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Measuring Primary Teachers' Attitudes Toward Teaching Science: Development of the Dimensions of Attitude Toward Science (DAS) Instrument

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Measuring Primary Teachers' Attitudes Toward Teaching Science: Development of the Dimensions of Attitude Toward Science (DAS) Instrument

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In this article, we present a valid and reliable instrument which measures the attitude of in-service and pre-service primary teachers toward teaching science, called the Dimensions of Attitude Toward Science (DAS) Instrument. Attention to the attitudes of primary teachers toward teaching science is of fundamental importance to the professionalization of these teachers in the field of primary science education. With the development of this instrument, we sought to fulfill the need for a statistically and theoretically valid and reliable instrument to measure pre-service and in-service teachers' attitudes. The DAS Instrument is based on a comprehensive theoretical framework for attitude toward (teaching) science. After pilot testing, the DAS was revised and subsequently validated using a large group of respondents (pre-service and in-service primary teachers) ($N = 556$). The theoretical underpinning of the DAS combined with the statistical data indicate that the DAS possesses good construct validity and that it proves to be a promising instrument that can be utilized for research purposes, and also as a teacher training and coaching tool. This instrument can therefore make a valuable contribution to progress within the field of science education.

Keywords: *Attitude instrument; Attitude toward science; Primary teachers; Science education; Primary education; Instrument validation*

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Introduction

Improving the attitudes of primary teachers toward teaching science is one of the major challenges in science education. Studies investigating these attitudes have indicated that teachers with less positive attitudes share a number of characteristics regarding science teaching, such as lower confidence and self-efficacy beliefs (Skamp, 1991; Tosun, 2000; Yates & Goodrum, 1990), spending less time discussing and teaching these topics (Goodrum, Hackling, & Rennie, 2001; Harlen & Holroyd, 1997), relying more on standardized methods and top-down instruction (Appleton & Kindt, 1999; Harlen & Holroyd, 1997; Jarvis & Pell, 2004; Plonczak, 2008), and being less able to stimulate the science attitudes of their students (Harlen & Holroyd, 1997; Jarvis & Pell, 2004; Osborne, Simon, & Collins, 2003; Van Driel, Beijaard, & Verloop, 2001; Weinburgh, 2007). Several authors have therefore stipulated the need to pay explicit attention to (pre-service) primary teachers' attitudes toward teaching science, apart from improving their pedagogical content knowledge and competencies in the field of science education (Bleicher, 2007; Haney, Czerniak, & Lumpe, 1996; Johnston & Ahtee, 2006).

Although the attitudes of primary teachers toward teaching science have been investigated widely, the scientific progress in this field is slow due to several major theoretical and methodological issues (Bennett, Rollnick, Green, & White, 2001; Blalock et al., 2008; Gardner, 1995; Kind, Jones, & Barmby, 2007; Osborne et al., 2003). Most importantly, both in research and in educational change projects, the concept of an attitude toward science is often poorly articulated (van Aalderen-Smeets, Walma van der Molen, & Asma, 2012; Barmby, Kind, & Jones, 2008; Bennett et al., 2001; Coulson, 1992; Osborne et al., 2003; Pajares, 1992). Even though attitude is a multidimensional and complex concept, many studies neither define the overall concept of attitude nor distinguish it from opinions, drives, or motivations (Ajzen, 2001; Pajares, 1992). In addition, many studies do not make a distinction between different attitude objects, such as attitudes toward science, attitudes toward teaching science, attitudes toward school science, scientific attitudes, or other related concepts.

In addition to and probably also because of the poor theoretical definition of what constitutes primary teachers' attitudes toward science, many current instruments that aim to measure attitudes toward science fail to accommodate to necessary theoretical and statistical standards (Blalock et al., 2008; Coulson, 1992; Gardner, 1995; Reid, 2006). Blalock et al. (2008) and Osborne et al. (2003) performed extensive reviews of the relevant literature and pointed at important flaws in the methodology of a majority of studies on *students*' attitudes toward science (in school), such as absence of or weak psychometric properties (e.g. failure to pilot test, validate, and evaluate the measurement instrument according to current psychometric standards). Similar flaws were encountered in a majority of studies in a review on *teacher* attitudes toward science and toward teaching science (van Aalderen-Smeets et al., 2012).

Also, many studies use instruments that measure only part of the attitude construct or measure multiple different attitude objects without treating them as independent entities. For example, the revised Science Attitude Scale puts different objects of attitude within one subscale, i.e. (a) self-efficacy related to science teaching, (b) self-efficacy related to understanding science, and (c) feelings toward teaching science (Thompson & Shrigley, 1986). These different attitude objects should be represented by different subscales since they measure different concepts. The Context Beliefs About Teaching Science (CBATS) instrument, which measures teachers' beliefs about the influence of context factors on science teaching behavior and the frequently used Science Teaching Efficacy Belief Instrument (STEBI), which measures self-efficacy and outcome expectancy related to science teaching, only measure a subpart of the construct of attitude (Enochs & Riggs, 1990; Lumpe, Haney, & Czerniak, 2000).

These theoretical and methodological problems have at least two important consequences. First, interpreting the results of previous studies is difficult because of the ambiguity of the concept that was measured. Second, comparing results between different studies on attitudes toward science or replicating such studies is hard or even impossible (Pardo & Calvo, 2002). In order to overcome these issues and boost scientific progress in this area, we developed and validated a new instrument measuring pre-service and in-service primary teachers' attitude toward teaching science, which we called the Dimensions of Attitude Toward Science (DAS) Instrument. Contrary to previous instruments, our instrument is based on an extensive conceptual and theoretical framework for the construct of teachers' attitudes toward science that we developed earlier (see van Aalderen-Smeets et al., 2012). It consists of a comprehensive composition of attitudinal dimensions for primary teachers' attitude toward science and toward teaching science. Using this framework as a basis for the development of a new attitude measurement instrument ensures that the complete range of relevant attitude dimensions and components is incorporated in the instrument. The resulting instrument can be used to investigate, guide, monitor, and evaluate teacher training programs aimed at improving science education in primary schools.

In this article, we describe the development process of the DAS Instrument and report on our investigation of the validity and internal consistency of the instrument by employing factor and reliability analyses. In addition, we report on our assessment of the quality of the individual items by inspection of the variance and discriminating ability. The total validation process includes these quantitative research methods as well as previously used qualitative research methods. The results of both methods will be interpreted in light of Trochim and Donnelly's (2006) framework for construct validity (see Dalgety, Coll, & Jones, 2003 and Velayutham, Aldridge, & Fraser, 2011 for a detailed description of the application of this framework). Before describing the methodology and the results of the validation process, we will briefly outline the theoretical and conceptual framework underlying the DAS. For a full description of the theoretical framework, we refer to van Aalderen-Smeets et al. (2012).

Framework for Primary Teachers' Attitudes Toward Science

As mentioned, the DAS Instrument is based on a new theoretical framework that describes the different dimensions of pre-service and in-service primary teachers' *professional* attitude, i.e. attitude toward *teaching* science and teachers' *personal* attitude, i.e. attitude toward science in general (see van Aalderen-Smeets et al., 2012). The DAS Instrument is based on the framework of teachers' professional attitude. The framework, presented in Figure 1 (van Aalderen-Smeets et al., 2012), consists of three dimensions (Cognition, Affect, and Perceived control) accommodating seven subcomponents that represent different thoughts, beliefs, and/or feelings toward teaching science, such as beliefs about the appropriateness and importance of science for children at the primary school level.

Cognition. The first dimension of the framework refers to cognitive beliefs about teaching science at the primary school level. This dimension encompasses three different subcomponents (see Figure 1). These are beliefs about the relevance and importance of teaching science to primary school children, the perceived difficulty that pre-service and in-service teachers attribute to the task of teaching science in primary school (this is different from teachers' perceptions about their *own* capability in teaching, which represents perceived self-efficacy), and gender-stereotypical beliefs about teaching science. Please note that this last component does not refer to *actual* differences between boys and girls or between men and women, but to teachers' perceptions or beliefs about differences between these groups.

Affect. The second dimension, affect, comprises both positive and negative emotions a teacher may experience when teaching science. These feelings can be categorized as

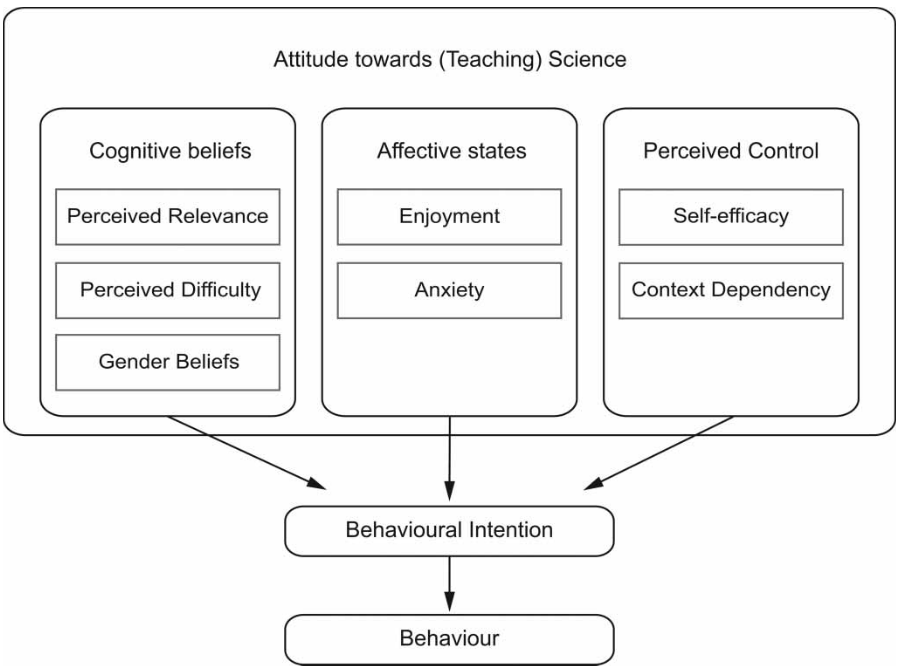

Figure 1. Theoretical framework for the construct of primary teachers' attitudes toward (the teaching of) science (van Aalderen-Smeets et al., 2012)

either enjoyment in teaching science or as the experience of anxiety when teaching science. These affective components are not two opposites or extremities of a single dimension, but are independent, although related, subcomponents. For example, it is conceivable that a teacher enjoys the teaching of science, but still feels somewhat nervous or anxious about it.

Perceived control. The third dimension refers to the amount of perceived control one has over teaching science. Similar to the cognitive and affective dimensions of attitude, which are necessarily subjective, this component reflects the subjective beliefs and feelings of individuals about internal and external obstacles that might hinder the teaching of science in primary school, and not the factual presence of such obstacles. Perceived control is determined by the subcomponents *self-efficacy* and *perceived dependence on context factors* (see Figure 1). The concept of self-efficacy is defined as a person's beliefs about his/her ability to perform a certain action, which is based on internal factors such as knowledge, confidence, and skills (Bandura, 1997; van Aalderen-Smeets et al., 2012). The beliefs and feelings that pre-service and in-service teachers have about the influence of external (i.e. contextual) factors on their teaching are defined as perceived dependency (PD) on context factors. For example, teachers may feel that they will only be able to teach science if enough time or teaching methods are available to them.

The Concept of Science

The concept of science as used in this article refers to the broad domain of natural and life sciences, to the ways of acquiring and applying knowledge according to the methods of natural science and technology, as well as the structured whole of knowledge and skills resulting from these methods (see Walma van der Molen, van Aalderen-Smeets, & Asma, 2010). It encompasses a broad domain of topics relating to physical, life, earth, space, and technical systems of knowledge, all of which involve the modeling of objective reality (for a conceptual account, see the report by the European Commission on Science Education) (Rocard et al., 2007).

Development of the DAS Instrument

The DAS Instrument is based on the aforementioned theoretical framework. The questionnaire is correspondingly composed of seven subscales that are based on the seven subcomponents of the framework. Each subscale comprises several items that aim to measure the underlying subcomponent (see Table 1 for all items included in the DAS Instrument). The DAS includes a total of 28 items.

The first subscale *Relevance of teaching science* measures the extent to which pre-service and in-service teachers find it important and relevant to teach science to primary school children. This component is measured by items such as: 'Science education is so important in primary school that inexperienced teachers should

Table 1. Factor loadings presented in the pattern matrix obtained by factor analysis using direct oblimin rotation on 28 items ($n = 556$)

		Factors								
Code	Items	1	2	3	4	5	6	7	SD	I-T corr.[a]
S2	I am well able to deal with questions from pupils about science	0.835							1.05	0.83
S1	I have enough knowledge of the content of science to teach these subjects well in primary school	0.810							1.11	0.79
S3	I have a sufficient command of the material to be able to support children well in investigating and designing in class	0.794							1.06	0.75
S4	If primary school children do not reach a solution during assignments about science, I think I can succeed in helping them make further progress	0.657							0.92	0.72
R2	I think that science must be anchored in primary education as early as possible		0.901						0.94	0.76
R1	I think that science education is essential for primary school children's development		0.790						0.89	0.69
R3	I think that science education is essential for making primary school pupils more involved in technological problems in society		0.610						0.86	0.61
R5	I think that science education in the primary school is essential for pupils to be able to make good choices about their studies (e.g. profile choice and choice of a course)		0.601						0.95	0.64
R4	Science education is so important in the primary school that inexperienced teachers should receive additional training in this area		0.538						1.06	0.60
G2	I think that male primary school teachers experience more enjoyment in teaching science than female teachers			0.712					1.09	0.62
G5	I think that boys at primary school would be more likely than girls to choose assignments that are concerned with science			0.676					1.06	0.56
G1	I think that male primary school teachers can do an investigation or technical assignment with pupils more easily than female teachers			0.601					1.14	0.53
G4	I think that boys in primary schools are more enthusiastic about experimenting with materials and chemical substances than girls are			0.584					1.15	0.52

G3	I think that I would unconsciously be more likely to choose a boy for a science demonstration than a girl			0.368					1.25	0.44
A4	I feel tense while teaching science in class				0.885				1.03	0.81
A3	I feel nervous while teaching science				0.844				1.02	0.80
A1	Teaching science makes me nervous				0.809				1.06	0.81
A2	I feel stressed when I have to teach science in my class				0.800				1.04	0.81
D2	I think that most primary school teachers find it difficult to teach subjects concerning science					−0.722			0.88	0.60
D3	I think that most primary school teachers find science a difficult subject to teach in terms of content					−0.715			0.87	0.59
D1	I think that teachers find the topics that come up in science complicated					−0.626			0.90	0.50
C2	For me, the availability of a ready-to-use existing package of materials (e.g. *Techniektorens*) is essential to teaching science in class						0.762		1.22	0.63
C1	For me, the availability of a science teaching method (e.g. *Natuniek*, *Leefwereld*) is decisive for whether or not I will teach science in class						0.755		1.27	0.62
C3	For me, the support of my colleagues and the school is decisive for whether or not I will teach science in class[b]						0.425		1.15	0.47
E3	I feel happy while teaching science							0.815	0.99	0.85
E4	Teaching science makes me cheerful							0.806	0.99	0.85
E2	I enjoy teaching science very much							0.624	1.07	0.81
E1	Teaching science makes me enthusiastic							0.595	1.07	0.81
	Initial eigenvalues	9.2	3.2	2.0	1.6	1.5	1.1	1.0		
	Initial % of explained variance	33	11	7	6	5	4	3		
	Explained variance (rotation sum of squared loadings)[c]	6.30	5.14	3.22	5.70	2.00	4.10	6.10		
	Cronbach's alpha	0.90	0.85	0.76	0.92	0.74	0.74	0.93		

Note: Factor loadings < 0.35 are omitted and factors loadings are sorted.

[a]Corrected item-total correlations are computed with respect to all items within that specific factor (subscale), not with respect to the complete set of items within the questionnaire.

[b]Cronbach's alpha of the subscale increases when this item is deleted (from 0.74 to 0.76).

[c]When factors are correlated, sums of squared loadings cannot be added to obtain a total variance.

receive additional training in this area'. The second subscale *Difficulty of teaching science* investigates whether primary teachers think that science in general is more difficult to teach than other topics. Since this component represents teachers' *general* beliefs about the difficulty of teaching science (and not their perceptions about their *own* capability to teach science), it was important that items in this subscale were unambiguous with respect to this difference. This was established by phrasing items in the following manner: 'Most teachers find science difficult to teach' instead of 'Science is difficult to teach'. The third subscale is labeled *Gender-stereotypical beliefs regarding teaching science* and is composed of two sets of items that measure two possible gender-related beliefs. The first type of belief involves potential differences between male and female teachers with regard to their ability to teach science and their level of interest and enjoyment in doing so. The second type of belief involves perceived differences between boys and girls in science. The fourth and fifth subscales are *Enjoyment in teaching science* and *Anxiety in teaching science*. These subscales measure the experienced positive and negative affects related to teaching science.

The sixth and seventh subscales measure the perceived control that teachers experience when teaching science. The sixth subscale measures *self-efficacy* and includes items that question teachers about their perceived ability to teach science in primary school and to handle problems that may arise when teaching science. Such perceptions are distinct from perceptions that teachers may have about external, contextual factors that could hinder or foster their science teaching. These latter perceptions, labeled *PD on context factors,* are measured by the seventh subscale, which comprises items questioning to what extent teachers feel dependent on certain context factors in order to teach science, such as 'For me, the availability of a science teaching method is decisive for whether or not I will teach science in class'.

Additional Considerations Concerning Item Development

In addition to the specific considerations for the design of items described for each subscale above, there are more general criteria and considerations to keep in mind when designing questionnaire items that address attitude, such as question wording, format, and sequence (for a detailed list of such criteria see Schwarz, 2008; Shrigley, 1974, or Shrigley & Johnson, 1974). We elaborated on these lists, for example, by adding the criterion that the wording of the items should connect to the world of the respondent group, i.e. primary teachers. In addition, items should be as specific and context rich as possible. Note, however, that this latter criterion is very precarious since items that are too specific could measure a different object of attitude than intended. For example, asking respondents whether they feel they possess enough knowledge of *astronomy* to be able to teach this subject well in primary school could measure a different attitude than asking about the knowledge of *content of science*. Furthermore, the items should be usable for measuring attitudes of both pre-service and in-service teachers and for experienced and novice teachers with respect to teaching science.

Likert-type Response Scale

For each item, respondents were asked to indicate to what extent they agreed or disagreed on a five-point Likert scale ranging from *totally disagree* (score 1) to *totally agree* (score 5). Although there are many different methods to measure attitudes, such as semantic differential scales, direct interviews, or implicit testing, we chose a Likert scale because this method has several advantages in comparison to the aforementioned methods. Likert-scale instruments are fit to include a large number of items organized in multiple subscales, they can be administered in an online version to a large number of respondents, the items can be answered quickly, and Likert scales enable parametric testing. The disadvantages of Likert scales can be partly overcome by adequate design (for more details about Likert-type scales, see Alwin, 1992 and Lyberg et al., 1997). For example, one criticism of Likert scales concerns the middle response option in a sliding response scale containing an uneven number of response options (Krosnick & Fabrigar, 1997). This midpoint is conceptually difficult to define. It represents something like *do not agree and do not disagree* and responses on this midpoint are therefore hard to interpret. The often-used labels for this midpoint *neutral*, *uncertain*, or *do not know* are conceptually different from a midpoint on a sliding scale ranging from agree to disagree. As a solution, some argue for using only even numbers of response options, forcing respondents to make a choice. However, this forced choice method might easily lead to a skewed image of teachers' attitudes. We therefore opted for a five-point Likert scale of which the three middle response options were labeled only by their respective number (i.e. *2*, *3*, or *4*) and not by a verbal label, in order to circumvent the conceptual ambiguous labeling of the middle response option. Only the two extreme options were labeled; 1 (*totally disagree*) and 5 (*totally agree*). In this way, we do not enforce a conceptual meaning to the respondent. The drawback of this method is that we cannot control which subjective meaning is assigned to the middle response option by the individual respondents.

Another criticism of Likert-scale instruments is that they easily elicit socially desirable answers because respondents are not always willing or able to admit their true beliefs. This is especially the case for the more controversial topics like gender-stereotypical beliefs. For example, not every teacher is willing to admit that he or she believes that boys are better in science than girls are. Using implicit tests, such as the Implicit Association Test (IAT), might overcome this problem, because the IAT does not ask directly about beliefs or attitudes, but tests by means of reaction times whether certain associations (e.g. boys and science) are stronger than others (e.g. girls and science) (Denessen et al., 2011). However, implicit tests have other drawbacks: they focus on one specific concept and cannot include multiple related subscales (or underlying concepts) as, for example, those within the theoretical framework presented here. In addition, they take more time to administer in comparison to Likert scales.

Additional problems with Likert-scale instruments might arise when respondents have different interpretations, impressions, or understandings of the concept under investigation. Individual teachers might have a narrow or a broader view of science. A narrow view of science refers to a view of science consisting of traditional exemplars of science, such as electricity, computer technology, doing experiments, or working in laboratories. Most people's definition of science incorporates these narrow, traditional impressions. However, *science* can also be understood as a more academic endeavor, such as improving our understanding of the world, acquiring and applying knowledge, or improving products. It is conceivable that teachers who have incorporated this broader view in their definition of science might display different attitudes toward these topics. In order to investigate teachers' view of science, we included a separate short questionnaire in the survey called the View of Science Scale that preceded the DAS.

Pilot Test of the DAS Instrument

An initial version of the instrument was piloted with a sample of 64 in-service and pre-service teachers. In addition to completing the DAS questionnaire, these respondents were urged to provide comments and feedback on the readability and perceived relevance of the items and the different subscales of the questionnaire. In addition, we asked three respondents to rewrite all items in their own words. By analyzing these interpretations we could assess whether the items were subject to one or more interpretations. Furthermore, we analyzed the discriminating ability of the items by investigating the variances in responses, i.e. computing the standard deviations of the responses for each item. A small variance means that only one or two neighboring responses are given by the respondents and that most respondents agree (or disagree) with the item. Such items are not likely to discriminate between respondents and were therefore deleted or, when possible, adjusted.

The pilot resulted in deleting or rewriting a number of items. The main reason for deleting items was poor discriminating ability of the item. This was especially problematic for the subscale *Relevance*. The majority of the respondents agreed that science is important to teach. The poor discrimination observed with the Relevance scale can be explained by the feedback we got from the teachers in our pilot study (see also Asma, Walma van der Molen, & van Aalderen-Smeets, 2011). Every teacher indicated that they thought science was important at primary school level. But in addition, some of them also indicated not feeling able to disagree because of a perceived lack of knowledge about the relevance of science for society. As a solution, we adjusted these items to phrase them in a more extreme manner, using words such as *essential* and *indispensable,* which improved the discriminating ability. For example, the item 'I think that science is important for the development of young children' was changed to 'I think science education is essential for the development of primary school children'.

The different subscales and the structure of the instrument all received positive feedback. We conducted an exploratory factor analysis, which gave promising results for the dimensionality of the instrument and which provided a first indication for the validity of the instrument. However, because of the limited number of respondents ($N = 64$) a factor analysis is not reliable and we therefore do not report it here. The initial instrument was revised and this revised version was submitted to a large-scale validation procedure in order to establish the validity and internal consistency of the instrument. This validation study is described in the remaining sections of the article.

Validation Study of the Revised DAS Instrument

Respondents

The revised DAS questionnaire was distributed digitally to two groups: pre-service and in-service primary teachers. The questionnaire was sent to schools and colleges after informed consent was obtained from a responsible authority. In some cases, the link to the survey was emailed directly to the respondents; in other cases the link was published via an intranet site or via digital newsletters. Since it is unsure how many pre-service and in-service teachers received this newsletter or read the intranet site, a total number of respondents summoned to participate cannot be provided. Filling in the questionnaires was voluntary and not linked to any program or course. A total of 579 respondents returned the questionnaire within our designated timeframe. Of this group, the data of 22 respondents contained more than five missing items. These respondents were removed from the dataset. A total of 556 respondents (158 in-service and 398 pre-service) remained and were included in the analyses. The respondents were mostly female (80%) with a mean age of 31 years (range 16–64 years). The in-service teachers had on average 19 years of teaching experience in primary education. The pre-service teachers had on average three years of experience mainly acquired through internships during their study. The in-service teachers taught in grades ranging from kindergarten (Grade 1 in the Netherlands, i.e. age 4) up to Grade 8 (age 11–12). The pre-service teachers represented all four years of teacher college (with a mean of 2.4 years of study).

Procedure and Materials

All questionnaires were administered online in the period between June 2010 and October 2010. The questionnaire took about 10 min to complete. In order to prevent the skipping of items, a maximum of 10 items were presented at the same time in one onscreen window so that all items were visible on the screen and there was no need to scroll down. An incentive to participate was given by raffling three science-surprise-packets after the survey was closed.

Preceding the attitude questionnaire, we included survey items measuring personal background information including age, gender, experience in teaching, and previous education. Separate questions were included for in-service teachers (e.g. grades they taught in) and pre-service teachers (e.g. year of study). In addition, we included a section investigating respondents' understanding and view of science: the View of Science Scale. The items asked respondents to indicate on a response scale from 1

Table 2. Factor loadings for the View of Science Scale presented in the pattern matrix obtained by factor analysis using direct oblimin rotation on 10 items ($n = 556$)

Code	Items	1	2	SD	I-T corr.[a]
N2	Working with chemical substances	0.91		0.87	0.74
N3	Working in a laboratory	0.82		0.88	0.70
N5	Stars and planets	0.65		0.86	0.66
N4	Sustainable energy	0.55		0.85	0.63
N1	Carrying out tests	0.45		0.67	0.48
B3	Devising new ideas		0.77	0.74	0.61
B4	Improving existing things		0.62	0.74	0.58
B5	Communicating ideas to other people		0.59	0.79	0.53
B2	Acquiring knowledge		0.56	0.61	0.47
B1	Researching and inventing		0.48	0.55	0.44
Explained variance (rotation sums of squared loadings)[b]		3.18	2.83		
Cronbach's alpha		0.84	0.76		

Note: Factor loadings < 0.35 are omitted and factors loadings are sorted.

[a]Corrected item-total correlations are computed with respect to all items within that specific factor (subscale), not with respect to the complete set of items within the questionnaire.

[b]When factors are correlated, sums of squared loadings cannot be added to obtain a total variance.

to 5 (*nothing* to *a lot*) to what extent a certain activity is related to science (see Table 2 for all items in the View of Science Scale).

In addition, we included a scale to measure how often respondents engage in activities related to teaching science (Behavioral Intention Scale, see Appendix). We developed two sets of items, one for in-service and one for pre-service teachers and each respondent was automatically directed to one of these sets of items based on their occupation (in-service or pre-service teacher). Items designed for pre-service teachers contained items measuring intention to teach science, while items designed for in-service teachers contained items measuring actual teaching (see Appendix). We expected respondents with a more positive attitude toward teaching science to engage more often in science-teaching-related behavior.

Data Analysis

The DAS Instrument was investigated at multiple levels; i.e. validity of the overall structure of the instrument, internal consistency of the subscales, and discriminating ability of the individual items. Construct validity of the DAS Instrument was determined by confirmatory factor analysis, which examines the underlying hypothesized factor structure based on the framework. The internal consistency of each subscale of the DAS was determined by Cronbach's alpha coefficient. Also, the item-total correlations were calculated. These provide an indication of the homogeneity within a subscale. To assess the discrimination of each item, we looked at the standard deviations of each item and range of the responses.

Results

Prior to analyzing the data, the responses for negatively phrased items were reverse coded. The percentage of missing items in the DAS was 0.06% and these missing values were replaced by mean values. Pre-service and in-service teachers were treated as one group since there is no reason to assume they would give differential results for the validation of the instrument.

Factor Analysis

The data were subjected to confirmatory factor analysis using principal axis factoring (Dalgety et al., 2003). The Kaiser–Meyer–Olkin (KMO) measure of sampling frequency and Bartlett's test of sphericity were used to ensure that the data were suitable for factor analysis (Dalgety et al., 2003). The DAS questionnaire had a KMO value of 0.92, well above the proposed minimum value of 0.6 according to Tabachnick and Fidell (2001) and passed Bartlett's test of sphericity ($p < 0.05$). In addition, visual inspection of the item correlation matrices showed evidence for coefficients greater than 0.3, which provides strong evidence for the suitability of the data for factor analyses (Tabachnick & Fidell, 2001). We rotated the data using Direct Oblimin rotation, since we expected correlations between two or more subscales. The factor correlation matrix showed that this method is justified since more than one correlation above 0.3 was present between the factors; see Table 3 (Tabachnick & Fidell, 2001). During iterative factor analyses, four items with overall low factor loadings (below 0.34) were removed from the dataset, resulting in the 28-item questionnaire, the items of which are presented in Table 1.

Table 3. Factor correlation matrix obtained by factor analysis using direct oblimin rotation on 28 items ($n = 556$)

	Factor correlation matrix						
Factor	1	2	3	4	5	6	7
1	1.00						
2	**0.40**	1.00					
3	−0.26	−0.18	1.00				
4	−**0.55**	−0.27	0.34	1.00			
5	0.00	−0.20	−0.25	−0.20	1.00		
6	−**0.52**	−0.26	0.28	**0.40**	−0.05	1.00	
7	**0.55**	**0.59**	−0.23	−**0.41**	−0.01	−**0.39**	1.00

Note: Correlations > 0.35 are printed in bold and only those correlations under the diagonal are presented.

Based on the theoretical framework, we expected the outcome of the factor analysis to be a multidimensional scale corresponding to our proposed framework of attitude (see Figure 1). Confirmatory factor analysis set at extraction of seven factors showed an excellent result. As shown in Table 1, the resulting rotated factor structure corresponds exactly to the hypothesized scale structure. The items are ordered by size of factor loading. Loadings of 0.34 and below are omitted to facilitate interpretation. None of the items shows a cross loading on any of the other factors.

As shown in Table 1, all items designed to address an individual attitude component loaded onto the same factor, resulting in a seven-factor structure that corresponds to the seven subscales of the instrument design. The factors 1–6 had initial eigenvalues that ranged between 9.2 and 1.1, and their explained variance ranged between 33% and 4.0%. Only the seventh factor had an eigenvalue just below 1 (eigenvalue = 0.96, explained variance = 3.4%); see bottom row of Table 1. The factor loadings vary between 0.37 and 0.90. The internal consistency of each factor proved to be high, as indicated by Cronbach's alpha values that range between 0.74 and 0.93, see bottom row of Table 1. The internal consistency of each subscale is also supported by the corrected item-total correlations computed within the factors (range between 0.44 and 0.85), which are well above the recommended minimum of 0.3; see rightmost column of Table 1.

In addition, we also analyzed the discriminating ability of each individual item by computing the standard deviation of the responses on the items and by looking at the minimum and maximum responses given by respondents. If an item is able to discriminate between respondents having different attitudes, we expect a large variation in responses. In this case, the standard deviation should hover around 1 and all response categories (1–5) should be ticked at least once (Coulson, 1992; Thompson & Shrigley, 1986). The standard deviations of all items range between 0.86 and 1.27 (see Table 1, column SD) and all response options are used at least once. This supports the discriminative ability of the items.

The factors 1–7 correspond consecutively to the following attitude subscales: Self-efficacy (items S1–S4) (1), Perceived relevance (items R1–R5) (2), Gender-stereotypical beliefs (items G1–G5) (3), Anxiety (items A1–A4) (4), Difficulty of science teaching (items D1–D3) (5), Perceived dependency on context factors (items C1–C3) (6), and Enjoyment (items E1–E4) (7). These results show that factor analysis supports the underlying scale structure of the DAS Instrument, which was based on the theoretical framework of pre-service and in-service primary teachers' attitudes toward (teaching) science. Furthermore, all seven factors represent internally consistent subscales containing well-designed items that have discriminating ability.

Factor correlations. Inspection of the factor correlation matrix (see Table 3) showed that the subscales within the dimension of Affect, which contribute in the opposite direction to attitude, correlated negatively ($r = -0.41$), indicating that a positive attitude on this dimension is characterized by high enjoyment and low anxiety. The same holds for the dimension of Perceived control ($r = -0.52$), indicating that a positive attitude is characterized by a high score on Self-efficacy and a low score on Context dependency. We found no substantial correlations between the subscales of the dimension Cognition (Relevance, Difficulty, and Gender). Furthermore, these three subscales did not correlate with any of the other scales with a correlation above 0.35. The only exception was the subscale Relevance, which correlated with Self-efficacy ($r = 0.40$) and Enjoyment ($r = 0.59$), indicating that there is a positive relationship between teachers' belief that teaching science at primary school level is relevant, their enjoyment, and feelings of self-efficacy when teaching science.

In addition, positive correlations were found between the subscales on which a higher score indicates a more positive attitude, e.g. between Enjoyment and Self-efficacy ($r = 0.55$), but also between subscales for which higher scores indicate a more negative attitude, e.g. between Context dependency and Anxiety ($r = 0.40$). The correlations between the *positive* subscales (high score is better attitude) and the *negative* subscales (high score is negative attitude) are negative. This correlation matrix shows that the subscales show fairly strong relationships in the direction that was expected from the underlying theoretical model, which adds to the construct validity of our instrument.

Results on the View of Science Scale

In addition to validating the DAS Instrument, we also analyzed the data of the View of Science Scale, using principal factor extraction (see Table 2). Only 0.03% of all data entries (three values) were missing and these were replaced by the mean value. The dataset proved suitable for factor analysis (KMO > 0.83, Bartlett's test of sphericity $p < 0.05$). Two factors were extracted based on eigenvalues and scree plot information. After rotation using direct oblimin, the results showed two factors clearly representing the two different views of science (KMO 0.83, 17% nonredundant residuals with absolute values greater than 0.05, $N = 556$). Factor one (initial eigenvalue = 4.2, explained variance = 42%) contains the complete set of items that refer to a narrow understanding of science. Factor two (initial eigenvalue = 1.5, explained variance = 15%) contains the complete set of items that refer to a broad understanding of science. Cronbach's alpha showed high internal consistency for both subscales (narrow view of science: $\alpha = 0.84$; broad view of science $\alpha = 0.76$), and the item-total correlations ranged from 0.44 to 0.74. The range in SDs for the items of both factors was from 0.55 to 0.88. The results provide support for the structure of the View of Science Scale.

To investigate the concurrent validity of the instrument, i.e. whether the instrument is able to discriminate between groups it should discriminate between, we analyzed whether pre-service and in-service teachers who have a broader view on science display a more positive attitude compared to teachers holding a narrow view. An ANOVA analysis compared the attitude scores on each subscale between these groups (broad view is mean score above 4 on the broad view items, B1–B5, Table 2 (49.1% of all respondents) and narrow view is a mean score of 4 and below). All subscales showed significant differences between the two groups of teachers ($p <$ 0.05), except Difficulty of science ($p = 0.40$).

Behavioral Intention

In order to assess the predictive validity of the DAS Instrument, we performed a regression analysis investigating whether scores on the subscales of the DAS have predicative value for the (intended) behavior of teaching science. A criterion vector was specified and seven predictor vectors representing the attitude components were generated. The linear model formulated to represent the relation between attitude component and behavior is:

$$Y = a + a_1X_1 + a_2X_2 + \ldots,$$

where $Y =$ science teaching behavior, $X_{1-7} =$ the attitude components 1–7, and $a_{1-7} =$ the regression coefficient for X_{1-7}. The regression solution showed that four out of seven subscales have predictive power for self-reported (intended) behavior: Self-efficacy (SE), Context dependency, Enjoyment, and Anxiety. The regression solution with these four components in the model found a multiple regression coefficient (R) of 0.46 (F change $(2, 551) = 16.3$, $p < 0.001$). The R square was 0.214, meaning that 21.4% of the variation in the behavior scores could be explained by a combination of these four attitude components.

As expected, there was a positive relation between self-efficacy and behavior ($B = 0.14$, $\mathrm{SD} = 0.04$, $t = 3.8$, $p < 0.001$). A higher self-efficacy was associated with more frequent teaching. Also, there was a negative relation between Context dependency and behavior ($B = -0.12$, $\mathrm{SD} = 0.03$, $t = -4.4$, $p < 0.001$), meaning that teachers who felt less dependent on context factors, such as a teaching method, were more likely to teach science on a regular basis. Furthermore, there was a positive relation between enjoyment and behavior ($B = 0.16$, $\mathrm{SD} = 0.03$, $t = 4.8$, $p < 0.001$), indicating that more enjoyment was associated with more frequent teaching. However, contrary to our expectations, there also was a positive association between anxiety and behavior ($B = 0.12$, $\mathrm{SD} = 0.03$, $t = 4.0$, $p < 0.001$). To our knowledge this is a new finding. An explanation for this finding could be that teachers who do not (intend to) teach science cannot feel anxious when doing so. However, those teachers that do teach science (at least occasionally) may still feel anxious about it, which could explain why those teachers report higher anxiety scores. The components within the dimension of cognition (relevance, difficulty, and gender) do not show a predictive value for behavior. These results show that at least two of the three attitude dimensions show predictive value for science-teaching behavior.

Profile Patterns of Individual Teachers

The DAS Instrument measures seven components of pre-service and in-service primary teachers' attitude toward teaching science. The output of the instrument thus provides an attitude profile consisting of seven separate scores. However, there is a possibility for combining teachers' scores on the dimensions of Affect and Perceived control, respectively, in order to provide a more straightforward attitude profile. A profile pattern of teachers' attitudes can be obtained by plotting the data of two related subcomponents from the same attitudinal dimension in a grid (i.e. a scatterplot) and labeling the new data points according to their location in the grid (see Figure 2). We suggest to combining the components within the dimension of Affect, i.e. Enjoyment and Anxiety, and within the dimension of Perceived control, i.e. self-efficacy and Context dependency, since these components are theoretically related and, as has been discussed above, show strong correlations.

The scores on the two related subcomponents of each individual teacher (e.g. Enjoyment and Anxiety) are plotted in a grid with Enjoyment on the x-axis and Anxiety on the y-axis (see Figure 2(a) for the dimension of Affect and Figure 2(b) for the dimension of Perceived control). This approach is comparable to the profiling of teachers by their respective Personal Agency Belief patterns described in Lumpe et al. (2000). The grid can be divided into four quadrants, each quadrant characterizing a certain type of attitude. We characterized and labeled these quadrants based on the probability that teachers will teach science, i.e. *high potentials*, *promising*, *reluctant*, and *indifferent*. The high potentials experience, for example, only positive feelings toward teaching science. They enjoy teaching science and do not experience any anxiety when doing so. The promising group characterizes teachers that enjoy teaching science, but also feel anxious about it. These teachers view teaching science as a challenge.

Teachers in the third quadrant feel reluctant to teach science. These teachers, for example, believe and feel that they do not possess the capabilities to teach science

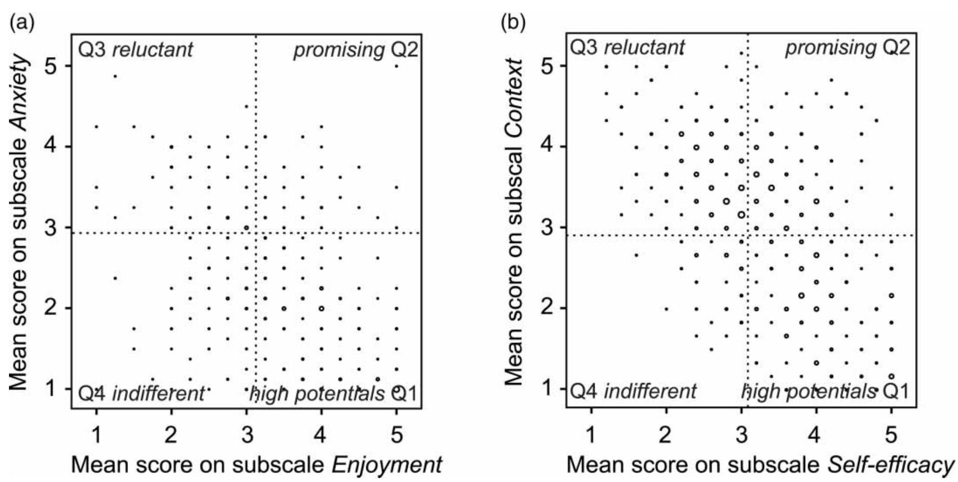

Figure 2. Scatterplots showing the distribution of scores of primary teachers ($N = 556$). Dot-size reflects percentage of teachers, with a larger dot representing a higher percentage of teachers at that location in the grid. (a) Enjoyment and anxiety scores. Dashed lines reflect the cut-off point for the quartiles (Enjoyment score > 3 is quartile 1 and 2; Enjoyment score ≤ 3 is quartile 3 and 4; Anxiety score ≥ 3 is quartile 2 and 3; Anxiety score < 3 is quartile 1 and 4). (b) Scatterplot showing the distribution of self-efficacy (SE) and perceived dependency (PD) on context factors scores. Dashed lines reflect the cut-off point for the quartiles (SE > 3 is quartile 1 and 2; SE ≤ 3 is quartile 3 and 4; PD ≥ 3 is quartile 2 and 3; PD < 3 is quartile 1 and 4)

and feel highly dependent on context factors. These teachers feel they are not in control of their science teaching. The fourth quadrant characterizes teachers as being indifferent and disinterested about teaching science. Profiling teachers based on their attitude scores may have several benefits in addition to other forms of data reduction. It provides the opportunity to characterize the attitude of teachers in a semantically understandable manner, as an extension of the description in terms of the seven attitude components. This may provide more accessible usage of the instrument for purposes beyond scientific research. This may be an especially valuable option when using the instrument for the characterization of the attitude of *individual* teachers, for example, in the light of training or professionalization of teachers in the field of science education.

Discussion and Implications

The goal of the present study was to develop and validate a new theoretically based instrument designed to measure the attitude of pre-service and in-service primary teachers toward teaching science (the DAS Instrument). In doing so, we employed different analysis methods to establish the validity and the internal consistency of the instrument and the subscales it entails. The excellent results of the validation procedure show that the DAS Instrument is capable of measuring the multiple dimensions of pre-service and in-service primary teachers' attitudes toward teaching science. In addition, the results of this study provide support for the underlying theoretical model of teachers' attitude toward teaching science that was developed previously (see van Aalderen-Smeets et al., 2012).

We established the construct validity of the instrument by achieving both translation and criterion validity (Dalgety et al., 2003; Trochim & Donnelly, 2006; Velayutham et al., 2011). Translation validity, i.e. the degree to which the instrument is operationalized accurately, was achieved by basing the design of the instrument on a comprehensive theoretical framework (content validity) and by pilot testing and evaluating the items by means of the feedback and interpretation of pre-service and in-service teachers (face validity). Criterion validity, i.e. whether the results and conclusions drawn from the use of the instrument can be expected based on the theoretical constructs, was determined by conducting factor analysis on the data of a large group of respondents. The resulting factor structure corresponded to the underlying theoretical model, consisting of three dimensions of attitude that incorporate seven subcomponents. Every item intended to measure a particular subcomponent loaded onto that particular factor, without cross-loadings on other factors. The obtained seven-factor solution confirms the hypothesis that the DAS questionnaire measures the seven underlying components of the framework of primary teachers' attitude toward teaching science.

Furthermore, the results of the internal consistency analysis showed high internal consistency in all seven subscales supporting convergent validity, i.e. that the items of a particular construct correlate highly with each other. These results support the notion that each subscale of the instrument is composed of items measuring the same concept. Please note that we do not assume the total set of 28 items to be internally consistent, since they measure different concepts, and therefore did not analyze the internal consistency of the *overall* instrument. The factor correlation matrix showed that the highest correlation between two factors was 0.59. This value implies that the factors representing the different attitude components do not overlap and the instrument meets the requirements for discriminant validity, i.e. that the different constructs are not highly correlated to each other.

Given the theoretical underpinnings, we expect teachers who display a broader and more academic view of science to hold a more positive attitude toward teaching science. The DAS Instrument should therefore be able to differentiate between teachers having a broader or narrower view of science and concurrent validity is confirmed if the subscales discriminate between these two groups. Results from an ANOVA analysis show that all subscales showed significant differences between the two groups of teachers except Difficulty of science. This suggests that each subscale in the DAS Instrument, except for the subscale Difficulty, shows concurrent validity. The Difficulty component refers to which beliefs *you* think the *average* teacher has regarding teaching science and therefore does not relate to a personal view or motivation. It might therefore be unrelated to your own attitude toward teaching science.

Another criterion by which the quality of a measurement instrument may be assessed is whether it has predictive validity, i.e. whether scores on the instrument can predict actual behavior. We showed that a majority of the subscales of the DAS indeed have predictive validity. The scores on the subscales Enjoyment and Anxiety and the scores on self-efficacy and Context dependency provide an indication of the likelihood and frequency that pre-service and in-service teachers will teach science in the classroom. The dimension of Cognition did not have any predictive value for behavior. This suggests that teaching science is not dependent on or related to the cognitive beliefs a teacher has about teaching science. As stated above, the Difficulty component refers to the belief that *you* think that the *average* teacher has. It might be unrelated to your own beliefs and (intended) behavior. In a similar way, gender-stereotypical beliefs refer to beliefs about the difference in ability between boys and girls or male or female teachers in general and such a belief may also be unrelated to your own intention to teaching science. The third component of the Cognitive dimension, Relevance, did correlate with the self-efficacy and the Enjoyment scores. The more important a teacher finds teaching science, the more likely it is that he/she enjoys teaching science and that he/she feels capable of teaching science. However, Relevance did not have predictive value for teaching science. This could be due to the complexity when measuring Relevance. There are not many pre-service and in-service teachers who believe teaching science is not important at all. Every teacher regards it important to some extent, but this does not imply that a teacher is willing to teach science him/herself. This can be explained by results of a previous focus group study that we conducted among pre-service and in-service primary teachers (Asma et al., 2011). In that study, many teachers expressed the relevance of teaching science at primary school level, but also expressed that they did not necessarily see themselves as the ones to do it. Rather, they would like to have special science teachers or technical coordinators who teach science at designated time slots, which is the practice in quite a number of primary school in The Netherlands.

In addition to analyzing the overall structure of the instrument and the internal consistency of each subscale, we analyzed the quality of each item. The large variation in response scores indicates that all items can discriminate between respondents displaying different beliefs, feelings, and thoughts toward teaching science. With the use of the DAS Instrument it is thus very well possible to distinguish between teachers having positive attitudes and teachers displaying negative attitudes toward teaching science at primary school level. These results show that the DAS Instrument is a valid, reliable, and comprehensive survey tool, which is able to measure a complex and difficult to define psychological concept, such as attitude toward teaching science.

We believe that the DAS Instrument is an important tool for the field of science education since it provides the opportunity to describe the attitude of teachers in a more refined and detailed manner than has been done before. In the past, the attitude of pre-service and in-service teachers would usually be described as being either positive or negative, without specifying what entailed these positive or negative attitudes. With this new instrument, primary teachers' attitude toward teaching science can be described in terms of their cognitive beliefs, affective states, and their feeling of being in control. However, with the use of the DAS Instrument, one can not only describe the different components of teachers' attitudes, but also compare attitudes of teachers in a more detailed manner, for example, when comparing attitudes of different groups of teachers or comparing the attitudes of individual teachers over time.

One very relevant application of the DAS is that it enables a more detailed investigation of the effects of professional development. The DAS can be used to assess the different attitude components and/or attitude profiles of teachers before and after the intervention and provide an indication of attitude change. When describing teachers in terms of attitude profiles (see Figure 2), an effective intervention (as compared to a non-effective or no intervention) is characterized by a significant number of teachers that have transferred to a 'more positive' quadrant. In addition, the DAS and the underlying attitude model can be used as a theoretical foundation for the development of professional development interventions that aim to improve the attitude or specific attitude dimensions of primary teachers in the field of science education. Recently, we used the attitude framework described in this article to develop an in-service training course for primary teachers that focused, among other things, on all the different attitude components described in the model. During six meetings, primary teachers were engaged in activities designed to improve their attitude toward science, their scientific attitudes, their awareness about their own attitudes, and metacognitive and creative thinking skills. The effect of this in-service training course was assessed using the DAS Instrument and additional qualitative measures (van Aalderen-Smeets & Walma van der Molen, in preparation).

In addition to this general approach for investigating the changing attitude of a larger groups of teachers, the DAS Instrument can also be used as a diagnostic or coaching tool in teacher training projects where the intervention is tailored to the specific attitude profile and corresponding needs of an individual teacher. Teachers who are low on self-efficacy might need different training or coaching than teachers who feel able to teach but feel anxious to do so. One could provide adapted training to teachers in each of the four quadrants. For example, high-potential teachers will need training that focuses on different aspects (such as learning a wider range of inquiry-based pedagogical techniques) than reluctant teachers (who might benefit from a more general approach that teaches them to recognize and become enthusiastic about the explorations of their pupils in the science domain). More research is needed to specify the specific needs of teachers in each of the quadrants, the development of adaptive training, and the effectiveness of these training courses. Attitude change might be fostered by making teachers aware of their own attitude profile. This metacognitive strategy could be a strong coaching tool related to the DAS Instrument.

Although the DAS Instrument has shown strong validity and reliability as presented in this article, there are some drawbacks concerning this study. Even though the factor analysis supports the underlying seven-component structure of the attitude model, additional analyses showed that two subscales (Difficulty and Gender beliefs) are unrelated to the other subscales, and did not have predictive value for teaching science, and that Difficulty does not discriminate between groups of teachers. More research into these concepts and their uses in the field of science education is therefore necessary.

In addition, the DAS questionnaire was administered to pre-service and in-service teachers from The Netherlands. The validation is therefore based on the Dutch version of the instrument. Although we expect the English version of the DAS to give similar validation results, more research is needed on the validation of the English version and we would very much like to invite other researchers to take up that challenge with us.

To conclude, the DAS Instrument proves to be a promising instrument within the field of science education and teacher training at primary school level. It can be utilized as a research instrument for effect studies of training methods, courses, and other interventions aiming to professionalize primary teachers. Furthermore, it can serve as a diagnostic tool for adapting training courses and interventions to the individual needs of pre- and in-service teachers. And finally, it can be used as a coaching tool for making primary teachers aware of their own view of science and their (changed) attitude toward teaching science. By means of these different uses, the DAS Instrument, designed to measure pre-service and in-service primary teachers' attitude toward teaching science, could therefore become a highly valuable instrument for making progress within the field of science education in primary schools.

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Appendix

Items of behavioral scale for both inservice and preservice teachers. Response options to the items were 1–5, labeled 'seldom or never', 'couple times a year', '1–3 times a month', 'weekly', and 'daily'

Subscale		Item
Inservice	Code	
	IS1	How often do you teach science in your class (separately and/or integrated)?
	IS2	How often do you specifically identify activities in class as technical/ technology/technology lessons/investigation/science etc.?
	IS3	How often do you personally devise and prepare a science lesson?
	IS4	How often do you make an excursion with your pupils in the context of science education (museum, exhibition, company visit, etc.)?
	IS5	How often do your pupils test or analyze an existing or personally designed product on its technical aspects?
	IS6	How often do you carry out an investigation together with your pupils?
	IS7	How often are your pupils allowed to genuinely carry out an investigation or try to discover something without following a pre-set procedure?
Preservice		
	PS1	How often are you taught science in your course?
	PS2	How often do you test or analyze an existing or personally designed product on its technical aspects in your course?
	PS3	How often do you personally carry out a full investigation in the context of your course?
	PS4	How often do you intend to teach science when you have a job as a teacher?
	PS5	How often do you intend to carry out an investigation with your pupils when you have a job as a teacher?
	PS6	How often do you intend to devise and prepare a new lesson in science when you have a job as a teacher?
	PS7	How often do you intend to integrate science subjects in your teaching when you have a job as a teacher?
	PS8	How often do you intend to make an excursion with your pupils in the context of science education (museum, exhibition, company visit, etc.) when you have a job as a teacher?