral control as “an individual's perceived ease or difficulty with performing a particular behavior” in a particular context. The greater a person’s perceived behavioral control, the stronger that person’s intention to perform a particular behavior. For instance, if a student feels that they have control over their time and access to resources he/she needs to pass a course he/she is more likely to have intention to perform well in the course.

This theory guided our approach to developing and testing the validity and reliability of the newly proposed instrument. Before introducing the methods we used to design and validate our proposed instrument, we provide a review of literature on students' attitudes towards science followed by measurement issues related to students' attitudes towards science.

Instruments

Students' Attitudes Towards Science

Several science educators have studied students' attitudes towards science. Butler (1999) conducted a study with 254 fourth, fifth, fifth, sixth, seventh and eighth grade students and looked at the relationship between students' attitudes towards science and their intentions to perform science learning activities. He found a significant correlation between students' attitudes and their behavioral intentions to perform science learning activities. Butler also found that students' interest in science decrease as they progress through grade levels. For instance, he found a significant difference between eight and fifth and sixth grade students in their attitudes towards performing science learning activities. Interestingly, Butler (1999) found no correlation between SES, ethnicity/race and students' behavioral intention for performing science learning activities. This finding, if supported with additional evidence, may suggest that students' attitudes towards the learning of science are shaped at school and are influenced by the classroom factors such as curriculum, peer influence and teacher influence.

Furthermore, this may connect with the existing deficit models that account for under-representation and underachievement of ethnic/racial minorities and women in science (Baker, 1985). Baker and Leary (1995) interviewed four female students in an effort to determine factors influencing their attitudes towards science. They looked at these female students' feelings about science, science careers, peer and parental support and science instruction. Their analysis revealed that female students felt confident about learning science and pursuing careers in science. Regarding instruction, female students reportedly liked socially interactive science classrooms instead of science classroom that promoted independent learning. Baker and Leary (1995) also found that female students chose science careers either because of their desire to help or affective experiences with a close family member or a friend. These findings blame girls' reportedly "poor performance" in science to the nature of school science curriculum and the modes of instruction employed by the teachers of science. This argument is supported by Cavallo and Laubach (2001).

Cavallo and Laubach (2001) conducted a study with 119 high school biology students to explore differences in students' enrolment decisions in high and low demanding elective science courses. The results show that students who were enrolled in high inquiry classrooms developed more positive attitudes towards science than those who were enrolled in low inquiry classrooms. Moreover, they found that significantly more females in high inquiry classrooms showed commitment to taking advanced science courses than the females who were enrolled in low-inquiry classrooms. In a similar study with high school students Freedman (1996) found that high school students who received laboratory instruction developed more positive attitudes towards science than those who did not.

Collectively, the results of these studies suggest that multiple factors can influence students' attitudes towards science learning and that gender alone does not have a bearing on whether a student shows positive or negative attitudes towards science. An instrument that account for these factors may aid our understanding of the problems with students' attitudes towards science. After providing a brief summary of review on students' attitudes in science, we turn to the issues with the measurement of the construct. A review of the measurement issues related to the attitude construct will help justify the need for development of a new instrument.

Measurement Issues Related to Students' Attitudes Towards Science

Science educators have measured students' attitudes both quantitatively (Cavallo & Laubach, 2001; Fraser, 1978; Moore & Foy, 1997) and qualitatively (Dalgety, Coll, & Jones, 2003; Osborne & Collins, 2001). In this study, we mainly focus on the limitations with quantitative instruments that are used in science education literature.

We provide a review of the existing instruments designed to measure students' attitudes towards science, identify their strengths and weaknesses. In this review, we focused on the conceptual clarity and practicality of the instruments. The main issue with the most quantitative instruments designed to measure students' attitudes towards science is that they tend to measure both students' scientific attitudes and their attitudes towards science simultaneously (Cf., Moore & Foy, 1997). This confusion can impact the validity of the data produced from the studies that use these instruments and consequently, the conclusions forwarded. Therefore, they need to be pointed out. There are five instruments that we were able to identify related to students' attitudes towards science; therefore, our analyses will focus on these four instruments only.

Review of Quantitative Instruments Measuring Students' Attitudes towards Science

Although there are multiple instruments designed to measure students' attitudes in the context of science, the dimensions of students' attitudes that are measured are often not clear. For instance, the distinction between students' attitudes towards science as a subject, towards science as a profession, science learning, and science instruction is often subtle in these existing instruments. Moreover, existing instruments often mix the terminologies of scientific attitudes and attitudes towards science and thus fail to generate meaningful information important for devising responsive instruction and developing connected curriculum to increase students' success and interest in science. German (1988) states, "very often an assessment includes several dimensions of attitude, and therefore, provides no clear idea of what was really measured" (p. 690).

Test of Science-Related Attitudes (TOSRA). Fraser (1981) developed an attitude survey called the Test of Science-Related Attitudes (TORSA) based on Klofler's (1971) theory of science attitudes. This instrument consists of seven (7) measures and 70 items, each scale having ten (10) Likert-type statements. These measures were labeled as, social implications of science, normality of scientists, attitude of science inquiry, adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science, and career interest in science. The inter-correlations between TOSRA scales range from 0.10 to 0.59 with a mean of 0.33, suggesting that each measure assesses a different component of students' feelings towards science. Without confirmatory factor analytic evidence, however, it is unknown whether the seven factors are indeed conceptually different. Furthermore, reliability of the scales range from 0.69 to 0.84 and the TORSA authors report the reliability for the total instrument as being 0.80 to 0.84 depending on sample. Critics argue, however, that each subscale should pass the alpha value of 0.80 for the instrument to be considered as reliable and produce quality data. What is more, reliability assumes unidimensionality of measurement and the low inter-correlations amongst the different scales suggests that the seven scales assess distinct constructs and are not likely even second-order unidimensional, thus reporting the total instrument reliability for TORSA is problematic.

TOSRA also has certain conceptual limitations. First, the test measures both students' attitudes towards science and their scientific attitudes. This can be problematic from the content validity perspective. If a survey measures more than one conceptually similar construct respondents can become confused thereby increasing the amount of error present in responses. Furthermore, there is also the issue of space constraints which leads to researchers needing to decrease the number of questions that can be asked to measure each construct. This can be problematic for capturing the full spectrum of factors related to students' attitudes towards science. From a practical perspective, answering 70 items may result in test fatigue among the subjects. In spite of these concerns the TORSA has made significant contributions to the field of attitudes towards science.

Relevance of Science Education Project. The second instrument that we chose to review is the Relevance of Science Education Project (ROSE) (Schreiner & Sjøberg, 2010). The motivation behind this instrument was "to collect data on students' experiences, interests, priorities, images and perceptions that are relevant to the learning of science and technology and their attitudes towards these subjects" (Jenkins & Pell, 2006, p. 6). ROSE consists of 245 questions that make it almost impossible to administer unless one is willing to administer different parts of the survey for different purposes Although the authors maintain that they could not detect evidence of test fatigue, they simply rely on students' completion of the whole survey to come to this conclusion.

The findings collected through this instrument can be limited in that some questions force students to assume a certain identity. For instance, one question asks,

> Assume that you are grown up and work as a scientist. You are free to do research that you find important and interesting. Write some sentences about what you would like to do as a researcher and why.
> I would like to . . . .
> Because . . . .

Another limitation is that depending on the course they are taking students can interpret science as physics, chemistry or biology and this interpretation can have significant implications for how we may interpret students' responses. In addition, the length of ROSE may introduce differential measurement error into students' responses over the length of the measure. Also, the survey has items that appear to measure one construct but are placed in sections of the survey purported to measure different constructs, creating a clear validity issue. For instance, the question "I would like to become a scientist" that appears under "my science classes" does not relate to science classroom but relate to students' general interest in science. Another question, which states, "I would like to get a job in technology" does not relate to science instruction yet it appears under this section. In spite of these concerns, ROSE has helped science educators to get a picture of students' interest and attitudes towards science at an international level.

Scientific Attitude Inventory. The third instrument that we reviewed was The Scientific Attitude Inventory (SAI) (Moore & Sutman,1970). This instrument was designed before the construct of attitude had been thoroughly examined by science education community. Moore and Foy (1997) revised the instrument to address this criticism posed by Munby (1983). The revised SAI consists of 12 position statements, six opposing positive and negative statements. These 12 positions were designed to reflect both the intellectual attitudes and emotional attitudes. The validity of this measure was tested by comparing the total scores of the top 27% students to the scores of bottom 27% and a statistically significant difference between the two groups was found. The authors argued that the t-test comparison of the two groups indicate that “the different subscales contribute positively to the total score of the instrument” (Moore & Foy, 1997, p.32). This test is a weak measure of validity by any psychometric criteria. The authors did not carry out more thorough validity tests such as confirmatory factor analysis, item response analysis, or criterion -related tests of the revised version of SAI. Therefore, the validity data accumulated for the SAI is weak at best. A simple face validity analysis of the SAI suggests that the items on the instrument measure an array of scientific attitudes, attitudes towards science, and scientists and the utility of science. In addition, there are some limitations with the language of the statements in the instrument. For instance, the use of double-barreled items (question 2-B), and the difficulty of language (questions 2-B and 3-B) places limitations on how students may respond to the items. For instance, the question, “the basis of scientific explanation is in authority” (Moore & Foy, 1997, p. 334) may be too difficult for 6th and 9th grade students to understand and respond to.

Colorado Learning Attitudes About Science Survey. Finally, there is the Colorado Learning Attitudes About Science Survey (CLASS) (Adam et al. 2005). This instrument consists of eight (8) categories asking students to show their level of agreements or disagreement with 42 statements. These categories include real world connections, personal interest, sense-making /effort, conceptual connections, applied conceptual understanding, a general problem solving, problem solving confidence, and problem solving sophistication. There are several issues with this instrument. First, although the CLASS is a comprehensive instrument that measures factors impacting students’ level of academic achievement in physics, the researchers did not use a conceptual framework for defining attitudes to construct the survey. Instead the instrument was developed using data revealed through student interviews. They also used exploratory factor analysis to modify the categories that they created based on data collected through student interviews. Consequently, the developed instrument is a measure of constructs that the researcher’s interview sample thought was important rather than a measure of constructs that are theoretically important, thus limiting the practical and theoretical utility of the measure outside of the particular sample with which it was developed. Second, some of the items again are clearly not measuring attitudes. For instance, the statement, “it is important for the government to approve new scientific ideas before they can be widely accepted” is epistemic in nature rather than an affective statement. The conceptual issues with the content of the statements undermine the robust statistical procedures used to validate the survey.

Summary

Although each of these measures have contributed to science attitudes knowledge in some way, as a consequence of the shortcomings of these existing “measures” of students’ attitudes towards science, there is a clear need for the development of a valid and reliable measure that is derived from the conceptual definition of attitude as explicated initially. For a summary and comparison of each of these instruments see Appendix A.

The argument provided thus far calls for the development of an instrument that is informed by current attitude theory in persuasion literature and has potential to help uncover information that teachers can put in use in their planning and instruction. By no means do we argue that previous instruments are not useful. As indicated in the Appendix A, each of the reviewed instruments can be used to explore different factors related to students' attitudes. However, we argue that an attitude instrument that is informed by assumptions of persuasion literature can provide better information about the relationship between students' attitudes and their behaviors in relation to science. The measure of attitudes towards science developed and validated in this study uses a definition of the attitude construct consistent with Azjen's (1993) theory of planned behavior. This theory was used because it can be useful in predicting the relationship between attitudes towards science and behaviors in science learning. This utility also led us to develop a comprehensive measurement model and a questionnaire called *Students' Attitudes Toward Science* (SATS). This questionnaire was designed to measure students' attitudes toward science as well as five other constructs hypothesized to be related to behaviors related to science learning. These five (5) constructs are: 1) students' motivation to learn science, 2) students' perceptions of the utility of science, 3) students' self-efficacy beliefs for the learning of science, 4) students' perceived subjective norms towards science, and 5) students' intentions to pursue a science related activities. The sections that follow elaborate on the measurement model and methods used to test the validity and reliability of the measure.

Method – Instrument Design

Subjects

A total of 205 high school students from five (5) schools within a southeastern United States school district were sampled. Of the 205 students in the sample, 27 % were in grade 8, 17 % were in grade 9, 35 % were in grade 10, 19 % were in grade 11, and 2 % were in grade 12. In terms of science achievement, 64 % of the students self-reported their science grades as being average, 12 % below average and 24 % above average. Almost the entire sample (94%) had intentions of pursuing a college degree. Few students in the sample (5%) spoke English as a second language. Similarly, few students in the sample (6%) had individualized education plans. Females composed slightly more than half of the sample at 53 %. Finally, Caucasians made up the bulk of this sample at 89 %, while African Americans (6%), Hispanics (4%), and Asian Americans (1%) comprised the remainder.

Procedures

Subjects responded to a questionnaire containing seven measures with a total of 72 items. The questionnaire took approximately 40 minutes for students to complete and required five minutes of teacher instruction. The investigators recruited classroom teachers to administer the questionnaire to students in their classrooms. After the teacher consent was received, the investigators trained the teachers to administer the questionnaire in the same manner. The investigators met with the teachers individually and described the purpose of the study, the instrument to be used and how to administer the survey in a short meeting. If the teachers had any questions the investigators addressed them. The teachers were instructed to read the purpose of the study to their students, ask students to complete the survey by providing honest answers. The students were encouraged to ask the teacher to clarify questions for them and if they did not understand the question. These teachers were also involved in the review of the original survey so they were familiar with the survey items. Teachers were selected based on their enrollment in a teacher education masters program at the investigators institution. All teachers were certified to teach science and had between one to three years of science teaching experience.

After obtaining parental consent and student assent, teachers instructed the subjects to complete the questionnaire by working quickly but carefully, reading each item and circling the response that they feel most closely approximated how they feel. The teachers also instructed the subjects to ask for clarification if they had difficulty understanding a word or item. None of the subjects required clarification, as the Flesch-Kincaid Reading Grade Level of the measure was 5.5. Subjects were further instructed to sit quietly once finished until everybody completed the questionnaire. Finally, the teacher collected the questionnaires once everybody was finished.

Instrument

The seven measures used to develop the questionnaire were designed to assess subjects' attitudes toward science, motivation toward learning science, utility of science, self-efficacy in science learning, normative beliefs about science involvement, intention to pursue science related activities, and demographics (Appendix B). These measures were based on a thorough review of the extant science education and theory of reasoned action literatures. Excluding the demographic items, items were structured as Likert-type items with seven-point response scales. The response options ranged from *disagree strongly* to *agree strongly* and were scaled such that a higher number corresponded to a greater amount of the construct being measured. Each measure, excluding the demographic items, was hypothesized to fit a unidimensional measurement model. Alternatively stated, if considered together the measures, again excluding the demographic items, were hypothesized to fit a six-factor measurement model. After the authors created a pool of questions for each subscale based on an extant review of literature (Butler, 1999; Koballa & Glynn, 2007; Osborne & Collins, 2001; Shrigley, Koballa & Simpson, 1988), the theory of planned behavior and analyses of previous scales, the authors and one high school science teacher met three times to review each item and evaluate the items' congruency with each subscale. After each meeting, some items were removed, some were modified and some new items were added. The other teachers who implemented the survey also contributed to the review process by evaluating the items and their readability and understandability middle and high school students.

Results

Measurement Model

Confirmatory factor analysis (CFA) was employed in this study to test the internal consistency and parallelism of the hypothesized measurement models (Hunter & Gerbing, 1982)[1]. The AMOS CFA algorithm using a maximum likelihood parameter estimation method was employed to perform the CFAs. Initially, the response distribution of each item was examined for normality; none were found to deviate substantially. The internal consistency of each measure was assessed next by constructing six inter-item correlation matrices according to the unidimensional model specifications. Based on a visual inspection of each matrix, several items on each measure obviously lacked internal consistency due to near zero inter-item correlations with other items hypothesized to measure the same construct. These items were removed from their respective measures and not considered in further analyses.

The AMOS CFA algorithm was then used to perform a more systematic analysis to locate less obvious internal consistency problems. This algorithm calculated factor loadings based on the hypothesized model specifications and generated a predicted inter-item correlation matrix. This predicted matrix was then subtracted from the observed inter-item correlation matrix to form a residual matrix. The residual matrix was then examined to assess model fit. To the extent that the residuals in the matrix were within sampling error of zero, there was evidence that the model fit the data. Based on these analyses several more items from some of the measures were found to lack internal consistency and removed from further analyses.

After examining the internal consistency of each of the measures the six-factor measurement model was tested to assess the parallelism of the measures. This test revealed several more items that produced substantial residuals is the parallelism matrices. These items were removed from the measures and not considered in future analyses. Overall, this CFA resulted in six unidimensional measures containing items with ample factor loadings (Table 1) and factor correlations consistent with theoretical predictions (Table 2).

Table 1.
Factor Loadings

	Attitude		Motivation		Utility
Item	Factor Loading	Item	Factor Loading	Item	Factor Loading
1	0.60	1	0.53	1	0.74
2	0.72	2	0.57	2	0.84
3	0.59	3	0.73	3	0.91
4	0.78	4	0.69	4	0.85
5	0.63	5	0.79	5	0.61
	Self-Efficacy		**Norms**		**Intentions**
Item	Factor Loading	Item	Factor Loading	Item	Factor Loading
1	0.87	1	0.40	1	0.83
2	0.86	2	0.72	2	0.82
3	0.66	3	0.79	3	0.72
4	0.91	4	0.67	4	0.83
5	0.59				

Table 2.
Factor Correlations

	Attitude	Motivation	Utility	Self-Efficacy	Norms	Intentions
Attitude						
Motivation	0.44					
Utility	0.70	0.46				
Self-Efficacy	0.31	0.21	0.18			
Norms	0.54	0.25	0.45	0.16		
Intentions	0.83	0.38	0.62	0.22	0.54	

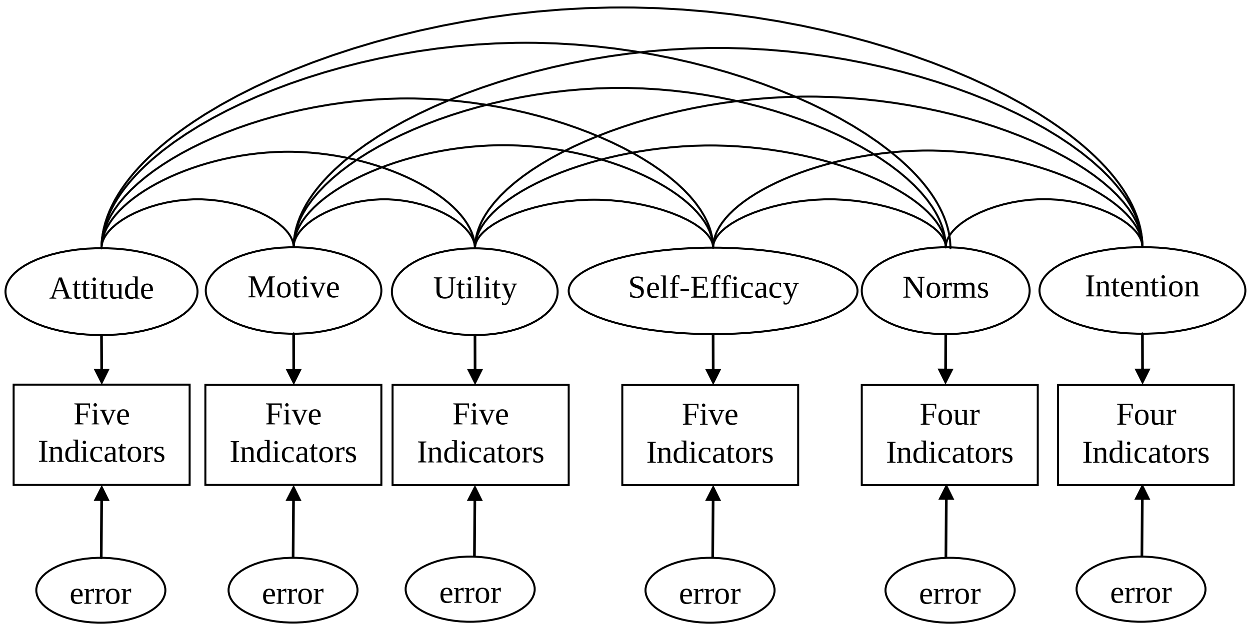
Based on visual examination of the items, residual matrices, and the model fit statistics there is evidence that these measures have evidence of face, content, and structural validity. Table 3 presents fit statistics for each model tested. Figure 1 presents the final six-factor measurement model.

Table 3.
Fit Statistics

	χ^2	χ^2/df	GFI	RMSEA
Unidimensional Models				
Attitude	(5, N = 205) = 7.37, *ns*	1.47	0.99	0.05
Motivation	(5, N = 205) = 9.22, *ns*	1.84	0.98	0.06
Utility	(5, N = 205) = 6.53, *ns*	1.31	0.99	0.04
Self-Efficacy	(5, N = 205) = 3.05, *ns*	0.61	0.99	0.00
Norms	(2, N = 205) = 2.98, *ns*	1.49	0.99	0.05
Intentions	(2, N = 205) = 0.37, *ns*	0.19	1.00	0.00
Six Factor Model	(335, N = 205) = 449.78, $p < .05$	1.34	0.87	0.04

Notes. GFI = Goodness of Fit Index, RMSEA = Root Mean Square Error of Approximation

Figure 1. Six-factor measurement model.



This figure shows the statistical fit model we used to conduct factor analysis. The questionnaire has 6 sub-constructs/categories represented in the oval shapes. The numbers indicate the number of items for each sub-construct/category. The model explores the interaction of each item with the subcategories of the scale.

Because these analyses demonstrated that each measure consisted of a set of unidimensional items, responses to the items comprising each measure were averaged to form indices. Items composing each of these final indices are those presented in Appendix B. Descriptive statistics for each of the six indices are presented in Table 4.

Table 4.
Index Statistics

Variable	M	SD	Min-Max	Skewness	Kurtosis	Cronbach's α
Attitude	3.48	1.34	1.00 - 6.80	0.08	-0.87	0.73
Motivation	5.17	1.19	1.80 - 7.00	-0.72	0.11	0.79
Utility	4.28	1.41	1.00 - 7.00	-0.29	-0.49	0.89
Self-Efficacy	4.51	1.73	1.00 - 7.00	-0.41	-0.90	0.89
Norms	2.38	1.10	1.00 - 6.00	0.97	0.83	0.73
Intentions	2.71	1.54	1.00 - 7.00	0.85	0.13	0.87

Additional Research Questions

As mentioned earlier, this study was designed to test the validity and reliability of a measure constructed to assess students' attitudes towards science that would also allow researchers to confidently explore the factors that impact those attitudes and, enable researchers to better understand the relationship between students' attitudes towards science and their behavior. The argument provided in previous section provides ample evidence that the instrument developed measures students' attitudes towards science and can help researchers understand the relationship between students' attitudes towards science and their behavior related to science related activities. Therefore, the secondary goal of this study was to answer several research questions based on the findings.

The first research question was aimed at determining the extent to which students' motivation to learn science could be predicted from variables in the measurement model as well as several demographic variables (e.g., college intentions, sex, and income) and academic performance (e.g., overall grades and science grades). Using multiple regressions, controlling for the other variables in the model, students' perceived utility of science accounts for a substantial amount of variability in the motivation towards learning science (β= 0.35, $p < 0.05$). All other predictors in the model were within a sampling error of zero (see Table 5).

Table 5.
Motivation Regression Model

Model	Component	*B*	se	*β*	*t*	sig
Motivation	Constant	2.24	0.57		3.93	$p < .05$
F (9, 167) = 6.55, $p < .05$	College Intentions	0.25	0.29	0.06	0.86	ns
$R_{adj} = .47$	Sex	0.20	0.16	0.09	1.22	ns
	Income	-0.05	0.13	-0.03	-0.38	ns
	Overall Grades	0.08	0.18	0.03	0.44	ns
	Science Grades	0.21	0.17	0.10	1.21	ns
	Utility	0.29	0.07	0.35	3.98	$p < .05$
	Self-Efficacy	0.08	0.05	0.11	1.59	ns
	Norms	0.05	0.08	0.05	0.60	ns
	Attitude	0.05	0.08	0.05	0.55	ns

The second research question examined what factors that would predict students' intention to participate in science-related activities. The results of a multiple regression analysis that regressed the variables in the measurement model as well as several demographic variables (e.g., college intentions, sex, and income) and academic performance (e.g., overall grades and science grades) onto intentions indicated that students' attitudes towards science (β= 0.41, $p < 0.05$), students' perceived utility of science (β= 0.25, $p < 0.05$), and students' perceived subjective norms (β= 0.18, $p < 0.05$) are the only substantial predictors of students' intentions to engage in science related activities (see Table 6).

Table 6.
Intention Regression Model

Model	Component	*B*	se	*β*	*t*	sig
Intention	Constant	-1.56	0.54		-2.87	$p < .05$
F (9, 167) = 24.27, $p < .05$	College Intentions	0.08	0.27	0.02	0.28	ns
$R_{adj} = .74$	Sex	-0.05	0.16	-0.02	-0.33	ns
	Income	0.10	0.12	0.04	0.83	ns
	Overall Grades	0.18	0.17	0.06	1.07	ns
	Science Grades	0.07	0.16	0.03	0.41	ns
	Utility	0.26	0.07	0.25	3.77	$p < .05$
	Self-Efficacy	0.06	0.05	0.08	1.4	ns
	Norms	0.23	0.08	0.18	2.93	$p < .05$
	Attitude	0.46	0.08	0.41	5.78	$p < .05$

Consistent with previous research (Butler, 1999) the analysis in this study did not indicate any statistically significant or substantial correlations between participants' socioeconomic status and their science learning motivation or intentions to engage in science related activities. Similarly, the present analyses did not find any statistically significant differences between male and female participants' intentions to engage in science related activities in contrast to Baker's (1986) findings. Factors such as self-efficacy, overall school grades, science grades, SES did not account for variability in students' intentions to pursuer science related activities.

Discussion

Students' attitudes toward science have been the subject of many studies since the 1950s (Koballa & Glynn, 2007). Interest in students' attitudes towards science is justified based on two factors; the correlation between attitudes and achievement as well as and the association between students' interest in pursuing science related careers and attitudes (Hough & Piper, 1982; Koballa & Glynn, 2007). Past research reports mixed findings, however, about the direction and magnitude of relationship between attitudes and achievement (Butler, 1999; Koballa & Glynn, 2007). As argued in this study, the conceptual and methodological issues in the extant literature have contributed to the inconsistencies in the literature.

Several instruments are in existence purported to measure science attitudes. Some of these instruments only measure the impact of classroom instruction on students' attitudes towards science, some look at the impact of curriculum on students' attitudes towards science and others look at the combination of factors related to student learning in students' attitudes towards science. Although each of these instruments has made a contribution in one way or another, each has its own limitations, however. While some of the limitations are methodological, the most serious limitation is conceptual (i.e. the distinction between attitudes towards science and scientific attitudes). This study has attempted to address some of these limitations by designing and validating a new measure derived from theory and a clear conceptual definition of attitudes.

The data presented in the results indicate convincingly that the instrument developed in this study to assess students' attitudes toward science has sound validity and reliability characteristics. This is a substantial improvement from earlier measures of the attitude construct in the science education literature. The instrument developed in this study was subjected to face, content, structural, and construct validity tests and passed each successfully. Furthermore, as reported in the results the reliability estimate for the developed instrument is very high, especially given the number of items that compose the measure. In sum, this instrument is of sufficient quality at its early stage of development for future validity testing and use in basic research.

Limitations

Although the evidence generated in this study is convincing there are limitations of the present study and of the instrument itself that must be mentioned. First, although a quantitative instrument derived from sound theory, possessing significant validity and reliability characteristics has the potential to provide useful information about groups of students, such instruments are unlikely to uncover all of the reasons for the choices that the students make about their attitudes towards science and the behaviors associated with attitudes such as interest in pursuing science related careers. It is arguable that a mixed methodology is could provide rigorous evidence that both curriculum developers and science educators can act upon to make a significant difference in the way students participate in science related activities and achieve in science classrooms. Therefore, it is advisable that the instrument developed in this study be used in conjunction with structured interviews to effectively uncover the full array of students' attitudes towards science.

Second, the validity and reliability evidence offered in conjunction with the development of this instrument is that of a single sample. Although unlikely, it is possible that the measurement model fit was an artifact of this particular sample rather than a feature of the measure. Given that measurement validity arguments are based on accumulated evidence and that the effects of sampling error wash out across large samples, additional research is needed before it would be advisable for this study to be used in high stakes testing or applied research.

Implications and Conclusions

The limitations above not withstanding, the measures developed and tested in this study have considerable potential for use in advancing understanding of the role of students' attitudes towards science in science achievement and the pursuit of science related opportunities and careers. For example, Crawley and Koballa (1992) used the theory of planned behavior and elaboration likelihood model to understand Hispanic students' registration in high school chemistry. Crawley and Koballa (1992) exposed an experimental group to an audio message that discredited negative associations with enrolling in a high school chemistry course. There were two subgroups under the experimental group: the students only and student/parent groups. Their analysis reveals that the attitude change intervention had a positive influence on Hispanic students' registration in high school chemistry and that theory of planned behavior is a useful model for studying the interaction between attitude and behavior.

What is more, Crawley and Koballa (1992) demonstrate that if one can effectively understand the impact of attitudes on science related behaviors, persuasion theory could be more effectively brought to bear on the issue. Specifically, it would be possible to integrate persuasive message and theory into the classroom to influence students to develop more positive attitudes towards science. These positive attitudes towards science would in turn make it more likely that students would pursue science related activities to the extent that attitudes are indeed strong predictors of science behavior intentions as indicated by the data in this study. As science educators there is a need to continue clarifying the definition of the attitude construct. By consulting the extant literature and theories across disciplines more closely and incorporating it into the already rich annals of science education knowledge, science educators can continue to develop a better understanding of the factors that impact students' attitudes towards science and success in the science classroom.

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Footnotes

[1] Whereas the internal consistency of a set of indicators purported to measure the same construct is the extent to which each indicator correlates predictably with other indicators in that set, the parallelism between two or more sets of indicators is the extent to which indicators purported to measure the same construct correlate predictably with indicators purported to measure a different construct.

Appendix A.
Summary/Comparison of Six Different Attitude instruments

Instrument	Students' Attitudes Towards Science (SATS)	The Scientific Attitude Inventory (SAI-II)	Colorado Learning Attitudes About Science Survey (CLASS)	Test of Science-Related Attitudes (TOSRA)	Relevance of Science Education Project (ROSE)
Grade level	Middle School/ High School.	Middle/High School	Undergraduates	High School	High School
About	This instrument is designed to measure middle and high school students' attitudes towards science.	This instrument is designed to measure students' scientific attitudes. There are 6 subscales in this instrument.	This survey probes students' beliefs about physics and learning physics. This instrument consists of eight categories asking students to show their level of agreements or disagreement with 42 statements.	Test of Science-Related Attitudes (TOSRA) is designed to measure seven distinct science-related attitudes among secondary school students. This instrument consists of 70 items and 7 subscales.	It is a questionnaire that explores the relevance of school science education from the perspective of the students themselves. The final ROSE questionnaire consisted of ten sections ranging from A to I.
Definition of Attitude	Attitude has been defined as sum of the product of all beliefs (b) and evaluations (e) about an attitude object ((Fishbein, 1967a; 1967b).	The construct attitude used in this instrument refers to scientific ways of thinking. Only two of the 6 subscales refer to affective domain.	No explicit definition of the construct attitude is given in the paper. The authors have not provided a definition for each of the 8 subscales either.	No explicit definition of the construct attitude is given. Just a description of subscales is given based on Klopfer' (1971) conceptions of "attitude to science".	No explicit definition of the construct attitude is given in an overview of the ROSE project.
Review	Expected	The main criticism of this instrument has been around content validity. Some scales that appear to be measuring scientific attitudes are actually measuring attitudes towards science.	No definition of the construct attitude is given.	Only 5 of the 7 subscales refer to attitude from an affective perspective. The other two are related to habits of minds associated with scientific inquiry.	This instrument measures not only attitudes towards science but also values and interest of students in relation to a range of science and technology related topics.
Instrument	Students' Attitudes Towards Science (SATS)	The Scientific Attitude Inventory (SAI-II)	Colorado Learning Attitudes About Science Survey (CLASS)	Test of Science-Related Attitudes (TOSRA).	Relevance of Science Education Project (ROSE).
Theoretical Grounds	Theory of Planned Behavior (Azjen,	Expert Panel: No explicit	Builds on review of previously	Klopfer' (1971) theory of attitude	Expert Panel and Previous Literature.

	1993) and review of literature and previous surveys.	references to social psychology theory.	published surveys. No theoretical framework has been used in the design of the survey.	to science.	
	Attitudes towards science This construct focuses on students interest in science, science related activities and careers.	The laws and/or theories of science are approximations of truth and are subject to change.	Personal interest (n=6). NA	Leisure interest in science (n=10). Development of interest in science and science related activities.	Sections A, C and E consist of a total of 108 items. Each section is headed 'What I want to learn about'. Respondents are invited to respond using the 4-point Likert scale from "Not interested" to "Very interested"
	Motivation towards learning science This construct deals with students' motivation to learn about science. Motivation refers to interest in learning science and importance assigned to achievement in science.	Observation of natural phenomena and experimentation is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that.	Sense making /effort (n=7). NA	Enjoyment of science lessons (n=10). This scale measures students' enjoyment level related to science learning activities.	Section D (18 items). Respondents are invited to indicate the extent to which they agree/disagree with a series of statements about the environment.
	Students' Attitudes Towards Science (SATS)	The Scientific Attitude Inventory (SAI-II)	Colorado Learning Attitudes About Science Survey (CLASS)	Test of Science-Related Attitudes (TOSRA).	Relevance of Science Education Project (ROSE).
	Utility of science. This construct deals with students' perceptions of the benefits that science has for personal or societal use.	The basis of scientific explanation is in authority. Science deals with all problems and it can provide correct answers to all questions.	Real world connections (n=5). NA	Social implications of science (n=10). Refers to attitude towards the social benefits and problems associated with scientific progress.	Section F (16 items) are concerned with students' views about their school science education.
Subscales	Self-efficacy in learning science. Refers to the confidence that	To operate in a scientific manner, one must display	Problem solving confidence (n=4). NA	Normality of scientists (n=10). Refers to the appreciation that	Section G (16 items) is designed to probe how students perceive the role and

	students have in accomplishing learning tasks related to science (Bandura, 1997).	such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence.		scientists are normal people rather than the eccentrics often depicted in the mass media	function of science and technology in society.
	Normative beliefs about science involvement. This aspect of attitude focuses on the influence of significant people in students' decision to participate in science related activities.	Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects.	Problem solving general (n=8). NA	Adoption of scientific attitudes (n=10). This subscale measures students' scientific attitudes such as curiosity and open-mindedness.	Section B (26 items). Students are invited to indicate the importance they attach to a number of issues for their potential future occupation or job.
	Students' Attitudes Towards Science (SATS)	Students' Attitudes Towards Science (SATS)	Students' Attitudes Towards Science (SATS)	Students' Attitudes Towards Science (SATS)	Students' Attitudes Towards Science (SATS)
	Intentions to pursue science related activities. This aspect of attitude deals with students' behaviors related to science.	Science is a technology-developing activity. It is devoted to serving mankind. Its value lies in its practical uses.	Problem solving sophistication (n=6). NA	Career interest in science(n=10). Measures students' interest in pursuing a career in science.	**Section H** (61 items) is designed to explore students' out-of-school experiences/activities.
		Progress in science requires public support in this age of science; therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work.	Conceptual connections (n=6). NA	Attitude to science inquiry (n=10). This subscale measures attitude to scientific experimentation and inquiry as ways of obtaining information about the natural world.	**Section I** begins with an invitation to students to imagine that they are grown up and working as a scientist and to write a little about what they would do and why. This is an open-ended question.

		Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life's work. I would like to do scientific work.	Applied conceptual understanding (n=7). NA		

Appendix B.
Students' Attitudes Towards Science (SATS)

1. I like watching science related TV.
2. Science is my favorite subject in school.
3. I like reading about famous scientists.
4. I find what we learn in my science class interesting.
5. I would enjoy working in a science lab.

Motivation Towards Learning Science

1. I will ask my teacher for an explanation if I do not understand the science topic.
2. I will look for an explanation in the textbook if I do not understand the science topic.
3. I care about completing assignments in this class.
4. Getting a good grade in science is important to me.
5. I am interested in understanding the teacher in this class.

Utility of Science

1. I use the science that I learn in school in my life.
2. What I learn in my science class helps me understand how things work in life.
3. Learning science makes me curious about things that I observe in my life.
4. What we learn in science class helps me to understand how science affects my life.
5. Learning science helps me to make wiser decisions about my health or diet.

Self-Efficacy in Science Learning

1. I am not the type who can do well in science.[R]
2. I believe science is too difficult for me to learn.[R]
3. The idea of taking science makes me nervous.[R]
4. People like me cannot do science.[R]
5. Even if I study very hard I cannot do well in science.[R]

Normative Beliefs about Science Involvement

1. I try to do well in science because my friends expect it of me.
2. My friends have a lot of respect for scientists.
3. Most of the kids I hang out with like science.
4. Watching science programming is something my friends and I like to do together.

Intentions to Pursue Science Related Activities

1. I would like to become a scientist.
2. I would like to take more science courses
3. I would like to join a science club.
4. I would like to become a scientist to solve important problems.

Demographics

1. I am a _____freshman _____sophomore _____junior _____senior
2. I am _____White _____African American _____Hispanic _____Asian American
3. I am _____female _____male
4. I am ESL student (English as a Second Language) _____no _____yes
5. I am on an IEP (Individualized Education Program) _____no _____yes
6. I plan on going to college after high school _____no _____yes
7. My parents make _____less than $50,000 per year _____between $50,000 and $100,000 per year _____more than $100,000 a year
8. My overall grades in school are _____below average _____average _____above average
9. My overall grades in science courses are _____below average _____average _____ above average