Development and Initial Validation of the Beliefs About Reformed Science Teaching and Learning (BARSTL) Questionnaire

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This article describes the development and the initial validation of an instrument that can be used to assess teachers' beliefs about science teaching and learning. The instrument, which is called the Beliefs About Reformed Science Teaching and Learning (BARSTL) questionnaire, draws on the current national science education reform efforts in order to define a traditional-reformed teaching and learning belief continuum that can be used to map teachers' beliefs. The reliability and validity of the instrument were examined using a multiple perspective approach. The psychometric properties of the BARSTL suggest that it is a valid and reliable instrument for measuring prospective elementary teachers' beliefs about science education.

Introduction

Teacher beliefs are a key to understanding and reforming science education (Crawford, 2007; Jones & Carter, 2007). A teacher's beliefs about science, learning, and science teaching influence virtually every aspect of their practice because beliefs serve as filters through which actions are viewed and decisions are made. The actions, decisions, and experiences of teachers, however, also shape their beliefs. Thus, measuring and understanding the beliefs of teachers, both preservice and in-service, remains a critical facet in the process of engendering reform in science education. The overall goal of this study, therefore, was to develop and validate an instrument that can be used by researchers and science teacher educators to identify teachers' beliefs about the teaching and learning of science and the degree to which these beliefs are consistent with the philosophy that underlies the current reform movement in science education. In this article, we present the results of this project and the new instrument, which is called the Beliefs About Reformed Science Teaching and Learning (BARSTL) questionnaire.

Theoretical Framework

Current reform efforts in science education can be traced to the publication of *Project 2061: Science for All Americans* (American Association for the Advancement of Science [AAAS], 1989) and the *National Science Education Standards* (National Research Council [NRC], 1996). These two seminal publications provided the foundation for the creation of two more crucial accompanying documents in *Benchmarks for Scientific Literacy* (AAAS, 1993) and *Inquiry and the National Science Education Standards* (NRC, 2000). Although many reform documents have been published, this collection of books remains the referents to which others are compared. Across the country, state and local science education syllabi have been created to mirror these standards. More recently, as high-stakes testing has become common at the state level, standards such as these have increasingly become the criteria against which student performance is judged.

A Reformed View of Science Teaching and Learning

The philosophical and theoretical rationale that underlies this reform movement is constructivism. Although there are a wide variety of epistemological and ontological stances at play within current conceptions of constructivism, this philosophy is characterized by an assumption that "knowledge is not transmitted directly from one knower to another, but is actively built up by the learner" (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p. 5). Each of us generates our own "rules" and "mental models," which we use to make sense of our experiences and develop our own understanding of the world. Learning, therefore, involves adjusting a current understanding in order to accommodate new experiences. Learning science from a constructivist perspective is an active, social process of making sense of experiences and "is something students do, not something that is done to them" (NRC, 1996, p. 22).

In addition to providing a philosophical foundation for the learning of science, the *National Science Standards* also outlined recommendations for the teaching of science and for the preparation of science teachers. There is an overarching demand in the standards that "teaching should be consistent with the nature of scientific inquiry" (AAAS, 1989, p. 147). In other words, good science teaching should (a) start with questions about nature, (b) engage students actively, (c) concentrate on the collection and use of evidence, and (d) not separate knowing from finding out (NRC, 1996, p. 30). From this perspective, “hands-on activities are not enough—students also must have ‘minds-on’ experiences” (p. 24). This type of instruction requires teachers to provide opportunities for students to “explain and justify their work to themselves and to one another” (NRC, 1996, p. 33) and “assess the efficacy of their efforts—they [must learn to] evaluate the data they have collected, re-examining or collecting more if necessary, and making statements about the generalizability of their findings. They plan and make presentations to the rest of the class about their work and accept and react to the constructive criticism of others” (NRC, 1996, p. 33).

Clearly, teaching in a way that is consistent with the *Project 2061: Science for All Americans* and the *National Science Education Standards* requires education in new ways of working with children that go far beyond simple notions of teacher as a transmitter of knowledge (Minstrell & van Zee, 2000). Teacher characteristics based on reform-minded ideas reposition the teacher as a facilitator that “models the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science” (NRC, 2000, p. 22). Reform-oriented teachers work to have their students construct their knowledge and understanding through more inquiry-based activities that engage students in learning communities where the ideas and thinking of others are shared and valued.

The social aspects of knowledge construction are further supported in the reform documents through a privileged focus on understanding the nature of science knowledge, including how scientific concepts are developed and applied. “The study of science as an intellectual and social endeavor—the application of human intelligence to figuring out how the world works—should have a prominent place in any curriculum that has science literacy as one of its aims” (AAAS, 1993, p. 3). Teachers in reform-oriented classrooms work to highlight the characteristics of scientific knowledge, including the benefits of its development over time and the limits of its applications.

Indeed, emphasizing the nature of science as a way of knowing the world can also facilitate teachers’ ability to focus on broader organizing science concepts that can engender student inquiries and less on vast assemblages of facts and formulas. Reform documents suggest that “we must reduce the sheer amount of material now being covered” (AAAS, 1993, p. XI), which emphasizes shallow learning associated with traditional views by placing “a premium on the ability to commit terms, algorithms, and generalizations to short-term memory and impedes the acquisition of understanding” (AAAS, 1993, p. XII).

These reform documents (AAAS, 1993; NRC, 1996) suggest a philosophical shift in the way science teaching and learning is perceived and enacted. Moving toward the visions of teaching and learning described in reform documents necessitates fundamental changes in teachers’ understandings of the dynamics of how people learn and how that should influence and shape the manner in which lessons are designed and implemented. These modifications necessitate an accompanying shift in defining important characteristics of both the teacher and the learning environment. Finally, reform visions of science teaching and learning emphasize a critical understanding of the nature of science as a way of knowing. These areas, which are targets for change in reform efforts, can serve as benchmark categories for tools that aim to understand how science teachers’ interpret and adopt the notions of reform.

Teachers’ Beliefs About the Teaching and Learning of Science: Are They Consistent with the Philosophy of the Current Reform Movement?

Current research indicates that teacher beliefs about students and student learning, the nature of science, student outcomes, and the role of the teacher in the classroom are all elements of teacher beliefs systems that can have significant influence on how teachers teach. For example, Feldman (2002) conducted a case study of two high school physics teachers’ incorporation of a reform-minded physics curriculum (minds-on physics [MOP]). He found that the teachers’ beliefs of their role in their students’ education were a contributing factor in their implementation of the curriculum. One teacher (Mr. Jones) believed his role, and the role of his course, was to prepare students to be critical thinkers and problem solvers, whereas the other teacher (Mr. Smith) believed his role, and the role of his physics course, was to promote interest in physics and possible future study of the topic. As a result of these beliefs, the teachers implemented the MOP curriculum in very different ways. Mr. Jones adopted the curriculum and used it on a daily basis, whereas Mr. Smith used it sparingly and eventually abandoned it for not aligning well with his beliefs of the role of his course. In the case of Mr. Jones, his beliefs were inline with the developers of the reform-minded curriculum, thus he found that the curriculum was useful for achieving his desired outcomes for his students. However, Mr. Smith had different beliefs about his role in the education of his students, and the MOP curriculum was not adequate for meeting his needs. This study suggests that a teacher's beliefs about teaching and learning can impact their implementation of reform-based curricula, and a teacher may not adopt a curriculum if his or her beliefs are not aligned with the beliefs of curriculum developers.

Although many teachers readily participate in state and national professional development opportunities and have collaborated enthusiastically with university-based researchers to improve their own science learning and teaching, implementing reform-based pedagogy in the classroom continues to be problematic (Lotter, Harwood, & Bonner, 2007; Luft, 2007; Luft, Roehrig, & Patterson, 2003). It has been shown, for example, that teacher beliefs about the need to cover the mandated curriculum are so strong that science teachers subvert reform-oriented curriculum, yet claim publicly that they are teaching it (Olson, 1981; Yerrick, Parke, & Nugent, 1997). Clearly, current studies confirm that teacher beliefs about the teaching and learning of science, the mandated curriculum, and the role of the teacher can impede and "filter" innovative practice suggested by professional development (Huberman & Middlebrooks, 2000; Munby, Cunningham, & Lock, 2000; Yerrick et al., 1997). Therefore, identifying and understanding the beliefs of teachers is critical to the process of educational reform (Bybee, 1993; Haney, Czerniak, & Lumpe, 1996).

Educational reform efforts privilege constructivist views of teaching and learning, and thus emphasize a shift in teachers' beliefs and practices toward these views. Yet, as described earlier, teacher beliefs and the underlying philosophies of reform efforts are often not well aligned. Kagan (1992), e.g., notes that several empirical studies have demonstrated that teacher beliefs (a) are stable and resistant to change, (b) act as a filter through which they interpret teaching events, and (c) reflect the nature of instruction the teacher provides to students. Some science teacher educators, as result, assume that the beliefs of teachers have a linear and one-way influence on the practice of teachers (Pajares, 1992). However, recent research has demonstrated that the relationship between teachers' beliefs and practices involves reciprocal influences on each other (Crawford, 2007; Smith & Southerland, 2007).

Smith and Southerland (2007), for example, examined the complex nature of the relationship between teacher beliefs and practice in light of the science education reform efforts. The case studies of two teachers crafted in this work highlight the interaction between teachers' own views and practice with the externally imposed reform efforts. Although both teachers held relatively positive, constructivist views of learning, these beliefs only partially shaped their interpretation of reform efforts coming from the national, state, and district levels. Contextual factors specific to these teachers were seen to play a more influential role in shaping these interpretations, and the resulting practices observed. The findings suggest a dialectical connection between teacher beliefs and practice, one where a teachers' practice bound by context provides substantial force in shaping their fundamental beliefs about science learning and teaching, as well as those beliefs determining the science teaching enacted in their classrooms and their response to external forces of reform. Smith and Southerland also note the influential role of teacher preparation programs in shaping these fundamental beliefs about science learning.

Research Questions

In light of this literature, the ability to ascertain teachers' beliefs about teaching and learning and then understanding any potential changes in those beliefs is a critical element to engendering meaningful reform in science education. Insights into both preservice and in-service teachers' beliefs can help inform teacher education and professional development in creating more fruitful experiences for these professionals, helping them to align their beliefs and practice more with the desired constructivist visions of current reform efforts. The development of an instrument that researchers, professional development designers, and teacher educators can use to identify and monitor changes in teacher beliefs, therefore, is important to the field. Thus, the guiding question of this study was, is it possible to develop an instrument that can provide a valid and reliable measure of the alignment of teachers' beliefs about science teaching and learning with the notions championed in the current science education reform literature?

Method

The BARSTL questionnaire was designed as a survey instrument that can be used to assess the degree to which science teachers' beliefs about the teaching and learning of science are aligned with the current reform movement in science education (AAAS, 1993; NRC, 1996). The design of the BARSTL is based on the assumption that teachers with different beliefs about the teaching and learning of science will respond to statements describing either reformed or traditional perspectives about science education differently. These perspectives, or frameworks, can be thought of as the two end points of a continuum on which teachers' beliefs about teaching and learning can be

Table 1

Dimensions of Traditional and Reformed Minded Beliefs Associated With Each Subscale of the BARSTL

BARSTL Scales	Traditional Perspective	Reformed Perspective
How people learn about science	Compared with "blank slates" Learning is accumulation of information	What students learn is influenced by their existing ideas. Learning is the modification of existing ideas.
Lesson design and implementation	Teacher-prescribed activities Frontal teaching—telling and showing students Relies heavily on textbooks and workbooks	Student-directed learning. Relies heavily on student-developed investigations, manipulative materials, and primary sources of data.
Characteristics of teachers and the learning environment	The teacher acts as a dispenser of knowledge Focus on independent work and learning by rote	The teacher acts as facilitator, listener, and coach. Focus on learning together and valuing others ideas and ways of thinking.
The nature of the science curriculum	Focus on basic skills (foundations) Curriculum is fixed Focus on breadth over depth	Focus on conceptual understanding and the application of concepts. Curriculum is flexible, changes with student questions and interest. Focus on depth over breadth.

mapped, providing an insight into teachers' views of how science should be taught and identifying possible barriers to the integration of constructivist-based reform into school science.

Design of the BARSTL Questionnaire

The BARSTL consists of 32 items which are divided into four subscales: (a) how people learn about science, (b) lesson design and implementation, (c) characteristics of teachers and the learning environment, and (d) the nature of the science curriculum. Each subscale consists of eight items. Four of these items are worded to be consistent with a reformed perspective of science education, while the remaining four are designed to represent a traditional perspective. Teachers indicate the degree to which they agree or disagree with each of these items using a Likert-type response scale. The items that represent a reformed perspective of science education are scored as 1, 2, 3, and 4, respectively, for the responses: strongly disagree, disagree, agree, and strongly agree, while the items that represent a traditional perspective are scored in reverse. Thus, possible scores range from 32 to 128 points, with higher scores reflecting beliefs that are more consistent with the current reform movement in science education (AAAS, 1993; NRC, 1996).

Development of the BARSTL

The method that we followed in developing the BARSTL began with the definition of the construct to be assessed and continues through item pool preparation, item refinement, and selection based upon field test data, and concludes with a study of the instrument's reliability and validity (Borg & Gall, 1989; Nunally, 1970; Rubba & Anderson, 1978). The seven-step plan described later was used in developing and building validity and high reliability into the BARSTL. Details on steps 6 and 7 of the instrument development, including supporting data, are provided in the result section.

Step 1: Defining the constructs to be measured. A construct, according to Borg and Gall (1989), "is a concept that is inferred from commonalties among observed phenomena and that can be used to explain those phenomena." The BARSTL is designed to assess the construct, *reformed beliefs about science education*. This construct refers to the remembered experiences, feelings, subjective evaluations, presumptions, and intuitive theories about teaching and learning that teachers hold in regard to the teaching and learning of science. In order to define this construct, we relied heavily upon research in science education and on the national standards documents in order to define the characteristics of the current reform movement in science education and to provide a philosophical and theoretical foundation for the BARSTL.

The professional literature dealing with science education reform in the United States (AAAS, 1993; NRC, 1996) was used to generate a content matrix that was used to define the content of the BARSTL in terms of the construct, *reformed beliefs about science education*, measured on four dimensions: (a) how people learn, (b) lesson design and implementation, (c) characteristics of teachers and the learning environment, and (d) the nature of the science curriculum. Table 1 presents the content matrix that was used in this study to define the content for the BARSTL in terms of the reformed beliefs construct, the dimensions of the construct adopted by the researchers, and the reformed verses traditional phrasing of Likert-type items. This content matrix was then used to develop the four subscales and to help ensure the content and construct validity of the BARSTL.

Step 2: Development of items for the questionnaire. For the first iteration of the BARSTL, the authors generated a list of 40 statements to represent teachers' beliefs about science education based on the content matrix. These initial statements were written based on recommendations made by Edwards (1957) to reduce item error because of ambiguity. These statements were then organized into the four subscales. Each subscale consists of 10 statements, five of which are worded to represent beliefs that are consistent with the current reform movement and five are designed to represent the traditional standpoint.

Step 3: Evaluation of items for clarity and comprehension. The 40 draft items, a letter that explained the review process, Edwards' (1957) criteria, and the definitions of a reformed perspective on science education and a traditional perspective were submitted to five doctoral students in science education. Based on this information, the doctoral students independently reviewed each of the draft items for clarity and comprehension by teachers. Comments for improvement were recorded directly on the draft items. The feedback was collected by the researchers and used to revise the items. The revised items were then resubmitted to the doctoral students and subsequently refined until all the five doctoral students judged that adequate clarity and comprehension was achieved for all the five items in each cell of the content matrix.

Step 4: Evaluation of the construct validity of the BARSTL items and the content validity of the subscales. According to the Standards for Educational and Psychological Testing, construct validity is the extent to which a particular test can be shown to measure a hypothetical construct, that is, "a theoretical construction about the nature of human behavior" (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 1985), while content validity is "the degree to which the sample of test items represent the content that the test is designed to measure" (Borg & Gall, 1989, p. 258). A seven-person panel composed of three professors of science education and four doctoral students in science education was created for the purpose of judging the construct validity of the 40 BARSTL items and content validity of the subscales.

Each member of the panel was given a letter of explanation, the revised items, and the definitions of terms used within the instrument. Individuals were then asked to independently evaluate each item using a Likert-type response scale. The items were scored as 1, 2, 3, and 4, respectively, for the responses: strongly traditional, traditional, reformed, and strongly reformed. Items that did not discriminate between a reformed and traditional perspective adequately were either dropped from the BARSTL or changed.

Table 2
Mean and Standard Deviation Scores for the Content Validity of Each Subscale as Ranked by the Review Panel (N = 7)

Content Validity of the Subscale*	Mean	Standard Deviation
How people learn	3.57	.53
Lesson design and implementation	3.29	.76
Teachers and the learning environment	3.43	.79
The science curriculum	3.29	.76

* 1 = content invalid, 2 = content valid with major revisions, 3 = content valid with minor revisions, 4 = content valid.

These individuals were also asked to evaluate independently the content validity of the subscales using a Likert-type response scale. The subscales were scored as 1, 2, 3, and 4, respectively, for the responses: content invalid, content valid with major revisions, content valid with minor revisions, and content valid. Table 2 shows the mean and standard deviation of each subscale. Panel members were encouraged to offer recommendations for revisions to improve content validity if needed. This independent feedback was used to revise or rearrange the items within each subscale as necessary in order to ensure content validity.

Step 5: First draft evaluation of the BARSTL. The BARSTL was then administered to a group of prospective elementary teachers enrolled in five different sections of a course called Elementary Science Methods, Management and Assessment that was offered at a large university located in the southwest United States (N = 104). These individuals represented one of the intended populations for the final instrument. Of the 104 questionnaires administered, nine were removed from the sample because they were either incomplete, or the participant chose to respond to every question using the same number. The data obtained from administering the BARSTL to the five sections of the course were used in formulating the final version of the BARSTL as described in step 6.

Step 6: Revision of the BARSTL. The data obtained from administering the first draft of the 40-item BARSTL in the methods course were used to identify the items to be included in the final instrument. The following guiding question was developed for this purpose:

> What is the most reliable and valid combination of items to compose the BARSTL for the purposes of assessing prospective elementary teachers' beliefs about the teaching and learning of science?

The question implied the need for the researchers to examine the contribution each item made to (a) the reliability and (b) the construct validity of the subscales using data from the first draft evaluation of the instrument (step 5). Item score to total test score correlation and item contribution to total test reliability were used to identify the strongest items. Coefficient alpha, a measure of internal consistency, was also used to examine the reliability of the instrument. Data from the first draft evaluation were then analyzed using exploratory factor analysis and the factor properties examined for evidence of construct validity. Ideally, four major factors would emerge: (a) beliefs about learning, (b) beliefs about lesson design and implementation, (c) beliefs about the characteristics of teachers and the learning environment, and (d) beliefs about the science curriculum. The strongest combination of construct valid and reliable items that had balanced representation from the content matrix was identified using these procedures in combination and was arranged to form the BARSTL.

Step 7: Second validity and reliability evaluation of the BARSTL. The BARSTL was then administered to another group of prospective elementary teachers enrolled in seven different sections of the course, Elementary Science Methods, Management and Assessment (N = 146). These individuals, once again, represent one of the intended populations for the final instrument. The data obtained from administering the BARSTL in these sections of the methods course were used to make the judgments concerning the validity and reliability of the BARSTL reported in the results section.

Results

In this section, we describe the results of our efforts to investigate and document the reliability and validity of the BARSTL using a multiple perspectives approach.

Reliability of the BARSTL

Two internal consistency estimates of reliability were computed for the BARSTL: a split-half coefficient expressed as a Spearman-Brown corrected correlation and coefficient alpha. For the split-half coefficient, the scale was split into two halves such that the two halves would be equivalent as possible. In splitting the items, we took into account the sequencing of the items as well as if they were worded to represent a traditional or reformed perspective of science education. The value of the split-half coefficient was .80, and the value of coefficient alpha was .77, indicating that the BARSTL has satisfactory internal consistency (DeVellis, 2003).

Validity of the BARSTL

Validity, as noted earlier, can be defined as "the degree to which an instrument measures what it purports to measure" (Borg & Gall, 1989, p. 258). The Standards for Educational and Psychological Testing (AERA-APA-NCME, 1985) states that validity "refers to the appropriateness, meaningfulness, and usefulness of the specific inferences made from test [instrument] scores" (p. 9). The American Psychological Association has defined guidelines for determining instrument validity and has identified four types of instrument validity: content, construct, concurrent, and predictive (Borg & Gall, 1989). Two of these measures of validity, content and construct, are the focus of this analysis.

Content validity. As previously mentioned, the BARSTL was developed to reflect the philosophical and theoretical rationale that underlies the current reform movement in science education. The content of BARSTL draws on four major sources: (a) the National Science Education Standards (NRC, 1996), (b) Inquiry and the National Science Education Standards (NRC, 2000), (c) Project 2061: Science for All Americans (AAAS, 1989), and (d) Benchmarks for Scientific Literacy (AAAS, 1993). These documents provide the theoretical framework of the BARSTL and define the content for each of the subscales (how people learn, lesson design and implementation, teachers and the learning environment, and the science curriculum).

Content validity refers to the degree to which the sample of test items represents the content that an instrument is designed to measure (Borg & Gall, 1989, p. 258). In order to ensure the BARSTL has adequate content validity, we had a panel of experts evaluate the items included in each subscale (how people learn, lesson design and implementation, characteristics of teachers and the learning environment, and the science curriculum). This panel rated all four subscales as having good content validity (see Table 2). The Likert-type items that are phrased in a way that is consistent with a reformed perspective and the items that are phrased to be consistent with a more transitional perspective are also distributed evenly throughout the instrument. Recall that the task in step 6 of the BARSTL development process (see, method section) was to identify a subset of items that (a) had high internal consistency and reliability and (b) is representative of the content matrix from the pool of items that had been judged

Table 3
Items Associated with Each Scale of the BARSTL

BARSTL Scales	Item Allocation			
How people learn about science				
Reformed perspective	1	2	5	8
Traditional perspective*	3	4	6	7
Lesson design and implementation				
Reformed perspective	9	10	13	14
Traditional perspective*	11	12	15	16
Teachers and the learning environment				
Reformed perspective	17	19	20	24
Traditional perspective*	18	21	22	23
The science curriculum				
Reformed perspective	25	28	30	32
Traditional perspective*	26	27	29	31

* Items that refer to a traditional perspective of science education are scored in reverse.

Table 4
Subscales as Predictors of the Total Score on the BARSTL

BARSTL Subscale	R^2 as a Predictor of the Total
Subscale 1: How people learn	.64*
Subscale 2: Lesson design and implementation	.64*
Subscale 3: Teachers and the learning environment	.63*
Subscale 4: The science curriculum	.47*

* $p < .001$.

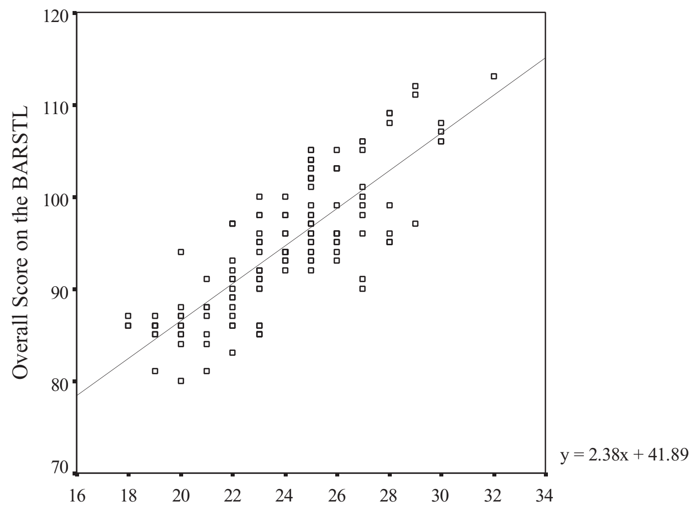

Figure 1. Subscale 2: lesson design and implementation as a predictor of the total score ($R^2 = .64$).

as construct valid. Because these two qualities can be antithetical to one another, that is, the most construct valid and reliable set of items might not be representative of the content matrix: These statistical techniques were applied multiple times and in combination to help select items for the BARSTL that gave the instrument the strongest profile across both qualities. Table 3 presents the final allocation of items that were used to ensure content validity of the BARSTL.

While content validity is a helpful characteristic, it is no means sufficient. Indeed, it can even be misleading in some situations. Construct validity is a critical kind of validity that an instrument such as the BARSTL must possess. Without high construct validity, high reliabilities and strong content validity can be meaningless.

Construct validity. Construct validity refers to the theoretical integrity of an instrument. The interrelationships among the constructs in the instrument should give rise to the empirical correlations that mirror the theoretical coherence. Because the BARSTL is a quantitative measure of the degree to which a teacher's beliefs about teaching and learning is in accord with the current science education reform movement, each of the dimensions measured by the subscales should be positively correlated to each other because they are measuring different aspects of the same theoretical framework. Thus, it would be expected that although the BARSTL consists of four different subscales, underlying each of these subscales would be a single construct of reformed beliefs about science education.

To test this hypothesis that reformed beliefs about science education is the single underlying construct in the design of the BARSTL, a correlation analysis was performed on each on the four subscales. Each subscale was used to predict the total score. High R^2 values would support this hypothesis, whereas low R^2 values would serve to reject it. Therefore, because the construct validity of each item on the BARSTL had already been established, support for this hypothesis would constitute support for the overall construct validity of the instrument. Table 4 provides the R^2 values for each subscale as a predictor of the total score. As can be seen, the R^2 values are high. This offers strong support for the construct validity of the BARSTL.

Because subscale 2 has the highest R^2 as a predictor of the total BARSTL score, a scatter plot of the prediction is shown in Figure 1 to provide a visual indicator for the overall coherence underlying the relationship between the subscale (beliefs about teachers and the learning environment) and the total score on the BARSTL (reformed beliefs about science education). Overall, these results suggest that the four subscales are good predictors of the overall score.

The construct, reformed beliefs about science education, produces an internal coherence across the 32 items and the four dimensions of the construct as measured by each of the subscales. In conclusion, this analysis suggests that the BARSTL has good construct validity.

To test the hypothesis that the BARSTL measures four dimensions of the underlying construct, reformed beliefs about science education, an exploratory factor analysis was conducted on the 32 items that make up the BARSTL using the data from the 146 respondents. Three criteria were used to determine the number of factors to rotate: The *a priori* hypothesis that the measure was multidimensional, a scree test, and the interpretability of the factor solution. Based on the scree plot, four factors were extracted using principle component analysis and rotated using a Varimax rotation procedure. The rotated solution yielded four interpretable factors. These four factors accounted for 39.52% of the item variance. Factor 1 accounted for 14.06% of the variance, factor 2 accounted for 11.65%, and factor 3 and 4 accounted for 7.59% and 6.22%, respectively. Six of the 32 items loaded on more than one factor. This analysis supports the expectation that the BARSTL measures four dimensions of the construct, reformed beliefs about science education.

A further examination of the construct validity of the BARSTL was conducted using the results of the exploratory factor analysis. The objective of this analysis was to define the dimensions underlying the BARSTL in order to ensure that the items were arranged into the subscales appropriately based on both expert opinion and perspective of the participants. To do this, a decision rule was adopted for this analysis that accepts as meaningful any factor loading greater than .30. A coefficient of .30 reflects an amount of variance shared between an item and a factor of approximately 10% (Piburn et al., 2000).

Using this procedure, the most factorially distinct group contains seven items, all with loadings greater than .30 on factor 1 and less than .30 on the other three factors (Table 5). These items are not from a single subscale on the BARSTL. Six items (1, 2, 5, 6, 7, and 8) come from the subscale, how students learn, while the remaining item (14) comes from, lesson design and implementation. These items either refer to the knowledge students bring with them to the classroom (1, 5, and 7), the learning process (2, 6, and 8), or the importance of students having an opportunity to “test, debate, and challenge ideas with their peers.” This analysis suggests that these items measure preservice teachers’ beliefs about how people learn about science and that subscale 1 was arranged appropriately based on the perspective of the participants.

Table 5
Correlations Between the BARSTL Items and the Four Factors

Item #	From the Subscale	Factor 1	Factor 2	Factor 3	Factor 4
1†	How people learn	.56			
2†	How people learn	.39			
5†	How people learn	.64			
6*	How people learn	.61			
7*	How people learn	.68			
8†	How people learn	.42			
14†	Lesson design and implementation	.41			
4*	How people learn		.55		
10†	Lesson design and implementation		.54		
20†	Teachers and the learning environment		.44		
22†	Teachers and the learning environment		.43		
23*	Teachers and the learning environment		.70		
24*	Teachers and the learning environment		.47		
29*	Science curriculum		.55		
3*	How people learn			.31	
21*	Teachers and the learning environment			.43	
25†	Science curriculum			.75	
27*	Science curriculum			.54	
31*	Science curriculum			.53	
32†	Science curriculum			.75	
9†	Lesson design and implementation				.64
12*	Lesson design and implementation				.51
15*	Lesson design and implementation				.54
16*	Lesson design and implementation				.65
18*	Teachers and the learning environment				.35
19†	Teachers and the learning environment				.43
11*	Lesson design and implementation		.48		.50
13*	Lesson design and implementation	.46			.47
17†	Teachers and the learning environment		.35	.57	
26*	Science curriculum	.39	.44		
28†	Science curriculum	.34		.45	
30*	Science curriculum	.45		.39	

* Items worded to reflect a traditional perspective.
† Items worded to reflect a reformed perspective.

The next set of items consists of seven statements with loadings greater than .30 only on factor 2 (Table 5). These items are also not from a single subscale on the BARSTL. One item comes from the subscale how students learn (4); one comes from lesson design and implementation (10), four from teachers and the learning environment (20, 22, 23, and 24), and one from the science curriculum (29). There seems to be a single unifying theme among these items—the role of the teacher in the classroom. Items 20, 22, 23, and 24 all describe what “teachers should do” in one way or another, and item 4 states that "Students are more likely to understand a scientific concept if the *teacher* explains the concept in a way that is clear and easy to understand." Item 29 is also consistent with this theme because it describes the importance of "preparing students for future classes, college, or career." This analysis suggests that these items measure teachers' beliefs about the characteristics of the teacher and the learning environment when viewed from the perspective of the participants in this study.

The next factorially distinct group consists of six items that load only on factor 3 (Table 5). One of these items (3) came from how people learn, one from teachers and the learning environment (21), and four from the science curriculum (25, 27, 31, and 32). Although these items come from more than one subscale, there seems to be a single unifying theme among these six items—what should be taught in science classrooms. For example, items 25, 27, 31, and 32 all make reference to what students "should learn" while item 3 discusses achievement (based on ability) and item 21 deals with students' willingness to "accept the ideas and theories presented to them without question." This analysis suggests that these items measure teachers' beliefs about the purpose or goal of a science curriculum when viewed from the perspective of the participants in this study.

The next set of items consists of six statements with loadings greater than .30 on factor 4 (Table 5). These items are from more than one subscale on the BARSTL. Four come from lesson design and implementation (9, 12, 15, and 16) and two come from teachers and the learning environment (18 and 19). As with the items that loaded on factor 2 and 3, there seems to be a clear underlying theme among these six items—how science should be taught. Items 9, 12, and 15 refer to the use of experiments in science classrooms; item 16 refers to the use of assessment during a lesson and items 18 and 19 refer to the activity of students during a lesson. Therefore, this analysis suggests that these items measure teachers' beliefs about lesson design and implementation when viewed from a preservice teacher's perspective.

The remaining six items load on more than one factor (Table 5). Although these items seem to measure multiple factors, in all likelihood, this is probably because of the participants focusing on key words found within the item. For example, item 13 refers to both learning, "allows students to learn new concepts" and classroom activity, "through inquiry instead of through a lecture, a reading or a demonstration," so it is not surprising that it loads on both factor 1 (how people learn about science) and 4 (lessons design and implementation). Item 11 loads on both factor 2 (characteristics of the teacher and the learning environment) and on factor 3 (the science curriculum), which is also not surprising given that it deals with the importance of "giving" step-by-step instructions so that students "get the correct results." Because of the high construct validity of the items and content validity of the subscales as judged by the experts, however, we assume that these complexly determined items are a result of the preservice teachers in this study interpreting these items differently than experienced teachers. In support of this interpretation, research that examines teacher cognition indicates that beginning and experienced teachers often think about teaching in different ways (Adams & Krockover, 1997; Hollingsworth, 1989). For example, rather than interpreting an item such as "the science curriculum should help students develop the reasoning skills and habits of mind necessary to do science" as an educational outcome as an expert would, some novices may interpret this item as an instructional approach. As a result, the item seems to measure multiple factors. However, further analysis will be needed to determine if such an assumption is warranted.

In essence, this analysis is an attempt to assess the degree to which the BARSTL has accurately translated the construct, reformed beliefs about science education, into an operationalization. In terms of validity, both the items and subscales have strong content validity based on expert opinion, which means the BARSTL reflects the relevant content domain of a reformed perspective on the teaching and learning of science. In terms of construct validity, a panel of experts agrees that the operationalization of the items and the four subscales accurately reflect the construct. Furthermore, using the score on each subscale to predict the overall score on the BARSTL indicates that the instrument also has good theoretical coherence despite being divided into four different subscales. An exploratory factor analysis indicates that 32 items of the BARSTL do load on four distinct factors, and the way the items load reflects the four dimensions proposed by the authors; although in some instances, the participants in the study assigned a different meaning to some of the items. In conclusion, this analysis suggests that the BARSTL has good overall content and construct validity.

Conclusions and Educational Implications

In this study, the results indicate that the BARSTL is a valid and reliable instrument for measuring the reformed beliefs about science education held by prospective elementary teachers. After the process of development and revision, all the items appear to be functioning to discriminate among beliefs that reflect a traditional perspective concerning the teaching and learning of science and those that are consistent with the philosophy of the current reform effort in science education. Factor analysis supported the expectation that the BARSTL assesses four dimensions of the construct reformed pedagogical content beliefs, and these factors coincided well with the four subscales that were presupposed to measure aspects of reformed pedagogical content beliefs. As predicted, the dimensions of reformed beliefs about science education measured by the subscales are positively correlated to each other because they seem to be measuring different aspects of the same core construct. The validity of the BARSTL is also supported by the results of the construct validity test of the items and content validity test of the subscales conducted by the experts in science education. The two internal consistency estimates of reliability that were computed for the BARSTL, a split-half coefficient expressed as a Spearman–Brown corrected correlation and coefficient alpha, were .80 and .77, respectively. Therefore, these results support the expectation that the BARSTL is a reliable instrument for measuring reformed beliefs about the teaching and learning of science.

Science educators are engaged today in a substantial effort of reform. In part, this is evidenced by the many recommendations being made by professional organizations for improving the way science is taught. However, rather than using these recommendations or standards to guide their practice, science teachers tend to rely on a personal belief system to guide their thinking about science teaching and learning (Yerrick et al., 1997). This research suggests that these beliefs, along with practical knowledge, have a strong influence on classroom action. These beliefs include intuitive ideas and assumptions about students and the learning process, teachers and teaching, the nature of knowledge, and the goals of the curriculum, which teachers develop before and over the course of their career (Bruner, 1999; Joram & Gabriele, 1998; Kagan, 1992; Munby, 1982; Nespor, 1987).

Research on teacher beliefs suggests that the success of the current science education reform effort will depend, in part, on the ability of in-service and preservice teachers to integrate the philosophy of the current science education reform movement with their existing philosophy without compromising the intent of the reform movement (Cronin-Jones, 1991; Joram & Gabriele, 1998). Overall, this body of research suggests that the role of a teacher's beliefs in the process of science education reform should not be underestimated and that the successful implementation of the current science education reform movement will require a considerable adaptation of teachers' beliefs in order to align their practice with the philosophy of the reform.

To help teachers develop a set of beliefs about teaching and learning that are consistent with the philosophy of the current reform movement in science education will require teacher education and professional development programs in science education to focus on identifying, understanding, and if necessary, changing the beliefs of teachers (Bybee, 1993; Haney et al., 1996). In order to focus on teachers' beliefs during instruction, teacher educators must have a way to assess teachers' beliefs about the teaching and learning of science that is valid and reliable. This information can then be used as a springboard from which subsequent teacher interviews, discussions, and classroom observations could take place. The quantitative and qualitative data could then be used to help change the philosophical stances of preservice teachers and as a means of reflecting on and improving the teaching practices that take place within teacher education programs. The BARSTL fulfills this need and can be a valuable tool for science teacher educators working in practical and research settings to assess the beliefs of prospective elementary teachers concerning the teaching and learning of science.

In using the BARSTL, professionals should be mindful that the total score produced reflects the relative position of a subject's beliefs about science teaching and learning along a continuum capped by traditional and reform-minded philosophical stances. Thus, the actual scores of BARSTL provide a vehicle for the quantitative comparison of teachers' reform-minded beliefs and observation of changes over time. We do not suggest that BARSTL scores should be used to define ranges that characterize teachers' level of reform-mindedness. Additionally, the BARSTL could be used with other data collection techniques such as structured interviews or observations of teachers engaged in the teaching of science. These data could then be combined as a means to help identify, and if needed, change the stances of preservice teachers, and as a way to improve teacher education and teacher professional development programs. When approached in this way, targeting teachers' beliefs in teacher education may have a significant impact on changing their beliefs about teaching and learning (Joram & Gabriele, 1998; Levitt, 2001).

In conclusion, based on the standardized development procedures used and the associated evidence, the BARSTL appears to be a reliable and valid instrument for use with prospective elementary teachers. However, establishing the validity of an instrument is an ongoing process. It is incorrect to speak of validity as ever being established in the once and for all sense of the word (Nunally, 1970). Thus, there is a need for further research focused on validating and refining the BARSTL through application of the BARSTL to diverse populations (e.g., experienced elementary teachers, middle school science teachers) and in various contexts (e.g., teachers who work in school districts with low socioeconomic status or with high English language learners populations).

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Appendix: The BARSTL Questionnaire

How People Learn About Science

The statements below describe different viewpoints concerning the ways students learn about science. Based on your beliefs about how people learn, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

1. Students develop many ideas about how the world works before they ever study about science in school.	SD	D	A	SA
2. Students learn in a disorderly fashion; they create their own knowledge by modifying their existing ideas in an effort to make sense of new and past experiences.	SD	D	A	SA
3. People are either talented at science or they are not, therefore student achievement in science is a reflection of their natural abilities.	SD	D	A	SA
4. Students are more likely to understand a scientific concept if the teacher explains the concept in a way that is clear and easy to understand.	SD	D	A	SA
5. Frequently, students have difficulty learning scientific concepts in school because their ideas about how the world works are often resistant to change.	SD	D	A	SA
6. Learning science is an orderly process; students learn by gradually accumulating more information about a topic over time.	SD	D	A	SA
7. Students know very little about science before they learn it in school.	SD	D	A	SA
8. Students learn the most when they are able to test, discuss, and debate many possible answers during activities that involve social interaction.	SD	D	A	SA

Lesson Design and Implementation

The statements below describe different ways science lessons can be designed and taught in school. Based on your opinion of how science should be taught, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

9. During a lesson, students should explore and conduct their own experiments with hands-on materials before the teacher discusses any scientific concepts with them.	SD	D	A	SA
10. During a lesson, teachers should spend more time asking questions that trigger divergent ways of thinking than they do explaining the concept to students.	SD	D	A	SA
11. Whenever students conduct an experiment during a science lesson, the teacher should give step-by-step instructions for the students to follow in order to prevent confusion and to make sure students get the correct results.	SD	D	A	SA
12. Experiments should be included in lessons as a way to reinforce the scientific concepts students have already learned in class.	SD	D	A	SA
13. Lessons should be designed in a way that allows students to learn new concepts through inquiry instead of through a lecture, a reading, or a demonstration.	SD	D	A	SA
14. During a lesson, students need to be given opportunities to test, debate, and challenge ideas with their peers.	SD	D	A	SA
15. During a lesson, all of the students in the class should be encouraged to use the same approach for conducting an experiment or solving a problem.	SD	D	A	SA
16. Assessments in science classes should only be given after instruction is completed; that way, the teacher can determine if the students have learned the material covered in class.	SD	D	A	SA

Characteristics of Teachers and the Learning Environment

The statements below describe different characteristics of teachers and classroom learning environments. Based on your opinion of what a good science teacher is like and what a classroom should be like, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

17. Students should do most of the talking in science classrooms.	SD	D	A	SA
18. Students should work independently as much as possible so they do not learn to rely on other students to do their work for them.	SD	D	A	SA
19. In science classrooms, students should be encouraged to challenge ideas while maintaining a climate of respect for what others have to say.	SD	D	A	SA
20. Teachers should allow students to help determine the direction and the focus of a lesson.	SD	D	A	SA
21. Students should be willing to accept the scientific ideas and theories presented to them during science class without question.	SD	D	A	SA
22. An excellent science teacher is someone who is really good at explaining complicated concepts clearly and simply so that everyone understands.	SD	D	A	SA
23. The teacher should motivate students to finish their work as quickly as possible.	SD	D	A	SA
24. Science teachers should primarily act as a resource person, working to support and enhance student investigations rather than explaining how things work.	SD	D	A	SA

The Nature of the Science Curriculum

The following statements describe different things that students can learn about in science while in school. Based on your opinion of what students should learn about during their science classes, indicate if you agree or disagree with each of the statements below using the following scale:

SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

25. A good science curriculum should focus on only a few scientific concepts a year, but in great detail.	SD	D	A	SA
26. The science curriculum should focus on the basic facts and skills of science that students will need to know later.	SD	D	A	SA
27. Students should know that scientific knowledge is discovered using the scientific method.	SD	D	A	SA
28. The science curriculum should encourage students to learn and value alternative modes of investigation or problem solving.	SD	D	A	SA
29. In order to prepare students for future classes, college, or a career in science, the science curriculum should cover as many different topics as possible over the course of a school year.	SD	D	A	SA
30. The science curriculum should help students develop the reasoning skills and habits of mind necessary to do science.	SD	D	A	SA
31. Students should learn that all science is based on a single scientific method—a step-by-step procedure that begins with “define the problem” and ends with “reporting the results.”	SD	D	A	SA
32. A good science curriculum should focus on the history and nature of science and how science affects people and societies.	SD	D	A	SA