

Improving Primary Teachers' Attitudes Toward Science by Attitude-Focused Professional Development

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Abstract: This article provides a description of a novel, attitude-focused, professional development intervention, and presents the results of an experimental pretest-posttest control group study investigating the effects of this intervention on primary teachers' personal attitudes toward science, attitudes toward teaching science, and their science teaching behavior. The training course integrated an explicit focus on attitudes towards (teaching) science with an inquiry-based learning approach and refrained from recipe-like, pre-structured, and content-based instruction examples. Results show that the training course had profound positive effects on primary teachers' professional attitude towards teaching science. Teachers improved in self-efficacy beliefs regarding science teaching, felt less dependent on context factors, and enjoyed science teaching more. In addition, the training course had positive effects on teachers' personal attitude towards science, including improved self-efficacy and relevance beliefs, and decreased anxiety. Furthermore, there was a large effect on teachers' science teaching behavior in the classroom and on the number of science related activities they engaged in during their personal lives. These results show that an attitude-focused approach is more effective in changing teachers' attitudes and science teaching behavior compared to merely being engaged in science teaching. © 2015 Wiley Periodicals, Inc.

Keywords: attitude towards science; inquiry; primary teachers; science education; professional development; training

Over the last decades, teacher professional development in the field of primary science education has received increased attention. This is not surprising, since there is heightened awareness that individual teachers are critically important for science education and reform efforts (Borko, 2004; Cobern & Loving, 2002; Desimone, 2009; Haney & Lumpe, 1995; Nye, Konstantopoulos, & Hedges, 2004). However, thus far progress in enhancing primary teachers' skills, knowledge, and attitudes in the field of science has been slow (Bennett, Rollnick, Green, & White, 2001; Kind, Jones, & Barmby, 2007; Osborne, Simon, & Collins, 2003). Past research has shown that teachers' attitudes towards science are essential for science education in primary education: Teachers' own beliefs and attitudes were found to be predictive of their intention to teach science in the classroom (Haney, Czerniak, & Lumpe, 1996; van Aalderen-Smeets & Walma van der Molen, 2013) and of their classroom practices when they teach science (Haney, Lumpe, Czerniak, & Egan, 2002).

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Primary teachers holding a negative attitude toward science spend less time discussing and teaching science topics and are less able to stimulate a positive attitude towards science in their students (Goodrum, Hackling, & Rennie, 2001; Harlen & Holroyd, 1997; Jarvis & Pell, 2004; Osborne et al., 2003; Van Driel, Beijgaard, & Verloop, 2001). On a positive note, it has been shown that when teachers gain greater confidence, as the result of an intensive large-scale professional development approach combined with continuous coaching and mentoring, they obtain higher student achievement in their class (Lumpe, Czerniak, Haney, & Beltyukova, 2012). Primary teacher professional development in science education should therefore explicitly aim for improvements in teachers' attitudes and beliefs regarding science and science teaching (Bleicher, 2007; Haney & Lumpe, 1995; Mulholland & Wallace, 1996; Osborne & Dillon, 2008; Rosenfeld & Rosenfeld, 2008; Tobin, Tippins, & Gallard, 1994; van Driel et al., 2001).

This article presents a new approach to professional development of primary teachers in the field of science education, which is directly focused on improving teachers' attitudes towards (teaching) science. We believe that improving attitudes is a first and essential step for teacher professional development in science education. This approach is in accordance with the increasing consensus that science should be taught as the *process* of acquiring scientific knowledge (inquiry-based learning approach) and should stimulate an understanding about the nature of scientific inquiry, rather than teaching science as a *body of knowledge* (e.g., Lederman et al., 2014; Mant, Wilson, & Coates, 2007; Sanger, 2008).

A recent study showed that the impact of a science content-based intervention is minimal (Diamond, Maerten-Rivera, Rohrer, & Lee, 2014). Providing teachers with content knowledge did show a small positive effect on teachers' knowledge, but this improvement in knowledge was not observed in the classroom. Furthermore, student achievement outcomes were predicted by the level of science content knowledge a teacher had, but this was unrelated to whether these teachers had taken part in the intervention or not. It is not clear from the study whether there were additional, confounding, variables that could explain this relation. For example, maybe the teachers showing relatively high amounts of knowledge are also the teachers that show a more positive attitude toward science teaching. This could explain both findings: the observed relation between teacher knowledge and student outcomes and the fact that the content-based intervention had no predictive value on these outcomes.

Professional development should focus on the improvement of the competency of teachers to adjust their teaching to the students instead of on the teaching of a certain "proven" method or content. A recent review study on the effects of elementary science teaching methods on student outcomes shows that providing teachers with science kits does not affect student outcomes (Slavin, Lake, Hanley, & Thurston, 2014). Inquiry based methods that emphasize teacher professional development did show an effect on student outcomes.

Over the past years, a growing number of intervention studies have been published that recognize the relevance of a focus on the process of science and on an inquiry-based learning approach adhering to a constructivist model of learning, i.e., hands-on science activities, inquiry-based teaching methods, cooperative learning, open-ended investigations, using role-models, and challenging misconceptions about science content (Appleton, 1995; Carleton, Fitch, & Krockover, 2008; Jarvis & Pell, 2004; Liang & Gabel, 2005; Martin-Dunlop & Fraser, 2007; McDevitt, Heikkinen, Alcorn, Ambrosio, & Gardner, 1993; Osborne, 2014; Palmer, 2006). Although this approach seems more effective in changing attitudes toward science than a content knowledge approach (e.g., Knapp, 1997), these studies still assume that attitude change is an emergent by-product of merely being involved in science teaching, improved hands-on experimenting skills or inquiry-based learning pedagogy skills. However, the relation between being actively involved in science teaching and increased scientific inquiry skills on the one hand and attitudes towards

science on the other is far from clear. Although some positive relations have been reported (Appleton, 1995; Cox & Carpenter, 1989; Lumpe et al., 2012; Martin-Dunlop & Fraser, 2007; McDevitt et al., 1993; Murphy, Neil, & Beggs, 2007; Palmer, 2006), other studies did not report positive effects of teachers' improved inquiry-based learning skills on their attitudes towards science (Carleton et al., 2008; Liang & Gable, 2005). Even within studies, the relation between increased skills and knowledge on the one hand and attitudes on the other remains unclear (Avery & Meyer, 2012; Ucar & Demircioglu, 2011).

A possible explanation of these conflicting results is the ambiguity of the concept of attitude toward (teaching) science, which refers to a variety of thoughts, values, and feelings about science and science teaching. The studies mentioned above used various different definitions of the concept of attitude, which makes it difficult to interpret and compare the effects of these interventions (for a review see also van Aalderen-Smeets, Walma van der Molen, & Asma, 2012). Furthermore, it should be noted that attitudes are highly dependent upon context (Ramey-Gassert, Shroyer, & Staver, 1996; Schoon & Boone, 1998). Thus, interventions that focus on specific scientific content knowledge or on doing hands-on experiments on topics such as the growth of plants or building bridges might lead to improved attitudes towards hands-on activities in the field of biology or engineering, but not necessarily to improved beliefs about the importance of teaching science, improved curiosity, or critical reflection in formulating one's own research questions. So, although the use of inquiry-based learning approaches has increased and the focus on attitude improvement is becoming more widespread within professional development of primary teachers, it is still not evident how to improve primary teachers' attitudes toward science.

With this study, we aim to provide an approach to improve these attitudes toward science and present a new professional development intervention, developed for this purpose, which integrates an explicit focus on improving attitudes towards (teaching) science with an inquiry-based learning approach. We investigate the effects of this intervention on teachers' attitudes toward science and their attitudes towards teaching science using an experimental pretest-posttest control group design. Additionally, we investigate whether such an attitude driven approach has effects on teachers' science teaching practices. The questions this study tries to answer are: 1. Does an attitude-focused professional development course improve primary teachers' attitudes towards teaching science and their personal attitudes towards science to a greater extent than merely being trained or engaged in hands-on science or inquiry teaching? And 2. Does the attitude-focused course improve primary teachers' self-reported science teaching behavior to a greater extent than merely being trained or engaged in hands on science or inquiry teaching? We hypothesize that challenging and reflecting upon teachers' attitudes toward (teaching) science, their scientific attitudes, and their knowledge and skills about science, without focusing explicitly on science content knowledge, will improve both teachers' attitudes and their science teaching behavior more so than merely being trained or engaged in science teaching and inquiry learning.

To our knowledge, thus far only one professional development study integrated explicit attention to teachers' attitudes toward science in its intervention program. Cox and Carpenter (1989) describe a course that explicitly focused on teachers' anxiety and confidence and the study showed positive results on teachers' attitudes. However, the study measured only two attitudinal components (anxiety and confidence) and failed to compare the results of the teachers in the intervention group to a control group.

Theoretical Framework of Attitude

Attitude towards science is a complex concept and different studies use a multitude of definitions (van Aalderen-Smeets et al., 2012). This emphasizes the relevance of a sound theoretical framework of attitude towards science when investigating changes in attitudes. The

present study built upon the theoretical framework of primary teachers’ attitudes towards science that was developed recently (see van Aalderen-Smeets et al., 2012). This framework distinguishes primary teachers’ *professional* attitude, i.e. attitude toward teaching science, from teachers’ *personal* attitude, i.e. attitude toward science in general. In addition, the framework explicates and structures the range of underlying components of these attitudes towards science. The framework was based on an extensive review of previously used concept definitions of the construct of primary teachers’ attitudes towards science and these components were related to general psychological attitude theories, such as the Tripartite Model of attitudes (e.g., Eagly & Chaiken, 1993) and The Theory of Planned Behavior (e.g., Ajzen & Fishbein, 1980). The resulting framework, presented in Figure 1, consists of three dimensions (Cognition, Affect, and Perceived control) accommodating seven subcomponents that represent different thoughts, beliefs, and/or feelings toward teaching science. Cognitive beliefs refer to teachers’ beliefs and opinions about (a) the relevance of science and science education, (b) beliefs about the relative difficulty of (teaching) science, and (c) gender stereotypical beliefs regarding science and science teaching. The second dimension of affect contains the independent subcomponents of (a) enjoying (teaching) science and (b) anxiety related to (teaching) science. The third dimension, perceived control, refers to the amount of control teachers perceive to have over (teaching) science and it consists of (a) self-efficacy (an internal sense of control, such as the perceived capacity to teach science) and (b) perceived dependency on context factors (beliefs about the extent to which you feel dependent on external factors to teach science, such as the availability of teaching-methods or materials, enough time, or other resources). In our view, the perception of teachers regarding their dependency on context factors (e.g., their belief that they can teach science only if their school ensures the availability of the proper materials or sufficient preparation time) is an indispensable component of a complete theoretical framework of primary teachers’ attitudes toward science. For a full description of the theoretical framework, we refer to van Aalderen-Smeets et al., (2012).

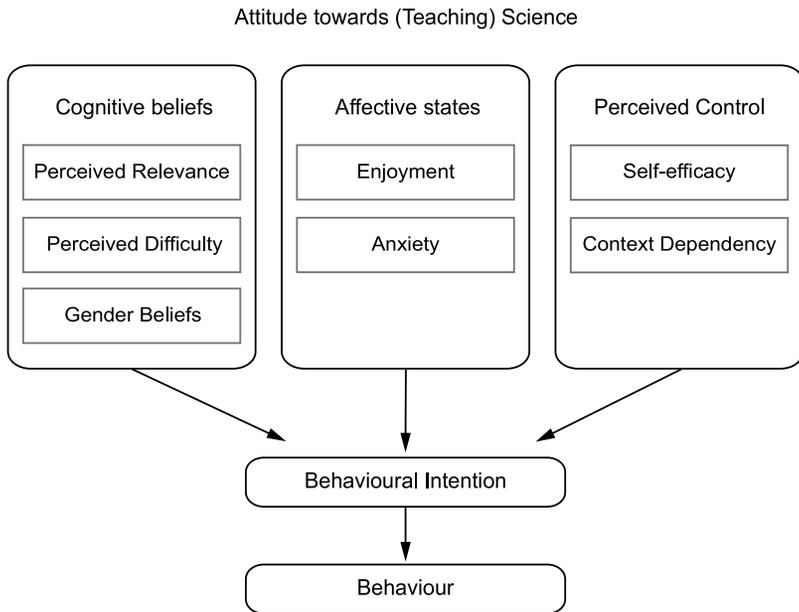


Figure 1. Theoretical framework for the construct of primary teachers’ attitudes toward (the teaching of) science. (figure originally printed in: van Aalderen-Smeets et al., 2012).

The intervention investigated in this project aims to improve both teachers' professional and personal attitude. We assume, based on the Theory of Planned Behavior (Ajzen, 2002; Ajzen & Fishbein, 1980) that professional attitude towards teaching science is the most direct antecedent of the intention to teach science and of actual science teaching, since it refers directly to the behavior that is at stake. However, the aim of the training course is that teachers change their own attitudes, and not only learn how to teach science. This requires that they change themselves as a person. Teachers' personal attitude towards science is part of this personal change and is presumably related to their professional attitudes. A qualitative focus-group study conducted by Asma and colleagues (2011), investigating perceptions of primary teachers regarding their own personal and professional attitudes toward science, shows that teachers perceive a distinction between their personal and professional attitude toward science and that it is possible for these attitudes to develop independently. In addition, they report causal influences going both ways; i.e. some teachers stated that their professional attitude toward teaching science was influenced by their personal attitude, whereas others reported the reverse. Although no knowledge is available on the relation between the two attitudes, both could play a role in science teaching.

Overview of the Intervention

The training course was developed as part of a Dutch governmental initiative to stimulate primary science teaching in the Netherlands. The aim of the training course was to improve primary teachers' professional and personal attitudes, stimulate their science teaching behavior, and to empower them to stimulate the attitudes of children toward science. It has been shown that interactive science lessons that incorporate cognitively challenging activities increase children's enthusiasm, their engagement with science, and their science performance in school (Mant et al., 2007). Our professional training course was based on the contention that in order for teachers to be truly able to stimulate and improve students' attitudes towards science, teachers should first develop these attitudes themselves. The same holds for the process of inquiry; it has been shown that making teachers go through the experience of an inquiry investigation themselves has positive effects on their understanding of inquiry-based teaching, their self-efficacy, scientific attitudes, and the use of science in their classroom (Morrison, 2008). The approach of the training course was unique within the Netherlands, in a sense that all information, tasks, and assignments were explicitly designed to challenge and improve teachers' attitudes. The imposed science content was minimized and only served to support attitude-focused and inquiry-based assignments. The training course consisted of six meetings, each with a length of 3 hours, spread out over a period of 6 months and was led by one of the researchers or a trained teacher educator. Participants spent a total of 18 hours on the meetings of the course and an additional 35–40 hours on preparation and assignments.

Key Elements in the Training Course

The training course contained three key elements: (1) the previously described components of attitudes toward (teaching) science, (2) scientific attitudes, and (3) knowledge about (teaching) science and scientific skills. The training course included assignments or discussions that challenged and created awareness about each of the components of attitude towards science. The second category (scientific attitudes) is defined as a collection of trainable attitudes that characterize scientific thinking. These features include curiosity, being inquisitive (a longing to know and understand), being able to wonder about your environment, taking a questioning approach to all statements, being critical about all sorts of statements (including your own), having a demand for verification, a respect for logic, and being able to deal with research and knowledge related insecurities (Osborne et al., 2003; van Aalderen-Smeets et al., 2012).

The third category (improving teachers' knowledge about (teaching) science and scientific skills) refers to knowledge about the process of science and the skills needed for performing an actual scientific inquiry, as defined by Osborne (2014). This includes knowledge about the empirical cycle and of the different steps in the research process, e.g., formulating research questions, knowing different research methods, data analysis, and presentation of the results. Knowledge about scientific skills refers to the set of academic skills needed to perform or coach students with an investigation, such as higher order thinking skills, as in the taxonomy of Bloom (Anderson & Krathwohl, 2001), creative thinking skills, metacognitive thinking skills, devising a research design, or being able to apply inquiry based learning methods.

The structure of the course was designed in such a way that attitudes, knowledge, and skills in these three domains were gradually built up during the meetings and that elements in these domains were linked to each other where possible (see Table S1 in Supplementary material for a schematic overview of the course with key elements and assignments).

Detailed Description of the Training Course

The training course consisted of six meetings. The first five meetings were a combination of activating assignments, information transfer, and interactive workshops about attitude towards science, scientific attitudes, and inquiry. During the last meeting the participating teachers presented and demonstrated a science lesson or science activities, which they developed and taught in their classroom. During this presentation they were asked to reflect upon the designing and implementation process of the science activities. In between meetings, the participants conducted personal and/or student-oriented take-home assignments, which were reflected upon during the following meeting. Personal assignments aimed to improve the attitude and scientific skills of the teachers themselves. The student-oriented assignments were designed to let teachers experience the effects of teaching science on their students and to become aware of their own beliefs and attitudes in their classroom environments. All assignments were open-ended and required creative, higher order, and reflective thinking skills. Each participant received a 150 page course book written by the authors of this article, which contained information about the training course, theoretical background information, specific information and assignments for each meeting, the take home assignments, and inspiring examples, websites, and web links.

The first meeting was used to create awareness about participants' own view of science, to emphasize the relevance of their own attitude towards science, to stimulate their curiosity and to manage their expectations of the course. For example, one assignment asked teachers to put everything they had with them on the table that, in their view, was somehow related to science. This assignment aimed to stimulate a broad view of science, by making teachers realize that almost everything is somehow related to science (component of relevance of (teaching) science). The personal take-home assignment required participants to keep a "wonderment diary", asking them to write down three wonderments or curiosities a day, for seven days in a row. This assignment aimed to stimulate teachers' own curiosity and awareness about daily life objects and to make them aware of their own inquisitiveness (stimulating self-efficacy and creating awareness about the joy of science).

During the second meeting, the entries from teachers' wonderment-dairies were taken as a starting point to develop research questions and hypotheses. It taught teachers how to formulate a research question and made them realize they were able to do so (stimulating scientific skills and self-efficacy). In addition, attention was given to formulating coaching questions in order to make students think more deeply when doing inquiry in the classroom, i.e., stimulating higher order thinking skills, problem solving, and their awareness of the uncertainty and on-going process of scientific inquiry (stimulating teachers' self-efficacy regarding science teaching). In addition, the

second meeting challenged teachers' beliefs about the relevance of science teaching and about potential gender stereotypical beliefs.

The research questions formulated during the second meeting were used as a starting point in the third meeting to let participants think about appropriate research methods to investigate their questions. The participants also conducted a small-scale experiment. As an example of a simple and fun experiment, participants investigated whether adding a small amount of peanut butter to your bubble-gum would make you blow larger bubbles (which is sometimes claimed, but has never been verified). Participants were stimulated and coached to think about different research questions and hypotheses (e.g., can we verify the claim, would it work because of the peanuts or because of the oil in the peanut butter, or does it also work with honey, etc.) and to design an actual investigation with bubble-gum and all necessary ingredients. After these preparations, they were asked to actually conduct the experiment, write down the results, and reflect upon these. This assignment aimed to let teachers think about logical steps in the empirical cycle, research design, possible confounds, and measurements, and to have them practice simple investigations with everyday materials. But the second important goal was to let teachers experience the joy of doing research (especially doing something in class that is usually not allowed—chewing bubble-gum), to reduce their anxiety of doing experiments in the classroom, and to boost self-efficacy. These attitude components were extensively reflected upon with the participants after the assignment. In a take-home assignment teachers were asked to conduct a small-scale experiment with their students, which was reflected upon during the next meeting (boosting enjoyment and self-efficacy regarding science teaching and diminishing anxiety and perceived context dependency).

The fourth meeting put emphasis on creative and higher order thinking skills; how can we describe, recognize and stimulate them, and why are they important for science education? Creative thinking skills were practiced with participants and were reflected upon. Participants were asked how they would stimulate these skills in their students. In addition, attention was given to the higher order thinking skills of the taxonomy of Bloom (Anderson & Krathwohl, 2001). Bloom describes six levels of thinking, of which the lower-order thinking skills are remembering, understanding, and applying. Most existing science teaching methods in the Netherlands only include these lower levels of thinking, although the scientific process is mainly about higher-order thinking skills, that is, about analyzing, evaluating, and creating.

During the fifth meeting all previous meetings were reflected upon and participants were challenged to describe the changes and development of their own attitudes towards (teaching) science and scientific attitudes. These personal stories were related to the third dimension of attitude, perceived control of both professional and personal attitude, which is comprised of teachers' self-efficacy and their perceived dependency on context factors, such as time, methods, or materials. In addition, this meeting was used to discuss participants' ideas and plans for the final assignment: the development and teaching of a science lesson and/or activities.

During the sixth and final meeting, participants presented visual reports of their science lessons to each other. They were encouraged to develop these science lessons in cooperation with participants working at the same school and were obliged to include the stimulation of attitudes in these science lessons.

Method

Subjects

A total of 64 Dutch primary teachers participated in the intervention group, from 18 different primary schools in the Eastern part of the country, see Table 1 for teacher characteristics. The group was divided into three comparable intervention groups, with a maximum number of 25

Table 1
Background characteristics of participating teachers

	Intervention group $n = 61$	Control group $n = 45$
Age in years, Mean (SD)	43,4 (10,9)	31,8 (14,1)
Teaching experience (years), Mean (SD)	18,0 (11,4)	8,1 (11,7)
Gender	74% Female	80% Female
Prior training in science teaching	14,8%	17,8%

participants per group. During the training course, three teachers dropped out due to personal reasons, so a total of 61 participants finished the course (74% female, mean age 43.4 years, $SD = 11$). The teachers represented primary teachers from every grade (K-8 in the Netherlands, i.e. age 4–12) and were enrolled on the basis of personal interest and interest of their schools in science education. The average years of teaching experience were 18 years ($SD = 11$).

The control group consisted of 45 primary teachers from different schools than the intervention group (80% female, mean age 31.8 years, $SD = 14$), who were recruited via the National Science Centre Teacher Club, a club of teachers who are interested and engaged in science and science teaching. They had an average teaching experience of 8 years ($SD = 12$), and also participated in the research on a voluntary basis. We selected this group of teachers in order to circumvent the problem of a naïve control group, which is not engaged or experienced in any science teaching at all. Primary teachers in the Netherlands were, at the time of the research, not obliged to teach science in their class, and most schools did not teach science at all. The teachers in the control group were actively involved in a number of different science teaching activities and part of them had followed a variety of hands-on or inquiry-based training courses. One could therefore expect that the attitudes of this group were already positive and/or would become more positive over time. Previous research shows that time spent with science teaching is predictive of self-efficacy regarding science (Lumpe et al., 2012). We therefore assumed that this control group, which was demonstrably engaged with and interested in science teaching, would make an ecologically valid comparison to our intervention group.

To gain insight into the involvement of these control-group teachers in science education during the research project, we included posttest questions addressing the amount and sort of science related (teaching) activities they engaged in between pre- and posttest. The results showed that 82% of the respondents in the control group were engaged in science related activities during that period. More than half of the control group participants (56%) indicated to have taught science in their classroom, a third (33%) indicated to have been involved in personal science related activities, and almost a quarter of the participating teachers (22%) indicated that they had taken part in a science course or training. These results confirm that the control group was highly interested in science education and actively engaged in it.

Design and Procedure

A quasi-experimental pretest-posttest control group design was used to assess the effects of the training course. Participants were not randomly assigned to the intervention and control group. Teachers (and their schools) in the intervention group were interested in science education professional development and enrolled deliberately into the training course. Participants in the intervention group were asked to fill in our pretest survey instrument before the start of the training course and the posttest survey at the end of the last meeting, after a final summary of the course was given. The control group was invited via email and filled in an online version of our survey instrument twice, with an interval between the two measurements of 6 to 8 months.

Measurement Instrument

Attitude toward *teaching* science was assessed using the Dimensions of Attitude toward Science (DAS) questionnaire, a validated questionnaire to assess primary teachers attitudes towards *teaching* science, i.e. professional attitude (van Aalderen-Smeets & Walma van der Molen, 2013). The DAS questionnaire was developed according to the previously described theoretical framework of attitude and it measures each component of primary teachers' professional attitude with a separate subscale. Professional attitude items always refer to science teaching, for example: "I think that science education is essential for primary school children's development" (cognitive relevance), "I feel stressed when I have to teach science in my class" (anxiety), "I have a sufficient command of the material to be able to support children well in investigating and designing in class" (self-efficacy), or "For me, the availability of a science teaching method is decisive for whether or not I will teach science in class" (context dependency). For each item, respondents indicated to what extent they agreed or disagreed on a five-point Likert scale ranging from *totally disagree* (score 1) to *totally agree* (score 5). For more detailed information about the psychometric analyses and validity of the DAS questionnaire, see van Aalderen-Smeets & Walma van der Molen (2013).

In order to also measure teachers' *personal* attitude towards science, i.e., their general attitude toward science in their personal life, we adapted the DAS instrument, by rephrasing the original items of the DAS to fit personal attitude towards science. Personal attitude items referred to science in personal life, such as: "I think that it is essential in your daily life to have knowledge about science" (cognitive relevance), "I feel uneasy if a discussion with friends suddenly turns to science" (anxiety), "I often find scientific topics difficult to understand" (self-efficacy), or "If I had more time I would read the science supplement of the newspaper more often" (context dependency). Please note that, compared to the original DAS instrument, we excluded the cognitive subscale for Difficulty in both the professional and personal survey, since this component refers to beliefs that teachers have about other teachers' views regarding the difficulty of science or science education. We do not expect this belief to change following a training course. Both the professional and personal attitude survey thus consisted of six subscales measuring the six remaining components of primary teachers' attitudes towards (teaching) science (see Fig. 1).

We determined the internal consistency of each subscale with Cronbach's alpha coefficient. The internal consistency of each subscale of both professional and personal attitude at both pretest and posttest proved to be high, as indicated by Cronbach's alpha values that ranged between .76 and .91. Only the subscale Gender showed a lower, but still sufficient, alpha of .63 on the posttest. The internal consistency of this scale on the pretest was higher (.78).

In addition to the professional and personal attitude scales, we included a self-report scale measuring science teaching behavior and science related daily activities. Both used an eight-item scale, including items such as: "How often do you personally devise and prepare a science lesson?" or "How often do you buy a book for yourself on science?" The internal consistencies of these scales were moderate to high, with Cronbach's alpha values ranging between .65 and .86. Response options to the items were 1–5, labeled *seldom or never*, *couple times a year*, *1–3 times a month*, *weekly*, and *daily*.

We also measured teachers' view of science, i.e., whether teachers' view of science is narrow (traditional) or also includes broader views of science, using a 10-item scale. Items for a narrow view of science were for example: "Science is about carrying out tests" and "Science is about working with chemical substances." Examples of broad view items are: "Science is about acquiring knowledge" and "Science is about researching and inventing." The items asked respondents to indicate on a response scale from 1 to 5 (*nothing* to *a lot*) to what extent they

believed a certain activity is related to science. The internal consistencies of both View of Science subscales at both pretest and posttest proved to be high, as indicated by Cronbach's alpha values that ranged between .73 and .88. In addition, background information was acquired, such as age, working experience, education, etc.

Data Analysis

The effects of the training course were analyzed using GLM repeated measures MANOVA's, including post-hoc univariate analyses, performed on weighted sum scores of each subscale for professional attitude toward teaching science and for each subscale of personal attitude toward science. We were mainly interested in interaction effects that would show that the attitude scores of the intervention group improved to a greater extent than the attitude scores of the control group on each subcomponent of attitude. To gain further insight into the (non)-effects of the training course on each attitude component, we performed additional analyses within each group separately (intervention and control group) using paired *t*-tests. Similar MANOVA analyses and post-hoc univariate analyses were used to investigate changes in teachers' narrow and broader views of science. To test the effects of the training course on science teaching behavior and the engagement in science related daily activities, we conducted GLM repeated measures ANOVA's, where we looked at the interaction effect of time and condition on the behavioral scores.

Results

Initial data checks showed that the distributions of the attitude scores on each attitude component satisfied the assumptions underlying analysis of variance. All effects were assessed at the .05 level. We report only on the outcomes of the relevant effects for this study, i.e. the interactions between condition (intervention and control group) and time (pre- and posttest) for each attitude component.

Professional Attitude

The results of the study are presented in Figure 2a and b and corresponding Table 2. The figure shows the mean pretest and posttest scores of the intervention group (Fig. 2a) and the control group (Fig. 2b) on each attitude component and the univariate analyses results. Note that a higher score indicates a more positive attitude for the components of relevance, enjoyment, and self-efficacy, while a lower score indicates a more positive attitude for gender, anxiety, and context dependency.

To investigate the general effects of the training course on teachers' professional attitude, i.e., attitude towards teaching science, a 2 (intervention vs. control group) \times 2 (time 1 vs. time 2) \times 6 (relevance vs. gender beliefs vs. enjoyment vs. anxiety vs. self-efficacy vs. context dependency) repeated measures MANOVA was conducted with condition as between-subjects factor, time as a within-subjects factor, and the six attitude components as dependent variables. The test of within-subjects effects using Wilks' statistic revealed a significant overall interaction effect of time and condition, $\Lambda = .70$, $F(6, 97) = 6.81$, $p < .001$, $\eta^2 = .30$. This shows that, across the six professional attitude components, the change in attitude was larger for the intervention group compared to the control group.

To gain further insight into the origins of this interaction effect, we looked at the changes in each attitude component separately using post-hoc univariate analyses. We report the results on each component in the same order as the components are depicted in the attitude framework (relevance, gender beliefs, enjoyment, anxiety, self-efficacy, and context dependency).

There was no statistically significant univariate interaction effect of time and condition for the component of relevance of teaching science $F(1, 104) = 1.77$, $p = .187$, $\eta^2 = .02$. However, we did

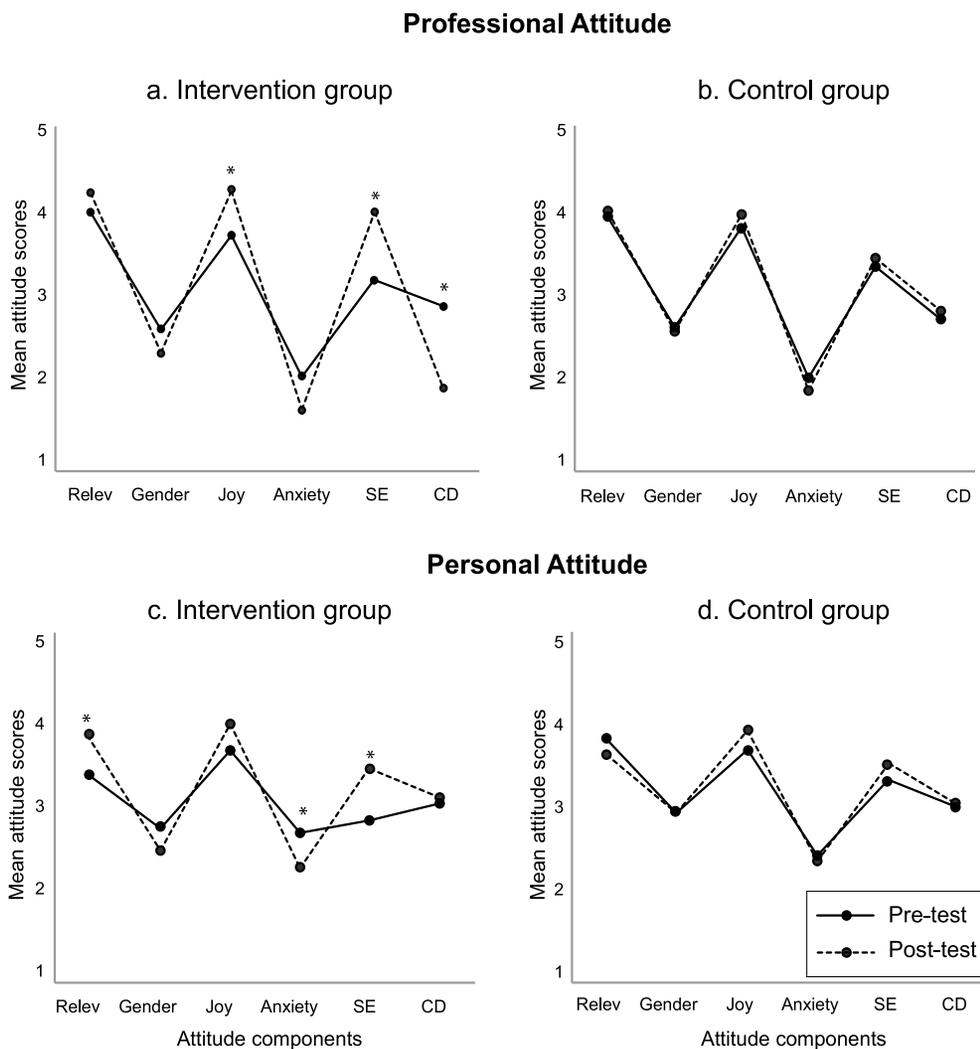


Figure 2. Mean attitude scores before and after the training course of the intervention and the control group on each component: Relevance (Relev), Stereotypical gender beliefs (Gender), Enjoyment (Joy), Anxiety, Self-efficacy (SE), and Context dependency (CD). The figure shows the scores for (a) the intervention group on the components of professional attitude, (b) the control group on the components of professional attitude, (c) the intervention group on the components of personal attitude, and (d) the control group on the components of personal attitude. The connecting lines between the dots are only for presentation purposes and do not depict actual data. Shows significant interaction effects (time x condition) from the univariate analyses on each attitude component.

observe a trend, i.e., an increase in relevance scores for the intervention group indicated by a paired t -test, $t(60) = 3.22, p = .002$, while this effect was absent in the control group, $t(44) = 0.79, p = .432$.

We see the same pattern for teachers' stereotypical gender-beliefs regarding teaching science. There was no statistically significant univariate interaction effect for stereotypical gender beliefs $F(1,104) = 1.90, p = .172, \eta^2 = .02$, but paired t -tests did show a decrease for the intervention group, $t(60) = -2.60, p = .012$, which was absent in the control group, $t(44) = -.48, p = .634$.

Table 2

Mean scores on each attitude component of professional and personal attitude and the interaction effects (time of measurement* condition) for each attitude component

	Intervention group				Control group				Time × group interaction		
	Pre		Post		Pre		Post		F	<i>p</i>	Part. η^2
	M	SD	M	SD	M	SD	M	SD			
Professional attitude toward teaching science											
Cognition											
Relevance	4.0	.56	4.2*	.50	3.9	.73	4.0	.73	1.8	.19	.02
Gender	2.7	.76	2.4*	.71	2.7	.82	2.6	.70	1.9	.17	.02
Affect											
Enjoyment	3.7	.79	4.3*	.58	3.8	.93	4.0	.92	5.4	.02	.05
Anxiety	2.1	.86	1.7*	.72	2.1	.99	1.9	.88	2.5	.12	.02
Perceived Control											
Self-efficacy	3.2	.89	4.0*	.60	3.6	1.03	3.7	.93	23.5	.00	.19
Context dependency	2.9	1.11	1.9*	.66	2.8	1.12	2.8	1.17	27.8	.00	.21
Personal Attitude toward science											
Cognition											
Relevance	3.4	.62	3.8*	.50	3.6	.62	3.6	.65	15.4	.00	.13
Gender	2.8	.94	2.5*	.81	2.9	.91	2.9	.87	2.9	.09	.03
Affect											
Enjoyment	3.7	.76	4.0*	.65	3.7	.75	3.9*	.64	0.2	.66	.00
Anxiety	2.7	.94	2.3*	.87	2.5	.88	2.4	.89	5.1	.03	.05
Perceived Control											
Self-efficacy	2.9	.89	3.5*	.60	3.2	.98	3.5*	.87	9.0	.00	.08
Context dependency	3.0	.75	3.1	.68	3.0	.88	3.0	.94	0.07	.79	.00

Mean scores could range between 1 (*totally disagree*) and 5 (*totally agree*).

p-values printed in bold indicate a significant interaction effect ($p < 0.05$) between time and condition. This sentence is added in the new version of the table.

*Significant difference ($\alpha = .05$) between pre- and post-test analyzed with a paired *t*-test.

The data did show a statistically significant interaction effect of time and condition for the component of enjoyment when teaching science, $F(1,104) = 5.44, p = .022, \eta^2 = .05$. Additional paired *t*-tests showed a significant increase in enjoyment for the intervention group from pre- to posttest, $t(60) = 5.18, p < .001$, which was absent in the control group, $t(44) = 1.04, p = .305$. However, the effect size, with a partial η^2 of .05 was relatively small (Cohen, 1988) and accounts for only 5% of the variance. These results indicate a small, but significant, effect of the training course on teachers' enjoyment when teaching science.

There was no statistically significant interaction effect of time and condition for the component of anxiety $F(1,104) = 2.48, p = .118, \eta^2 = .02$. However, we did observe a trend, i.e., a larger anxiety decrease in the intervention group compared to the control group, which was supported by paired *t*-tests showing a decrease in anxiety within the intervention group, $t(60) = -3.96, p < .001$, and no decrease within the control group, $t(44) = -1.07, p = .293$.

There was a statistically significant interaction effect of time and condition for self-efficacy. Participants in the intervention group showed a significantly larger increase in self-efficacy scores compared to the control group, $F(1,104) = 23.47, p < .001, \eta^2 = .19$. The effect size is large (Cohen, 1988) and indicates that the training course accounted for 19% of the overall variance. The paired *t*-tests showed a significant increase in self-efficacy scores within the intervention group, $t(60) = 8.39, p < .001$, which was not present within the control group, $t(44) = 1.46, p = .152$.

The univariate analysis for perceived dependency on context factors also showed a statistically significant interaction effect of time and condition $F(1,104) = 27.80, p < .001, \eta^2 = .21$. The effect size is large and accounts for 21% of the overall variance (Cohen, 1988). Paired t -tests showed a significant decrease in perceived dependency within the intervention group, $t(58) = -7.11, p < .001$, while there was no significant change within the control group, $t(44) = 0.61, p = .544$. These results indicate that trained teachers felt less dependent on the availability of materials, methods, and time for teaching science after the training course.

To sum up, the training course had a large effect on the components of self-efficacy and perceived context dependency, and a small effect on enjoyment. The attitude components relevance, stereotypical gender beliefs, and anxiety did show a trend for greater improvement within the intervention group compared to the control group, but the overall univariate interaction effects for these components were not statistically significant.

Personal Attitude

To investigate the effects of the training course on teachers' personal attitude toward science, a 2 (intervention vs. control group) \times 2 (time 1 vs. time 2) \times 6 (relevance vs. gender beliefs vs. enjoyment vs. anxiety vs. self-efficacy vs. context dependency) repeated measures MANOVA was conducted with condition as between-subjects factor, time as a within-subjects factor, and the six attitude components as dependent variables. The data of the univariate analyses for personal attitude are presented in Figure 2c and d and corresponding Table 2.

The results of the repeated measures MANOVA using Wilks' statistic, showed a statistically significant difference between the intervention and control group across the six attitude components over time, $\Lambda = .82, F(6, 99) = 3.64, p = .003, \eta^2 = .18$. This shows that, across the six personal attitude components, the change in attitude was larger for the intervention group compared to the control group. To gain further insight into the origins of this interaction effect, we looked at the univariate analyses for each individual personal attitude component.

The univariate analyses showed a statistically significant interaction effect of the training course on relevance beliefs. $F(1,104) = 15.43, p < .001, \eta^2 = .13$. This was supported by paired t -tests that showed a significant increase in relevance scores within the intervention group, $t(60) = 5.49, p < .001$, but not within the control group, $t(44) = 0.16, p = .875$. The effect size of the univariate interaction effect (partial $\eta^2 = .18$) was high (Cohen, 1988), indicating that 18% of the overall variance in personal relevance beliefs was accounted for by the training course.

The univariate analysis for gender stereotypical beliefs showed no interaction effect, $F(1,104) = 2.87, p = .093, \eta^2 = .03$, although we did observe a trend, i.e., a decrease within the intervention group as shown by a paired t -test, $t(60) = -2.47, p = .017$, and no significant change within the control group, $t(44) = 0.05, p = .961$.

The univariate analysis for the component of enjoyment also showed no interaction effect, $F(1,104) = 0.20, p = .656, \eta^2 < .01$. When looking more closely at the data using paired t -tests, we found significant increases in enjoyment in both the intervention, $t(60) = 3.12, p = .003$, and in the control group, $t(44) = 2.40, p = .021$. This means that both groups showed increased personal enjoyment of science over time.

The univariate analysis for the component of anxiety did show a statistically significant interaction effect of time and condition, $F(1,104) = 5.13, p = .026, \eta^2 = .05$. Paired t -tests showed a significant decrease in anxiety from pre- to posttest within the intervention group, $t(60) = -4.28, p < .001$, and no such effect within the control group, $t(44) = -0.57, p = .569$. The effect size is relatively small with a partial η^2 of .05, meaning that 5% of the variance was accounted for by changes in personal anxiety.

There was a statistically significant interaction effect between time and condition on the personal attitude component of self-efficacy, $F(1,104) = 8.98, p = .003, \eta^2 = .08$. Paired t -tests showed that there were significant increases in personal self-efficacy scores both within the intervention group, $t(60) = 6.91, p < .001$ and the control group, $t(44) = 2.36, p = .023$. However, although both groups showed an improvement in self-efficacy, this increase was significantly larger for the intervention group. The effect size of the univariate analysis (partial $\eta^2 = .08$) was small to medium (Cohen, 1988), indicating that 8% of the overall variance was accounted for by changes in self-efficacy.

The analysis of the sixth component of personal attitude towards science, perceived dependency on context factors, showed no interaction effect of time and condition, $F(1,104) = 0.07, p = .790, \eta^2 < .00$. Additional paired t -tests did not show any significant changes within the intervention or the control group.

To sum up, the training course had a positive effect on the personal attitude components of relevance, self-efficacy and anxiety. Stereotypical gender beliefs did show a trend for greater improvement within the intervention group compared to the control group, but this difference between groups was not statistically significant. Finally, we observed no difference between the intervention and control group on the components of enjoyment (both improved approximately the same amount) and perceived dependency on context factors (no improvements in both groups).

Behavior

To investigate the effects of the training course on teachers' behavior, two 2 (intervention vs. control group) \times 2 (time 1 vs. time 2) repeated measures ANOVA's were conducted with condition as between-subjects factor, time as a within-subjects factor, and either teachers' science teaching behavior or their engagement in science-related activities in their personal life as dependent variables. The results of the univariate repeated measures analyses for both forms of behavior are presented in Table 3. We found a significant interaction effect of time and condition for science teaching behavior, $F(1,95) = 64.71, p < .001, \eta^2 = .41$. The observed effect size is very large and this indicates that the training course accounts for 41% of the variance in the science

Table 3
*Mean scores on behavior and view of science and the interaction effects (time of measurement * condition) for these variables*

	Intervention group				Control group				Time \times group interaction		
	Pre		Post		Pre		Post		F	p	Partial η^2
	M	SD	M	SD	M	SD	M	SD			
Science related behavior											
Teaching science	1.8	.53	2.6*	.55	2.4	.69	2.3	.51	64.7	.00	.41
Science activities in daily life	2.3	.50	2.6*	.55	2.4	.66	2.5	.70	8.7	.00	.08
View of science											
Narrow view	3.7	.67	3.9	.72	3.9	.58	3.7	.71	5.2	.02	.05
Broad view	4.3	.48	4.5*	.41	4.3	.45	4.3	.43	5.2	.03	.05

Mean scores for "science related behavior" could range from 1 to 5 (*seldom or never, couple times a year, 1-3 times a month, weekly, and daily*); mean scores for "view of science" could range from 1 (*nothing*) to 5 (*a lot*). p -values printed in bold indicate a significant interaction effect ($p < 0.05$) between time and condition.

teaching behavior scores. To gain further insight into this effect, we conducted paired *t*-tests on the mean pre- and posttest scores within each condition separately. These analyses showed a significant and large increase in the amount of science teaching activities in the intervention group, $t(58) = 10.15, p < .001$, while there was a non-significant decrease in the amount of science teaching activities for the control group, $t(37) = -1.72, p = .094$ (when tested one-sided this decrease would be significant: $p = .047$).

In addition, results showed a significant interaction effect for the engagement in science related activities in teachers' personal lives, $F(1,104) = 8.70, p = .004, \eta^2 = .08$. Paired *t*-tests showed that this interaction was explained by a significant increase in the amount of science related activities in the intervention group, $t(60) = 6.06, p < .001$, and a non-significant increase in the control group, $t(44) = 1.14, p = .260$. The effect size here is small to medium, and indicates that the course accounted for 8% of the total variance.

View of Science

To investigate changes in teachers' view of science, a 2 (intervention vs. control group) \times 2 (time 1 vs. time 2) \times 2 (narrow vs. broad view) repeated measures MANOVA was conducted with condition as between-subjects factor, time as a within-subjects factor, and the narrow and broad views as dependent variables. The results of the analyses on view of science scores are presented in the bottom part of Table 3. Tests of within-subjects effects using Wilks' statistic, revealed a significant interaction effect across the two dependent variables between time and condition, $\Lambda = .94, F(2,103) = 3.50, p = .034, \eta^2 = .06$. To gain further insight into the origin of this interaction effect, we looked at the univariate analyses of the broad and narrow views separately. The first analysis showed an interaction effect of time and condition for teachers' broad view of science, $F(1,104) = 5.20, p = .025, \eta^2 = .05$, which corroborated that the intervention group showed a broader view of science after the course and that this shift towards a broader view was larger compared to the control group. Supporting this, the results of paired *t*-tests showed a significant positive shift in the intervention group, $t(60) = 4.77, p < .001$, but no statistically significant change in the control group, $t(44) = 0.88, p = .382$.

The univariate analysis of teachers' narrow view of science also showed a significant interaction effect, $F(1,104) = 5.23, p = .024, \eta^2 = .05$. Further analyses of the changes in the two groups separately, using paired *t*-tests, showed that there was a small non-significant positive shift in the intervention group, $t(60) = 1.89, p = .064$ (two-sided), meaning that these teachers expanded their collection of explicit, narrow view exemplars representing science, while there was a small non-significant negative shift in the control group, $t(44) = -1.40, p = .170$.

Number of Teachers with Positive Attitudes

The statistical analyses listed above provide information on the direction of mean attitude changes due to the training course. However, they do not provide insight in the *number* of teachers that actually hold a clear positive attitude after the training course, compared to the number of teachers in the control group with a positive attitude. To that end, we looked at the percentage of teachers with high attitude scores on the individual attitude components at the time of the pre- and posttest for both groups. We provide these data only for the professional attitude of teachers, since we assume that this is a better predictor for actual teaching behavior and because this was the main interest of our study. We did not perform statistical analyses on these data.

We operationalized *positive attitude* by defining a range of scores for each attitude component. The mean score of a teacher should fall within this range in order to be categorized as positive. The range for those components on which a higher score denotes a more positive attitude (relevance, enjoyment, and self-efficacy) was defined as a mean score equal to or higher than four

(on a scale of 1–5 this implies a clear positive agreement with the attitude items). The range for those components on which a higher score denotes a more negative attitude, was defined as a mean score equal to or smaller than two (on a scale of 1–5 this implies a clear disagreement with the attitude items). We did not include mean scores between three and four (or three and two for negative components) because it is conceptually unclear whether these scores reflect a mildly positive attitude or a neutral attitude. For science teaching *behavior* we used a cut-off point of three (mean score equal to or higher than three), which indicates that teachers taught a science lesson at least once a month. After defining these ranges, we calculated the percentage of teachers that fell within these ranges using frequency information.

In the intervention group, the number of teachers with a positive attitude increased on each attitude component (see Fig. 3). For the control group, the number of teachers with a positive attitude increased on three of the attitude components and declined on the other three and on science teaching behavior. At the pretest, a majority of the teachers in both groups already regarded science teaching as relevant (60% for the intervention group and 49% for the control group), enjoyable (50% for the intervention group and 56% for the control group) and did not feel anxious about science teaching (60% for the intervention group and 58% for the control group). However, for the trained teachers these percentages increased to 85% (in the case of relevance beliefs and enjoyment) after the course. While for the control group the percentage for enjoyment

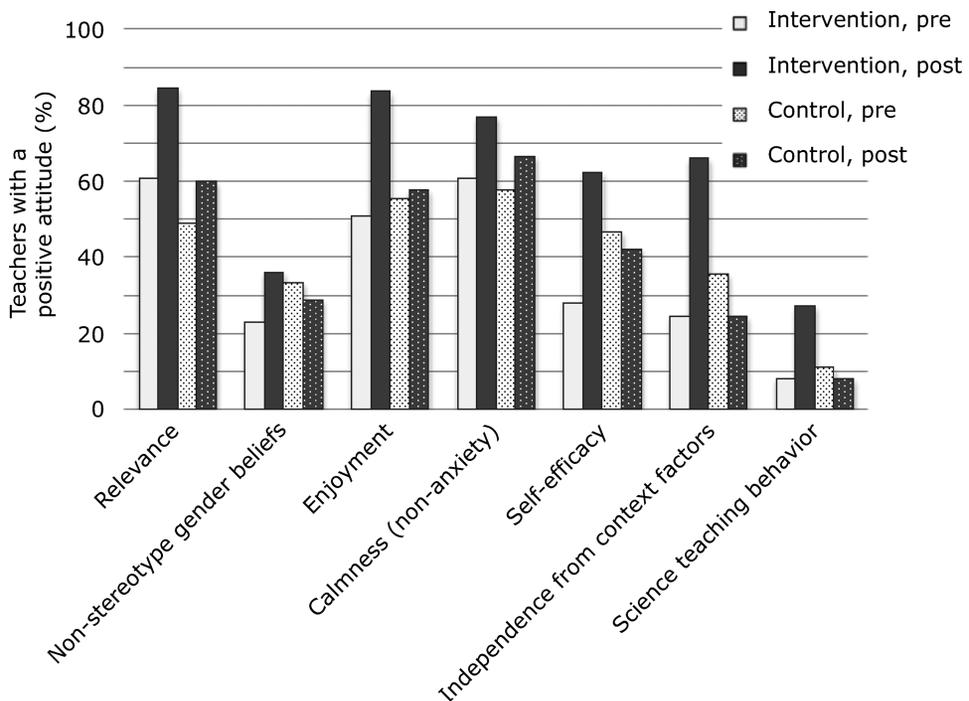


Figure 3. Percentage of teachers in the intervention and control group showing a positive attitude at pretest and posttest. Positive attitude is calculated as the percentage of teachers showing an average score equal to or larger than 4 for Relevance, Enjoyment, and Self-efficacy, and equal to or smaller than 2 for Gender, Anxiety, and Context dependency. These latter components are rephrased as non-stereotypical gender beliefs (contrary to gender stereotypical beliefs), calmness (contrary to anxiety), and independency from context factors (contrary to context dependency). For *behavior* a cutoff point of equal to or higher than 3 is used, reflecting teachers that teach science at least once 1 per month. Please note that for *each* component a higher percentage indicates more teachers showing a more positive attitude, in contrast to Figure 1 where, for some components, a lower score denotes a more positive result.

(58%) did not change and for relevance increased about 10% (60%). Regarding feelings of anxiety, the percentage of teachers not feeling anxious increased 15% in the intervention group (to 75%), and only 9% in the control group (to 67%).

Furthermore, before the course, only about 25% of the trained teachers felt confident about their own ability to teach science, felt independent from context factors for science teaching, and did not have stereotypical gender beliefs regarding science teaching. These percentages increased to 62%, 65%, and 35% respectively, after the course. For the control group these percentages decreased by a small amount (from 33% to 29% of the teachers that did not have gender stereotypical beliefs, from 27% to 24% of the teachers that felt confident about their capacity to teach science, and from 36% to 24% of the teachers that did not feel dependent on context factors). Around 10% of all teachers intended to teach science more than once per month at the time of the pretest. This percentage increased to 27% in the intervention group, while in the control group, this declined to 8% at the time of the posttest.

To summarize the results, the attitude-focused training course positively affected teachers' self-efficacy beliefs regarding science and science teaching. They felt more able to teach science and to deal with science in daily life. Teachers also enjoyed teaching science more and felt less dependent on context factors in order to be able to teach science. In addition, the trained teachers felt less anxious about dealing with science in daily life and regarded science as being more relevant to society. Teachers reported to be more engaged in science teaching and in science-related daily activities. These improvements are supported by the increased percentage of teachers that showed a positive attitude towards science on these attitude components, and that reported to conduct more science related activities in their classroom.

Discussion

The results of the present study indicate that attitude-focused professional development has positive effects on primary teachers' professional and personal attitudes towards science and has a major impact on teachers' self-reported science teaching behavior and science related activities in daily life. These effects support our hypothesis that in order to stimulate teachers' attitudes towards science it is important to reflect upon and challenge their attitudes toward (teaching) science, their scientific attitudes, and their knowledge and skills about science.

The results of our post-hoc paired-*t*-test analyses per group indicated that the primary teachers who participated in our training course clearly improved on all attitude components that constitute their professional attitude towards teaching science and on almost all components of their personal attitude towards science (as will be discussed below). This was not the case for the control group, although they did show some improvements, as could be expected since they were engaged with science teaching during the period of the intervention. However, the positive attitude change of the intervention group did not result in a statistically significant univariate interaction effect for every attitude component (a combined effect of time and condition). One factor that might contribute to this lack of interaction effects is the rather small number of participants in the intervention and control group, which may have lowered the statistical power of our analyses.

Which Components Improved?

Professional Attitude. The largest professional attitude effects of the training course were observed for perceived dependency on context factors and self-efficacy. This indicates that trained teachers felt more in control over science teaching: they felt more able to teach science, had greater self-confidence, and felt less dependent on the availability of context factors such as time, methods, and materials after the training course. Furthermore, the increase in enjoyment when

teaching science was stronger for the intervention group compared to the control group. How these variables relate to each other is not yet known, but we speculate that feeling more in control over science teaching may also increase feelings of enjoyment.

An evaluation of the course, using open questions, yielded several qualitative responses and comments of the teachers that provide more insight into the mechanisms that might have led to these attitude changes. These comments are on the level of opinions and experiences and are therefore not analyzed. Teachers frequently commented that the course made them realize that science teaching does not have to be complex at all. This made them feel that science teaching became more accessible to them. Teachers initially believed that science teaching was about complex systems and required in-depth, content knowledge of the teacher. After the course, they viewed science teaching more as being about inquiry learning and a scientific habit-of-mind. As one female teacher stated: "I expected science to be difficult and was even a bit scared. But it turns out not to be that difficult at all. I do not have to know everything and I can bring inquiry in the classroom in small steps." A male teacher wrote: "I was often thinking way too complex, but you can reach a lot in science teaching using very simple materials and methods." This realization might have decreased teachers' feelings of anxiety for teaching science and their feelings of dependency on context factors. At the same time, it may have increased their self-efficacy beliefs.

As stated in the introduction, although we believe it is important to stimulate all professional attitude components with professional development, the components of the third attitude dimension, Perceived control, seem to be the most essential antecedents of science teaching behavior. Self-efficacy has been recognized as a very salient component, which was investigated in many science education studies (e.g., Bleicher, 2007; Carleton et al., 2008; Koballa, 1986; for an overview see van Aalderen-Smeets et al., 2012). Correspondingly, one of the most frequently used instruments in science education research is the Science Teaching Efficacy Beliefs Instrument (STEBI), which measures perceived self-efficacy in science teaching (Bleicher, 2004; Enochs & Riggs, 1990). However, the second component of the dimension of Perceived control, the component of Perceived dependency on context factors, has not been investigated that widely (e.g., Carleton et al., 2008; Haney et al., 1996; Lumpe, Haney, & Czerniak, 2000; for an overview see van Aalderen-Smeets et al., 2012). Despite this lack of attention for context factors in science education literature, we believe this to be an equally important component. A previous study demonstrated that even primary teachers who hold fairly positive attitudes towards science teaching in terms of enjoyment or self-efficacy, often choose not to teach science in their curriculum because of a perceived lack of time, teaching materials or other contextual resources (Asma et al., 2011).

The proposed relevance of self-efficacy and perceived dependency on context factors is supported by the Theory of Planned Behavior that states that self-efficacy and the concept of controllability, similar to dependency on context factors, are among the major antecedents of behavioral intention and actual behavior (Ajzen & Fishbein, 1980). Ajzen (2002) argues that, depending on the purpose of the investigation, these two concepts can be regarded as a unitary concept (called Perceived Behavioral Control) or as two related, but separate, concepts, as was done in the theoretical framework for primary teachers' attitudes towards science described in the Introduction (van Aalderen-Smeets et al., 2012). Focusing on teachers' self-efficacy alone is therefore not sufficient to stimulate science teaching in primary school. The results of the current study support these claims by showing that a large decrease in perceived context dependency occurs simultaneously with a large increase in science teaching behavior.

The lack of effect for the component of relevance could reflect a ceiling effect. The mean pretest scores in the intervention group ($M=4.0$, on a scale from 1 to 5) and control group ($M=4.0$) are already rather high, which restrains the room for improvement. Supporting this,

many teachers stated in the evaluation that their belief regarding the relevance of *teaching* science did not change; they already found science teaching important before the course. That could be why they voluntarily signed up for the course. However, some teachers did add that the course gave them additional ideas of how to teach science. They initially believed that science was just another subject they were stimulated to teach by the government in order to boost pupils' STEM educational choices and that, therefore, science teaching was relevant for society. The course, however, made them realize that science is also about the process of science, about developing creative and critical thinking skills and a scientific attitude. They became aware that science could enrich students' personal development. One teacher stated: "Inquiry is an important way of learning and I started using this when teaching other subjects as well." So, another explanation for the lack of statistically significant results on teachers' relevance beliefs could be that the content of these beliefs did change (from "relevance to society" to "relevance for the development of children's thinking") but not the value of the responses.

Furthermore, teachers stated that they did not believe there to be any gender differences, or that these beliefs changed much due to the course. This explains why there are no significant changes in the measured stereotypical beliefs.

Personal Attitude. We assume that professional attitude toward teaching science is a stronger predictor of actual science teaching behavior than teachers' personal attitude towards science, because of the more direct link to actual science teaching. Nonetheless, we do assume that improvements in personal attitude toward science will sustain and may positively influence improvements in professional attitude.

Effects on personal attitude were observed for the components of relevance, self-efficacy, and anxiety. Trained teachers felt better able to discuss scientific subjects with other people, they felt they were better able to understand science, and they felt less anxious to engage in science-oriented activities. Please note, that these changes occurred without providing these teachers with scientific content knowledge during the course. Both the intervention and control group improved in enjoyment of science in their daily life and self-efficacy. The control group was involved with and engaged in science activities during the period of the project, which could explain these effects. However, for self-efficacy we see that the intervention group improved to a greater extent, which was not the case for enjoyment.

The most salient comment given by almost all teachers during the evaluation of the course referred to the increase in their personal curiosity and inquisitiveness, such as "The course made me see the world around us in a different way, I became so much more curious" or "Being curious is fun!" In addition, many teachers stated that they became much more aware of the fact that science is related to everything we see around us in our daily lives: "Science is everywhere" These personal developments could underlie the improvement observed in relevance beliefs. Having a better understanding about the nature of science and a broader view of science might also have decreased their anxiety and may have boosted their personal self-efficacy. How these personal attitude beliefs relate to teachers' professional attitude is not clear. More research into the strength and direction of a possible relation between personal and professional attitude could provide insight into the relevance of personal attitude when stimulating science teaching.

Science Related Behavior. The above-described positive changes in attitude among the trained teachers are corroborated by a large increase in the amount of science teaching behavior in the classroom and by an increase in engagement with science related activities in teachers' personal lives. Since the aim of our professional development course was to increase the time and amount of science education and inquiry learning in primary school, this result is very encouraging. Nevertheless, this success must be tempered with a reservation. Inspection of

Figure 3 shows that after the training course, still only a quarter of the trained teachers (27%) indicated to teach science at least once a month. This low frequency in science teaching behavior might be due to the fact that (a) the training course only spanned half a year, and (b) the posttest was administered directly after the last meeting of the course, which means that the teachers did not yet have the chance to improve their science teaching behavior. Comments made by the teachers during the evaluation of the course support this last option. Many teachers stated that their school would only start implementing science teaching and inquiry learning the subsequent year. This means that these teachers were not encouraged or supported to teach science by the school administration at the moment of the posttest. Nevertheless, teachers stated that they were already implementing science teaching in their own classrooms on a small scale, such as using more inquiry-based teaching in the classroom; “I do not follow the pre-structured method that closely anymore. The lessons are more child-oriented, the students direct the lesson by their questions” or “I feel so much more secure in deviating from the pre-structured boring methods and use more inquiry learning.” Even though these comments are very encouraging, we would like to see a much higher percentage of teachers teaching science or performing inquiry-based practices in primary education. Participating teachers reported that their students became very enthusiastic about this new way of learning. This hopefully stimulates the teachers, in turn, to continue and further develop and expand their actual science teaching.

The teacher comments provided during the evaluation provide more insight in how attitude change could impact actual classroom teaching. Improved attitudes made teachers implement science teaching in small steps in their lessons, for example, by asking different questions or adopting a more child-oriented way of teaching, i.e., stimulating the children to ask questions and taking these questions seriously. But improved teacher attitudes may also boost science teaching through the stimulation of students’ curiosity and critical thinking skills. Furthermore, some teachers stated that they started using inquiry-teaching methods for non-science school subjects as well. The most salient mechanism through which these attitude changes were obtained was through creating awareness and reflection, i.e., reflecting upon ones attitudes and beliefs, reflecting upon ones emotions, and reflecting upon ones teaching and behavior. This indicates that reflection is a very valuable characteristic of professional development.

Coherence With Other Professional Development Approaches

Although the present training course took an innovative attitude-focused approach, and refrained from merely teaching science *content*, it follows most other criteria deemed essential for successful professional development defined by previous research (Desimone, 2009; Tytler, 2007; van Driel et al., 2001). First, active learning forms a major part of our training course, which is stated to be one of the most influential elements of professional development (Desimone, 2009). During each meeting, teachers performed two or three open-ended assignments, which forced them either to reflect on their own attitudes or to apply part of the empirical cycle. These assignments prepared teachers for the take-home assignments in which they were also actively engaged with science or science education. Second, the current training course challenges the knowledge and beliefs of teachers by first creating awareness about teachers’ own beliefs and knowledge. This adheres to the notion of coherence in professional development, i.e., the extent to which learning is consistent with the existing knowledge and beliefs of teachers regarding science and science teaching (Desimone, 2009; van Driel et al., 2001). But it is also related to teachers’ *practical knowledge*, i.e., teachers’ knowledge and beliefs about their own teaching practice in general (van Driel et al., 2001), which is relevant since teachers’ practical knowledge is believed to have a major influence on how teachers perceive and respond to educational change.

Third, the course emphasizes the importance of wonderment and curiosity in science education and includes assignments that explicitly ask for curiosity about the world around you. This agrees with the notion that science education should be related to students' daily lives (Haney et al., 1996; Tytler, 2007). Using curiosity as a starting point implies that it is related to students' (in our case teachers') daily lives and their interests. This includes discussing the questions that participants come up with, working with themes brought up by the participants, or creating curiosity for the topics that need to be educated.

Conclusion

The results of the present study are promising but must also be interpreted in light of several procedural and methodological potential limitations. First, we must be cautious with generalizing the conclusions. The participants in both the intervention and control group participated voluntarily, which may reflect an increased interest in the subject compared to the "average" Dutch teacher. In addition, the participants in the study were, due to practical reasons, not randomly assigned to the intervention and control group. However, randomly recruiting and assigning teachers and schools for any science education research project is difficult, because schools and teachers that do not recognize or share the belief in the relevance of such a project are not likely to participate, especially when they are recruited as a control participant.

Second, the amount of time spent on the professional development course by participants (18 contact hours) was limited because of practical and financial reasons and was smaller than the 20 to 50 contact hours that are recommended by several scientific guidelines for effective professional development (Blank, De las Alas, & Smith, 2008; Borke, 2004; Desimone, 2009). However, there is no reason to expect different results with a more substantiated course that would run over a year with more contact and self-study hours. On the contrary, a more substantiated course would probably only enhance the effects of the present course.

Third, we did not compare the effects of our training course with the effects of traditional professional development focusing on only content and/or scientific inquiry. Since only the intervention group followed training, one could argue that it is not surprising that a training course has more effect than no training course. However, teachers in the control group were not naïve, but were actively engaged in science activities. Since they did so on a voluntarily basis (being a member of the Science Center Teacher Club), one could even expect that this group might show a higher than average interest in science and positive attitudes towards science. The fact that the control group did not improve in attitude, despite their involvement with science activities, whether this was actual teaching, following a course, or any other related activity, shows that merely being engaged with science or science teaching does not improve attitudes. In addition, our study showed that teachers' attitudes, which are usually regarded as being stable and hard to change (Ramey-Gassert et al., 1996; Schoon & Boone, 1998), can be changed with an attitude-focused training course based on a sound theoretical framework, within a duration of only 6 months, and therefore disproves the claim that attitudes cannot be changed.

Fourth, in a study on the relation between teachers' beliefs and their actual school practices, Mansour (2013) described that teacher practices only partially corresponded to their beliefs and attitudes. Some of their practices were consistent with their beliefs, while others were inconsistent. The current study only measured teachers' self-reported attitudes and science teaching behavior and did not measure teachers' actual teaching practices or the effects on students. However, it has been shown that increased teacher self-efficacy beliefs have a positive impact on students' beliefs and performance (Jarvis, 2004; Lumpe et al., 2012). Future research should investigate the effects of improvements in teacher attitudes and teaching behavior, as measured in this study, on the actual practices of primary teachers in the classroom and the effects on their students.

Notwithstanding these limitations, we feel safe to say that the positive effects in this study can be credited to our newly developed attitude-focused training course. Despite the fact that teachers in our control group were also highly engaged in science teaching, we observed a clear positive effect of our attitude-focused training course in the intervention group, which was not present in the control group. This shows that the process of raising awareness among primary teachers about their own attitudes towards science teaching, reflecting on these attitudes, and showing them how to teach science independent of specific science content or pre-structured teaching materials, indeed seems a necessary prerequisite for enhancing attitudes.

The training course presented in this study was aimed specifically at attitudes, and was small-scaled compared to the guidelines for professional development. We view this course as an essential, but not sufficient, first step in the professional development of primary teachers in science education. Once attitudes have improved and teachers have gained a basic knowledge of and about science, additional follow-up training should deepen and anchor teachers' attitudes, skills, and knowledge regarding science teaching and inquiry learning.

The present study has important implications for primary science education. It provides a clear argument for including an explicit focus on teachers' attitudes in the lists of critical components for effective primary teacher professional development in science education (as for example described by Desimone, 2009). First, explicitly focusing on teachers' attitude in professional development improves teachers' feeling of being in control over science teaching and their science related behavior. Second, such professional development can be a relatively short intervention, and third, improving attitudes towards science and towards teaching science is an essential start for the professional development of primary teachers in science education, since their attitudes are generally low. Future research is necessary to investigate the contribution of attitude-focused professional development to actual science teaching behavior in the classroom and to changes in teachers' and pupils' scientific attitudes, such as curiosity or being inquisitive.

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