A Structural Analysis of the Attitudes Toward Science Scale: Students' Attitudes and Beliefs about Science as a Multi-Dimensional Composition

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The Attitudes Toward Science Scale (Francis & Greer, 1999) was examined from an attitude versus beliefs perspective. We found that this instrument to manifest a multi-dimensional structure measuring two different factors: student attitudes toward science and their beliefs about science. Further, this study illustrated the importance of distinguishing between students' attitudes toward and their beliefs about science and recommends measuring beliefs independently from attitudes.

Students' attitudes represent an important dimension of their thinking about and affect toward particular subject domains in school. Students' attitudes may, for example, influence their motivation to pursue study in a domain and persist in their efforts to attain subject matter mastery (Koballa & Glynn, 2007). In the classroom, students' attitudes reflect how they manage their perceptions regarding academic content and learning as well as their behaviors. Thus, attitudes facilitate learning, but they are also products of students' learning activities.

In science education, research suggests that students' affect toward science, including attitudes, becomes increasingly less positive over time (National Education Goals Panel, 1992). Studies have found that science attitude scores tend to decline as students advance through the upper grade levels (George, 2000; Gibson & Chase, 2002). The examination of students' attitudes toward science provides important information about the general status of science education in the United States (Simpson, Koballa, Oliver, & Crawley, 1994). Further, the assessment of students' attitudes enables educational researchers and practitioners to both predict and influence students' classroom behaviors. For instance, an individual student holding a favorable attitude toward science might be expected to do well on science tests, look forward to science classes and lab experiments, or even choose to pursue a science career (and encouraged by science teachers to do so).

Therefore, it is important for educators to have knowledge of their students' attitudes about subject matter. Having assessments and instruments that derive stable score reliability and validity pertaining to students' attitudes toward science is foundational to the aspiration of advancing science education as such measures yield valuable data for educators. While investigators have assessed students' attitudes toward science in a variety of ways, for instance as drawings (Finson, 2002), surveys remain the predominant approach to measuring such attitudes.

The Attitudes Toward Science (ATS) scale was developed to assess secondary school students' feelings about science; both school science and science in general (Francis & Greer, 1999). From an original scale consisting of 62 items, 20 items were derived – based on "content analyses, exploratory factor analyses and item analyses" (p. 220) -- for the final version of the scale. Francis and Greer aimed to create a uni-dimensional scale, and they reported that the ATS "operationalizes the affective attitudinal domain independently of the behavioral and cognitive dimensions" (p. 220). According to the aforementioned authors, the ATS was found to have suitability score reliability. Content validity for the ATS was based on inter-item correlations and construct validity was determined by the observed statistically significant correlation between attitude scale scores and the number of science subjects that respondents studied in school.

For the current study, the ATS was employed in the Science-in-the-Moment (SciMo) study (Schmidt & Smith, 2008) to measure students' attitudes toward science. SciMo was an investigation of high school students' cognitive and affective experiences during science instruction and students' science attitudes served as a covariate in the investigation. Based on subsequent analyses of data derived from students' ATS responses, the current study argues that the ATS instrument does not manifest itself as a uni-dimensional structure, as reported by Francis and Greer (1999). Rather, results from a confirmatory factor analysis (CFA) indicated that the ATS consists of two distinct clusters of items that measure two different factors: student attitudes toward science and their beliefs about science.

Review of the Literature

Attitudes

As noted in the recent work of Van Aalderen-Smeets, Walma Van Der Molen, and Asma (2011), the concept of "attitudes" is quite complex, as "attitude is not a single unitary concept…it is a construct consisting of multiple dimensions and subcomponents" (p. 161). In fact, social psychologists across the decades have defined and operationalized attitudes in a variety of ways; reflecting distinct theoretical perspectives (Eagley & Chaiken, 1993). In perhaps the most comprehensive treatment of the psychology of attitudes, Eagley and Chaiken defined attitude as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (p. 1). Attitudes may also contain feelings and emotions associated with an object and, again, are assumed to result from one's prior experience with the object (Shrigley, 1983). However, as Eagley and Chaiken noted, direct experience with an attitude object is not necessary for an attitude regarding an object to be formed.

There are two principal theoretical perspectives on the nature of attitudes in social psychology and these prevailing schools of thought attempt to explain the relationship between attitudes and behavior. Each perspective also differs in its approaches to measuring attitudes. First, the multidimensional perspective views attitudes as consisting of three distinct domains: affect, behavior, and cognition. Proponents of this perspective argue that "man's [sic] social actions–whether the actions involve religious behavior, ways of earning a living, political activity, or buying and selling goods–are directed by his attitudes" (Krech, Crutchfield, & Ballachey, 1962, p. 139).

The affective component of an attitude refers to the emotions connected with the object (i.e., it may be pleasing or displeasing, liked or disliked). For instance, enjoyment for learning science will lead to positive feelings towards science-related activities and scientists. The behavioral component includes the behavioral readiness associated with the attitude (i.e., the inclination to take action with respect to the object). Thus, if a student has a favorable attitude towards science, then he or she may tend to read science magazines for pleasure or go to science museums and exhibitions, for example. The cognitive component consists of one's beliefs about the object. For instance, attitudes toward science may include beliefs about the ways in which scientists influence public policies about scientific matters, such as climate change, or about the validity of the theory of evolution. Any change in the cognitive aspect of an attitudinal object entails a change in the attitude toward that object. However, a belief can change independently of an attitude. For example, exposure to new information may change one's belief about the importance of science, but not lead to a change in attitude toward science content. So, a student might believe that science is important to learn, but still dismiss scientists' claims about global warming or hold an attitude of contempt toward the theory of evolution.

The second, uni-dimensional, perspective argues that attitudes should be measured solely within the affective domain – while acknowledging that there are actually four domains – affect (i.e., feelings toward and evaluation of an object, person, issue, or event), cognition (i.e., knowledge, opinions or beliefs about an object), conation (i.e., behavioral intentions toward the object), and behavior (i.e., observed actions)– that interact so that beliefs shape attitudes and attitudes, in turn, influence intentions that then lead to particular behaviors. Proponents of this perspective, such as Fishbein and Ajzen (1975), clearly distinguish between attitudes and beliefs; assigning attitudes to the affective domain and beliefs to the cognitive domain. Fishbein and Ajzen operationalized attitudes as learned predispositions of response in a consistently favorable, or unfavorable, manner to a given subject.

Accordingly, beliefs may change due to feedback resulting from one's attitudes and behavior. For instance, once established, an attitude may influence the formation of new beliefs. If a student repeatedly feels confused throughout a science course, for example, she or he may eventually develop a belief that science is difficult and boring. In the same vein, performance of a particular behavior may lead to a new belief about the object, which may, in turn, influence the attitude. For example, if a student performs successfully on a science test, he or she may form a new belief that science is not that difficult after all and may look forward to the next assignment.

Assessing Attitudes. According to Fishbein and Ajzen (1975), attitudes are affective variables and should; therefore, be measured accordingly. That is, if we want to know students' attitudes toward science learning or other science–related behaviors, we need to assess their feelings and not what they assume to be true about science (i.e., their beliefs). In other words, we should seek their personal evaluation of science-related behaviors (in concurrence with Butler, 1999 and Shrigley, Koballa, & Simpson, 1988) apart from their perceptions of science as a societal or technical enterprise. Thus, including aspects of students' knowledge about science, such as its usefulness; importance; or relevance as part of an attitude assessment, may lead to incorrect conclusions about students' attitudes.

Beliefs

According to Fishbein and Ajzen (1975), beliefs represent the information a person has about an object or idea. A belief links an object to some attribute associated with the object (Koballa, 1988). For instance, the object "science" is linked with characteristics such as important, relevant, or useful. The object, "money spent on science," is associated with an attribute: "worth spending." As Rokeach (1969) noted, "the content of a belief may describe the object as true or false, correct or incorrect" (p. 404). This implies that belief statements assess a person's opinion on its nature (i.e., true or correct). However, beliefs do not trigger or involve emotion or feelings (i.e., attitudes) toward the object.

Beliefs are described as the probability of a relationship between the object of belief and many other objects, concepts, or goals (Andre, Whigham, Hendrickson, & Chambers 1999). Thus, beliefs represent an individual's evaluation of the relationship between the given object and the particular attribute associated with the object. For example, the United States (a concept) is related to the phrase "needs to have many more scientists" (another concept). In this example, evaluation is aimed at the relationship between the two concepts and not at the concepts themselves. Response to this statement indicates how strongly a person believes in the expressed idea (i.e., that the U.S. needs many more scientists). Unlike an attitude statement, a belief statement does not evaluate the idea itself.

Fishbein and Ajzen (1975) reported that individuals learn or form beliefs about objects based on: (a) direct observation and (b) information received from outside sources, or (c) by way of various inference processes. However, more often beliefs are neither formed on the basis of direct experience with the object of the belief or by some inferential process. For example, students may have little direct experience with claims such as "the United States needs to have many more scientists," or "science has ruined the environment." Instead, students often accept information about an object as provided by an outside source such as the media (e.g., newspapers, books, radio, TV, Internet) or other people (e.g., parents, teachers, or classmates).

Students may conclude, logically, that science is important. Science is knowledge and most people agree that knowledge is important. However, no matter how this belief is formed (i.e., by direct observation, external source, or inferential process); it remains unrelated to students' attitude toward science. Asking students to evaluate statements on the importance or relevance of science assesses their level of agreement with the statement, but not the magnitude of their feelings about science.

As for the attitudes-beliefs relationship, Fishbein and Ajzen (1975) described it in terms of an expectancy-value model. The model assumes that when someone has to make a behavioral choice, the individual will select the alternative having the highest subjective expected value; that is, the alternative likely to lead to the most favorable outcome. A person's attitude toward an object is a function of his or her belief about the object's attributes and an evaluation of those attributes. The underlying assumption is that evaluative judgments result from cognitive processes (i.e., making associations between the attitude object and valued attributes). Although beliefs and attitudes are interrelated (Fishbein & Ajzen), beliefs are primary and attitudes are secondary. Therefore, a person's beliefs about science are the source of feelings toward science, which allows such beliefs about science to contribute to the formation of his or her attitudes toward science. Attitudes engender a predisposition to respond emotionally, but beliefs do not.

Assessing Beliefs. Fishbein and Ajzen (1975) suggested that beliefs should be assessed by a uni-polar response measurement to establish the link between an object and an attribute. Once the object-attribute link is established, belief statements can be rated on a probabilistic scale (e.g., likely-unlikely) to measure belief strength. Therefore, statements evaluating the relationship between two concepts (e.g., "science" and "is relevant to everyday life") measure the student's perception regarding the strength of the given relationship. To determine if statements assess beliefs, it is recommended that each statement be prefaced with the phrase "I believe…" An example of this is, "I believe that science has ruined the environment." Such a statement represents a dimension of subjective probability relating science to an attribute ("ruined the environment"). Respondents do not establish the existence of the relationship between the concepts (i.e., this has been done already by those who designed the statement). Respondents only evaluate the proposed relationship indicating to what extent they agree ("believe") or disagree with ("do not believe") the given statement.

The semantic meanings of statements are crucial in attitudinal measures and require special attention and care. The semantic meaning of some statements used in assessing students' attitudes toward science urges students to demonstrate their knowledge about science. This knowledge may be acquired from external sources, developed by internal mental processes, or based on personal experiences. Thus, responses to such statements represent cognitive processes and not affective reactions to a target statement. In summary, if statements measure students' evaluation of the relationship between science and other objects, concepts, and attributes, then these are belief statements and should not be included in attitude toward science measures.

Methods

Data Source

Analyses of the ATS scale were conducted using data collected from the SciMo project (Schmidt & Smith, 2008). SciMo employed a variety of data-gathering techniques comprised of student surveys (including the ATS), teacher interviews, and live and videotaped classroom observations. The purpose of the SciMo project was to learn more about the daily instructional processes and procedures that contribute to high school students' engagement and achievement in science.

Sample

The sample data were derived via a stratified random sampling technique (i.e., strata were based on gender and ethnic group) that consisted of 244 U.S. public high school students (i.e., grades 9-12) from 12 suburban science classrooms in one large, diverse school in the Chicago, Illinois suburbs. Students from the sample were representative of the greater secondary student population in Illinois. The sample was comprised of 48% females (state 52%) and 52% males (state 48%). Ethnically, the sample had: 42% Latino (state 23%); 37% Caucasian (state 51%), 12% African American (state 18%), 2% Asian American (state 4%), 1% Native American (state .10%), and 6% multi-racial (state 3%) (Interactive Illinois Report Card, 2011). Finally, the sample consisted of 44% of students from the 9th grade, 19% from the 10th grade, 34% from the 11th grade, and 3% of students from the 12th grade. The unbalanced percentages between grade level sub-samples were anticipated given that science is an elective at various stages in U.S. students' high school curricula.

Instrument

Students' attitudes toward science were measured by the ATS scale (Francis & Greer, 1999). The instrument contains 20 items on a 4 point Likert scale ranging from 1 = strongly disagree to 4 = strongly agree (see Table 1). According to Francis and Greer, the 20 items of the scale were culled from an original batch of 62 science-related questions. The initial 62 questions contained items indicative of cognitive and behavioral dimensions.

Based on our reading of the literature distinguishing attitudes from beliefs, and via a close examination of the 20 items on the ATS scale, it was evident that many of the scale's items expressed belief statements that were interwoven with attitudinal statements. Initial analyses of the ATS found that the scale did not correlate with any of the outcome measures of the SciMo study and scale scores were not predictive of students' science experiences (i.e., engagement) or science course performance (i.e., final course grades). Given this outcome, we examined carefully the ATS scale seeking an explanation. We speculated that the apparent mix of attitude and belief items on the ATS might have contributed to its lack of relationship to students' science classroom experiences and outcomes.

Results and Discussion

Purposes and Methods

One purpose of this study was to use sample-based data from the ATS scale to test dimensionality to determine if the one-factor structure (i.e., attitudes) developed by Francis and Greer (1999) was a proper model fit or if the a priori, literature-based two-factor model, comprised of attitudes and beliefs, was a more appropriate fit for our sample data. The concept of model fit was operationalized via the use of fit indices indicating that one model, compared to its rival, was stable with its data, yet not perfect and assumed a reasonable amount of error, but not so error-laden as to necessitate re-specification. Once the

Table 1. Descriptive Statistics of Items on the ATS Scale Item	Mean	SD
1. Science has ruined the environment*	3.14	0.66
2. Science that is taught in school is fun and interesting	2.62	0.74
3. Science is relevant to everyday life	3.03	0.77
4. Working in a science lab would be an interesting job for me	2.22	0.93
5. Science is very important to the future of the U.S.	3.26	0.70
6. Science is difficult subject for me to learn*	2.52	0.85
7. Money spent on science is well worth spending	2.77	0.70
8. I'd like to understand more about scientific explanation for things	2.51	0.86
9. In my future career, I'd like to use the science I am learning in school	2.04	0.83
10. Studying science in school is something that I love to do	1.94	0.96
11. Science will help to make the world a better place in the future	3.02	0.69
12. I very much look forward to science lessons and activities in school	2.18	0.83
13. Science discoveries do more harm than good*	2.96	0.64
14. I don't have much interest in science*	2.49	0.94
15. Science and technology are the cause of many of the world's problems	2.83	0.68
16. Science is a school subject that I enjoy	2.34	0.88
17. The U.S. needs to have many more scientists	2.73	0.71
18. I'd seriously consider becoming a scientist when I finish school	1.57	0.67
19. I would like to study science more deeply than I do now	1.86	0.82
20. Science is difficult for me when it involves doing math*	2.82	1.00
* These items were reverse coded		

two rival models were compared via measures of fit indices, using CFA to determine how well a particular model fit the data, a second purpose of the study emerged. This purpose was to make a decision about the number of factors, and their relational properties, which supported the set of measured items for the final model chosen. Criteria for the number of factors and the structure of the solution were: (1) eigenvalues; (2) factor loadings; and (3) communality measures.

Descriptives

In terms of subject to item ratio to determine the *a priori* sample size needed to conduct a factor analysis, the literature indicates that a 10:1 ratio is desired (Costello & Osborne, 2005). The current study's ratio was over 12:1. Descriptive statistics related to the sample's responses from the 20-item instrument are seen in Table 1. None of the skew or kurtosis critical ratios (c.r.) affiliated with the variables in the model exceeded the threshold of +/- 1.96, which was an indicator of univariate normality. Further, multivariate normality was established via a multivariate kurtosis (i.e., Mardia's coefficient) c.r. value that did not exceed +/- 1.96. Lastly, none of the variables in the model had Mahalanobis Distance values that were statistically significant ($p < .05$) for the p1 or the p2 criteria; thus, indicating that there were no multivariate outliers present in the data set. Therefore, given the results from the various tests conducted pertaining to the normal distribution of the data, maximum likelihood estimation was used for the CFA (Fabrigar, Wegener, MacCallum, & Strahan, 1999).

Model Fit Indices

Model fit indices were used to determine how closely a model represented the data and also how multiple models' fit indices compared to one another. Five categories of fit indices were employed: 1) the chi-square statistic (χ^2), 2) absolute (goodness-of-fit) indices, 3) relative (goodness-of-fit) indices 4), a badness-of-fit index, and 5) comparative fit indices. The χ^2/df (degrees of freedom) ratio assesses model fit with χ^2/df values < 2 meeting a strict criterion of model fit and χ^2/df values < 5 meeting a less strict criterion. As absolute fit measures, which assess how well an a priori model fits the observed data, the Goodness of Fit Index (GFI) and the Adjusted Goodness of Fit Index (AGFI) were used. As an assessment of relative fit of the proportion improvement in fit of the target model over a baseline model, the Comparative Fit Index (CFI) and the Normed Fit Index (NFI) were employed. For these four goodness-of-fit indices, cut-off points of $\geq$ .90 and .95, respectively were established (Kline, 1998; Schumacker & Lomax, 1996). The root mean square error of approximation (RMSEA) was used as a

Table 2. Fit Indices

Model	χ^2/df	GFI	AGFI	CFI	NFI	RMSEA	AIC	BIC
One-Factor	5.26	.69	.61	.72	.71	.13	875.31	1008.20
Two-Factor	1.95	.98	.98	.96	.96	.06	371.70	508.09

Table 3. Two-Factor Model: Item Loadings and Communalities (h^2)

Item	Beliefs: Loadings	h^2
1. Science has ruined the environment	.64	.41
3 Science is relevant to everyday life	.50	.38
5. Science is very important to the future of the USA	.66	.50
7. Money spent on science is well worth spending	.67	.52
11. Science will help to make the world a better place in the future	.79	.70
13. Science discoveries do more harm than good	.45	.20
15. Science and technology are the cause of many of the world’s problems	.59	.35
17. The United States needs to have many more scientists	.56	.46
Item	**Attitudes: Loadings**	**h^2**
2. Science that is taught in school is fun and interesting	.63	.46
4. Working in a science lab would be an interesting job for me	.70	.49
6. Science is difficult subject for me to learn	.44	.20
8. I’d like to understand more about scientific explanation for things	.69	.55
9. In my future career, I’d like to use the science I am learning in school	.79	.64
10. Studying science in school is something that I love to do	.75	.58
12. I very much look forward to science lessons and activities in school	.84	.73
14. I don’t have much interest in science	.73	.54
16. Science is a school subject that I enjoy	.84	.73
18. I’d seriously consider becoming a scientist when I finish school	.78	.60
19. I would like to study science more deeply than I do now	.86	.74

badness-of-fit measure. RMSEA scores of .05, .08, and, .10 have been suggested to represent the magnitude of population misfit, where lower values < .05 indicate close model fit and higher values between .05 and .10 indicate a sliding scale of increasing, yet reasonable, error (Browne & Cudeck, 1993; Hu & Bentler, 1998). Finally, the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) were used as measures of comparative fit between the two estimated models, where the model with the lower index value is deemed the better of the two models in terms of data fit (Kenny, 2011).

One-Factor Model

Looking at Table 2, the one-factor model had a χ^2/df value = 5.26, which exceeded the threshold of < 5 and indicated that model fit was not exacting. Further, the one-factor model did not meet the suggested cut-off values (i.e., ≥ .90) for the goodness-of-fit indices: GFI (.69) and AGFI (.61) as well as the threshold (i.e., ≥ .95) for CFI (.72) and NFI (.71). For the badness-of-fit measure, the RMSEA value (.13) was well-above the suggested cut-off points of ≤ .05, .08, or .10. For the comparative measures, the AIC (875.31) and the BIC (1008.20) values were much higher (i.e., double) than those from the two-factor model. Given this trend in results, it was concluded that the one-factor model, in totality, had varied problems with model misspecification and did not fit the data and; thus, would not be pursued as a viable, correctly-specified model.

Two-Factor Model

The two-factor model had a χ^2/df value = 1.95, which was below the threshold of < 2 and indicated that model fit was present and held to a strict criterion. Additionally, the two-factor model had goodness-of-fit indices values for GFI (.98), AGFI (.98), CFI (.96), and NFI (.96) that all exceeded the suggested cut-off points of ≥ .90 and .95, correspondingly. The RMSEA value (.06) was ≤ .08, which was in the middle of the suggested array of threshold values (i.e., ≤ .05, .08, or .10). The AIC (371.70) and the BIC (508.09) values were half of the size of the values found in the one-factor model. Lastly, the vast majority of the standardized residual covariances were less extreme than +/- 1.96 (i.e., they were small) and; thus, the reproduced (implied) covariance matrix was close to the original (observed) covariance matrix suggesting that the model fit the data well.

Regarding the entire model findings, results from Table 2 suggested that the two-factor model fit the data well, when compared to the one-factor model, and should be pursued further with the current CFA analysis. To be sure, it was evident that all of the fit indices for the two-factor model surpassed the suggested threshold values, which signified a model that incorporated only minimal specification error. Though, as is often the case with sets of guidelines provided in social science research, such as effect size measures, threshold values used with indicators of the goodness- or the badness-of-fit for a model serve as suggestions only and should be understood and evaluated as evidence of model fit, or lack thereof, within the context of the totality of data presented, which is examined below.

CFA

A CFA of two relatively uncorrelated factors (see Costello & Osborne, 2005 for a discussion that almost all factors in social science research are related to some degree) was hypothesized from the literature and employed to observe the structure and loadings of the proposed two-factor model. Based on eigenvalue data, two interpretable factors emerged: attitudes toward science and beliefs about science. The attitudes factor accounted for 38.62% of item variance and the beliefs factor accounted for 12.94% of item variance or 51.56% for the entire two-factor solution. Eleven items comprised the attitudes factor while eight items constituted the beliefs factor (see Table 3). There was one item (question 20) associated with the original 20-item scale that was not retained as a viable measure affiliated with the two-factor solution because its factor loading was extremely low (.12) and did not meet the a priori threshold of □ .40 for item salience (Ford, MacCallum, & Tait, 1986).

Data from Table 3 indicated that the 19 coefficients for the two-factor solution ranged from a low of .44 to a high of .86 with an average of .68. Comprehensively, 100% of the ATS's items had a coefficient ≥ .40 for item salience (Costello & Osborne, 2005; Tabachnick & Fidell, 2001), which indicated that all of the scale's items contributed, via a sufficient range of magnitude, to each of the two factors. The coefficients for the attitudes factor ranged from .44 to .86, with an average of .73. The coefficients for the beliefs factor ranged from .45 to.79 with an average of .61. Thus, both of the factors in the orthogonal two-factor solution exhibited moderate to high loadings.

Further, communalities (h^2), which are the proportion of each item explained by a factor, were computed and indicated typically observed magnitudes in social science research of between .30 to .70 per factor (i.e., 17 out of 19) without marginal cross-loadings on the other factor (Costello & Osborne, 2005). The overall two-factor solution's communalities ranged from .20 to .74 with an average of .51. The attitudes factor had h^2 values ranging from .20 to .74, with an average of .57. The beliefs factor had h^2 values ranging from .20 to .70 with an average of .44. Individually, item 19 had the highest h^2 value = .74 and both items 6 and 13 had the lowest h^2 = .20.

Reliability

Items from the ATS scale were examined by computing internal consistency estimates of reliability via Cronbach's alpha coefficient (α) with 95% confidence intervals (CI) (cf. Fan & Thompson, 2001). A recommended cut-off value for score reliability derive from survey research and/or used in applied settings is α ≥ .80 (Henson, 2001; Nunnally, 1978). The score reliability for the entire scale was α = .90 (CI = .88, .92) and for the two subscales comprised of attitudes was α = .92 (CI = .90, .93) and beliefs was α = .80 (CI = .76, .84), which signified that there was high internal consistency and the items that comprised each factor shared a large percentage of the variance.

Discussion

The present study determined, through a confirmatory factor analysis, that the ATS scale assessed both high school science students' attitudes toward and their beliefs about science. The results demonstrated that the ATS should not be considered uni-dimensional in terms of items' content, as Francis and Greer (1999) reported, but as a multi-dimensional structure consisting of two factors:

attitudes toward science and beliefs about science. Because students' attitudes toward and beliefs about science represent theoretically distinct psychological variables, these constructs should be assessed independently. That is, the semantic meanings of scale items such as "I very much look forward to science lessons and activities in school" (i.e., attitude) and "Science is very important to the future of the U.S." (i.e., belief), serve to trigger at least two independent notions in students' minds (e.g., science in school as behavior and the value of science for the society). Therefore, students' responses tend to represent the evaluation of two distinct concepts. While the former concept measures their attitudes toward the science-related activities they experience at school, the latter measures their beliefs about the nature and value of science in general.

The findings derived from this study are consistent with Fishbein and Ajzen's (1975) expectancy-value model of attitudes. An expectancy-value model assumes that when an individual has to make a behavioral choice, he or she will select the alternative that has the highest subjective expected value. Additionally, this model choice explains the beliefs-attitudes relationship in the sense that a student's attitude toward an object is a function of his or her belief about the object's attributes and evaluation of those attributes. According to the current study's two factor model, students' attitudes toward science appeared to be influenced by their beliefs that evaluated the nature and value of science in society. The results of the present study; however, suggest that students with positive beliefs about science are likely to have positive attitudes toward science learning. Thus, it is desirable for science educators to attempt to instill strong positive beliefs about science among students. Such positive beliefs may then yield more positive attitudes toward science. As a result of holding more positive attitudes, students' motivation to learn science may be enhanced and their subsequent achievement improved. There is evidence that certain curricular approaches to science, such as inquiry-based learning, have positive benefits to students' attitudes, motivation, and achievement over time (Gibson & Chase, 2002).

Additionally, the present investigation has implications for studying and understanding students' beliefs regarding science. Researchers and educators should direct their attention to students' beliefs about science. This is important because beliefs represent, in part, students' knowledge about the subject as well as their opinions related to the importance of the topic. Hopefully, science instruction conveys to students that science is important to understand. Further, examining the relationships between students' beliefs about science and their academic achievement in this area, as well as their likelihood of pursuing a science major in college and a science-based career, is important because beliefs may highly correlate with students' behaviors. That is, students may elect to pursue science-based careers because they believe that science is an important endeavor to undertake and has great value to society (Bryan, Glynn, & Kittleson, 2011; Menis, 1989).

In connection to the current research, a number of recent studies have assessed secondary school students' beliefs about science. These investigations have focused on students' epistemological beliefs and science learning (Conley, Pintrich, Vekiri, & Harrison, 2004; Sandoval, 2003); level of involvement in science as a transformative experience (i.e., engagement) encompassing cognitive, affective, and behavioral domains (Pugh, Linnenbrink-Garcia, Koskey, Stewart, & Manzey, 2010; also, see Van Aalderen-Smeets et al., 2011 for a proposed model comprised of affective, cognitive, and control domains from the perspective of teacher-based attitudes toward teaching science); curriculum re-designs predicated on the employment of project-based applications and discussions with students (Alozie, Moje, & Krajcik, 2010); the relationship between students' science self-efficacy and their science achievement (Bryan et al., 2011); and, the role of science and technology in students' educational experiences (Jenkins & Pell, 2006; Sjoberg & Schreiner, 2006). Thus, it is clear that educational programs and practices, which highly correlate with students' beliefs about science -- either by design or unintentionally -- bear greater scrutiny to determine how these programs and practices affect changes in students' science beliefs.

Limitations

The present study had at least two limitations. First, generalization of these results to a larger secondary school population throughout the United States should be done with caution because the study's sample was derived from a single school in Illinois, which may not be entirely representative of the U.S. high school population. Second, attitudes and beliefs were not observed directly; instead they were gathered as self-reports through surveys, an approach which can lend itself to perceptional bias and possibly threaten, to some extent, the validity of the data.

Future Research

Further research examining the within-and out-of-school factors that have relationships with both student's attitudes toward and beliefs about science is warranted. It is recommended that science educators and researchers investigate students' beliefs about science as distinct from their attitudes toward science. Students' beliefs about science have been neglected somewhat in the literature as more studies have focused on teachers' beliefs about science (Atwater, Gardner, & Kight, 1991; Bryan & Atwater, 2002; Gess-Newsome, 1999; Lumpe, Haney, & Czeniak, 2000).

Studies should continue to investigate factors that relate to students' beliefs about science as well as their attitudes toward science. Also, further study should ensue concerning students' attitudinal influences on their science-based motivations and connections to learning and behavior (see Simpson et al., 1994, for an accessible introduction), with the goal of the aforementioned areas and how these factors may differentially influence and/or predict science achievement and students' desires to pursue science careers. Finally, when employing the ATS, it is reasonable to suggest that items 6 and 13, which had quite low communality values that were below the literature-based threshold and also had item salience values just above its defined threshold, should be discarded from the ATS as incongruent items with the rest of the scale that do not help manifest either constructs of attitudes or beliefs, respectively.

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