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Primary teachers conducting inquiry projects: effects on attitudes towards teaching science and conducting inquiry

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ABSTRACT

This study used an experimental, pretest-posttest control group design to investigate whether participation in a large-scale inquiry project would improve primary teachers' attitudes towards teaching science and towards conducting inquiry. The inquiry project positively affected several elements of teachers' attitudes. Teachers felt less anxious about teaching science and felt less dependent on contextual factors compared to the control group. With regard to attitude towards conducting inquiry, teachers felt less anxious and more able to conduct an inquiry project. There were no effects on other attitude components, such as self-efficacy beliefs or relevance beliefs, or on self-reported science teaching behaviour. These results indicate that practitioner research may have a partially positive effect on teachers' attitudes, but that it may not be sufficient to fully change primary teachers' attitudes and their actual science teaching behaviour. In comparison, a previous study showed that attitude-focused professional development in science education has a more profound impact on primary teachers' attitudes and science teaching behaviour. In our view, future interventions aiming to stimulate science teaching should combine both approaches, an explicit focus on attitude change together with familiarisation with inquiry, in order to improve primary teachers' attitudes and classroom practices.

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KEYWORDS
Inquiry; attitude towards science; primary teachers; science education; professional development

There is growing public recognition of the importance and economic value of technological innovation and scientific knowledge. Despite this, the number of young people who choose a path of study or career in science, technology, engineering, or mathematics (STEM) is still low (Osborne, Simon, & Collins, 2003; Woods-McConney, Oliver, McConney, Schibeci, & Maor, 2014). In order to promote students' pursuit of STEM studies, it is crucial to positively influence their *attitudes* towards science, scientists, and the learning of science (van Aalderen-Smeets, Walma van der Molen, & Asma,

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2012; Osborne et al., 2003). Because children's interest in and images of science may develop at an early age (Osborne et al., 2003; Tai, Qi Liu, Maltese, & Fan, 2006), it is important to promote positive attitudes towards science and inquiry early on, preferably during primary education.

Students' attitudes towards science and their learning goals in science are strongly influenced by teacher–student interactions and by teachers' own expectations and attitudes (Hattie, 2009; Osborne et al., 2003). Unfortunately, however, primary teachers are often influenced by negative experiences with science during their own primary and secondary school education, which often results in negative attitudes towards science that persist even after their pre-service teacher training (Jarrett, 1999; Mulholland & Wallace, 1996; Palmer, 2002; Sanger, 2008; Tosun, 2000; Young & Kellogg, 1993). Such negative attitudes may manifest themselves in lower levels of confidence and self-efficacy beliefs about teaching science, in devoting less time to teaching science in the classroom, and in increases in teachers' self-reported feeling of dependency on standardised instructional methods (Appleton & Kindt, 1999; Goodrum, Hackling, & Rennie, 2001; Harlen & Holroyd, 1997; Jarvis & Pell, 2004; Skamp, 1991; Tosun, 2000; Yates & Goodrum, 1990). Promoting a positive attitude towards teaching science among primary teachers is therefore critical when aiming to foster primary school children's positive attitudes towards science (Borko, 2004; Cobern & Loving, 2002; Desimone, 2009; Haney & Lumpe, 1995; Nye, Konstantopoulos, & Hedges, 2004; van Aalderen-Smeets & Walma van der Molen, 2015).

Although attitudes are often regarded as stable personal beliefs that are difficult to change, these beliefs can be improved through professional training. A recent study by van Aalderen-Smeets and Walma van der Molen (2015) showed that in-service primary teachers' attitudes towards science and towards teaching science improved during six months of attitude-focused professional training. This intervention included assignments to create awareness about teachers' own attitudes towards science and included challenges intended to change these attitudes. It did not provide pre-structured, recipe-like science lesson examples. Instead, the focus of the training was mainly on assignments that stimulated attitude change and, to a lesser extent, on assignments that provided some experience with conducting inquiry.

In addition to feeling reluctant to teach science content, most primary teachers find it even more difficult to teach scientific practices in the form of inquiry-based science, as they lack sufficient familiarity with the process of scientific research itself (Roth, McGinn, & Bowen, 1998; Smith & Anderson, 1999; Yager, 1997). This is the case even though it has been well established that science education should not only address content knowledge, but should also be taught as the *process* of science. This means advocating teaching and learning by inquiry and adopting an inquisitive habit of mind, in order to foster students' positive attitudes towards and engagement with science (Earl & Katz, 2002; Lederman et al., 2014; Mant, Wilson, & Coates, 2007; Melear, Goodlaxson, Warne, & Hickok, 2000; Osborne, 2014). Inquiry learning is a constructivist practice that supports meaningful learning. It refers to minds-on and hands-on science activities, including solving real-life problems, asking open-ended questions, being curious, using critical and creative thinking skills, and perceiving the inquiry process as a way to learn, not just a way to obtain knowledge (Osborne, 2014; Tobin & Tippins, 1993). This definition of inquiry learning implies that teaching science through inquiry does not necessarily require a fully complete and delimited science lesson. It can be integrated within the curriculum as a whole, even through small activities such as asking different types of questions to stimulate children's curiosity. Therefore, encouraging inquiry practices in primary schools calls for teachers to become familiar at least to some degree with the process of conducting inquiry projects and for their attitudes towards science to improve.

Previous research has shown that familiarising *pre-service* teachers with inquiry through practitioner research, that is, having primary and secondary student teachers design and conduct authentic investigations themselves during teacher training, led to: (a) better understanding of science, the nature of science and scientific inquiry (Haefner & Zembal-Saul, 2004; Morrison, 2008; Shapiro, 1996); (b) improved attitudes towards inquiry (Haefner & Zembal-Saul, 2004; Morrison, 2008); (c) increased motivation for and greater skills in critical analysis (Melear et al., 2000); and (d) improvement in attitudes towards teaching and learning in general, unrelated to science education (Zeichner, 2003). These results show that practitioner research may positively influence pre-service teachers' *personal attitudes* towards science and inquiry, namely, their individual beliefs, views, and understandings about science and inquiry, independent from their role as a teacher. Although these results are relevant, they do not necessarily tell us whether increased familiarisation with inquiry also changes teachers' *professional attitude* towards *teaching* science (see van Aalderen-Smeets et al., 2012, for more information on the distinction between teachers' personal and professional attitudes towards science). Furthermore, the pre-service-oriented studies used qualitative interviews with small samples of pre-service teachers. These qualitative measures provided much detail about the underlying attitudes and views of the student teachers who participated in the studies. However, they did not provide us with more objective measures of changes in attitudes among a larger group of in-service teachers. In those cases where the above-mentioned studies did address pre-service teachers' professional attitude towards *teaching* science, they mostly investigated student teachers' future intentions to use inquiry in their teaching practices.

To gain further insight into the potential positive effects of practitioner research on teachers' attitudes towards teaching science and inquiry, we need to investigate the influence of practitioner research among in-service teachers and we need to use quantitative measures to explore changes in their attitudes over time. Compared to pre-service teachers, in-service teachers are more experienced with actual teaching, they have more established teaching practices and attitudes towards teaching, and they have the opportunity to directly change their daily teaching practices. On the other hand, they have less time for conducting their own inquiry research in addition to their normal teaching. In the present study we used an experimental, pre-post control group design to investigate whether practitioner research conducted by in-service teachers has positive effects on their professional attitude towards teaching science and on their attitude towards conducting inquiry. We hypothesised that familiarising in-service teachers with the inquiry process would have a positive effect on their attitude towards the act of conducting inquiry, on their attitude towards teaching science, and on their actual science teaching behaviour.

A framework for primary teachers' professional attitudes towards science teaching and inquiry

The present study used a theoretical framework for primary teachers' professional attitude towards science teaching, which was developed by van Aalderen-Smeets et al. (2012). The framework explicates and structures the range of underlying components of primary teachers' attitude towards science teaching. The framework was based on an extensive review of previously used conceptual definitions of the construct of primary teachers' attitude towards science. 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 behaviour (e.g. Ajzen & Fishbein, 1980). The resulting framework, which is presented in Figure 1, consists of three dimensions (cognition, affect, and perceived control) that encompass a total of seven components.

The components of the framework represent different attitudinal beliefs and feelings towards the teaching of science. The first dimension, cognition, refers to teachers' beliefs and opinions about (a) the relevance of science education in primary schools, (b) the relative difficulty of teaching science at the primary level, and (c) gender differences regarding science teaching. The second dimension, affect, includes the components (a) enjoyment of science teaching and (b) anxiety related to science teaching. The third dimension, perceived control, refers to the degree of control teachers perceive themselves to have over science teaching, 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 contextual factors (beliefs about the degree to which science teaching depends upon external factors, such as the availability of standardised teaching methods, adequate time, or other resources).

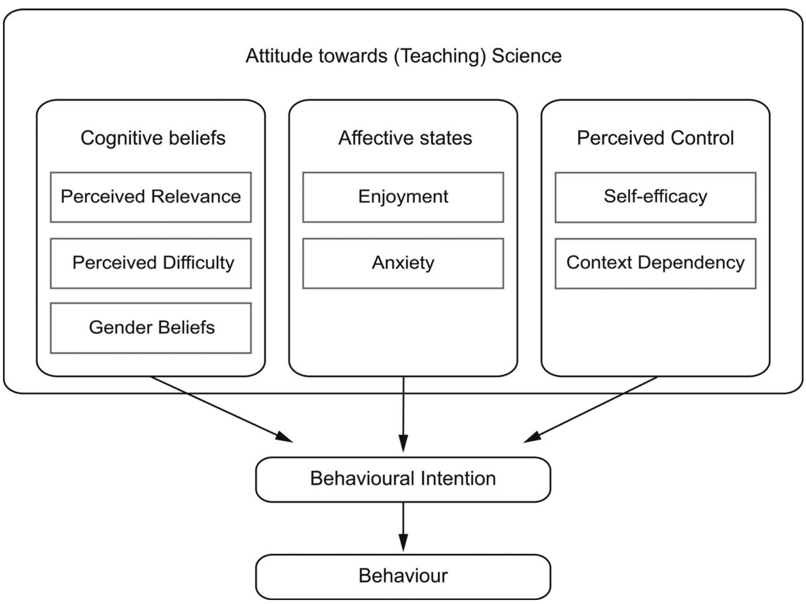

Figure 1. Theoretical framework for the construct of primary teachers' attitude towards teaching science (figure originally printed in van Aalderen-Smeets et al., 2012).

Thus far, no such framework has been available for primary teachers' attitude towards conducting inquiry. However, because the topic of interest – scientific inquiry – is highly related to science and science teaching practices, we believed it was reasonable to take the framework for attitude towards teaching science as a starting point for developing a conceptual framework that describes the components of primary teachers' attitude towards conducting inquiry. We evaluated and adapted each component of the framework to fit this concept. Within the first dimension, Cognition, we found the component of relevance to be applicable, as it provides insight into whether teachers find the process of conducting inquiry projects relevant for their own development as teachers and for their teaching practices. The component of relevance was defined as how important teachers think conducting research is for the quality of their own teaching practices and their development as teachers. We regarded the second component, difficulty of teaching science, as not applicable within this project. This component would refer to what other teachers believe about the difficulty of conducting inquiry and we believe this component would not change due to the intervention. The third component of Cognition, gender-stereotypical beliefs, refers to beliefs about male/female differences in science and, in this context, differences in conducting inquiry. There is no theoretical argument for expecting changes or differences in gender-stereotypical beliefs regarding conducting inquiry or research (Bibi, Lqbal, & Majid, 2012), and we therefore excluded this component (which is included in attitude towards teaching science).

Both components of the second dimension of attitude towards teaching science, affect, were also relevant for attitude towards conducting inquiry. These are enjoyment of conducting an inquiry project, and feelings of anxiety when conducting inquiry. Both components of the third dimension, perceived control, were also expected to provide insight into primary teachers' attitude towards conducting inquiry. Self-efficacy was defined as teachers' beliefs about their ability to conduct inquiry and to overcome obstacles when doing so. The component of perceived dependency on contextual factors was defined as feeling dependent on external contextual factors when conducting inquiry projects, such as support from colleagues, teacher educators, or researchers, the availability of time to work on the project, or the availability of materials.

Method

Subjects and design

A total of 62 Dutch primary teachers from 13 different primary schools in the Western part of The Netherlands participated in the study. The teachers represented primary teachers from all grades (K-8 in The Netherlands, ages 4–12). The study used a (quasi-) experimental-control, pretest-posttest design to investigate the impact of participation in an inquiry project on: (a) in-service primary teachers' attitude towards teaching science, (b) their attitude towards conducting scientific inquiry, and (c) their self-reported science teaching behaviour. Participants in both the experimental and control groups were asked to complete our online pretest survey instrument before the start of the project and the posttest survey at the end of the project.

The experimental group consisted of 38 teachers (90% female, mean age 44.6 years, SD = 10.9). Teachers in the experimental group conducted a large-scale inquiry project that they initiated, designed, and carried out, spanning a full academic year. Participants were not randomly assigned to the experimental and control groups. Teachers in the experimental group were interested in science education professional development and enrolled voluntarily. Of the teachers in the experimental group, 66% had no previous experience with inquiry within the school context, 24% had experience with inquiry over the past 1–3 years, and 10% had experience with inquiry within the school context over the past 3 years or more.

The control group consisted of 24 primary teachers from the same schools as the participants in the experimental group (92% female, mean age 43.2 years, SD = 10.4). Teachers in the control group also enrolled in the study on a voluntary basis, but did not actively participate in the inquiry project; they did not conduct inquiry, or attend any of the coaching sessions or general meetings. Of the teachers in the control group, 83% had no previous experience with inquiry within the school context, 8% had experience with inquiry over the past 1–3 years, and 9% had experiences with inquiry within the school context over the past 3 years or more, which indicates that the control group had slightly less prior experience with research in the school context. These teachers were not expected to invest time in science teaching. We recruited the control group from the same schools as the teachers in the experimental group because this allows attribution of possible differences in outcomes between the experimental and control groups to the active participation of teachers in an inquiry research project (experimental group) compared to standing on the sidelines, that is, taking notice of the research projects and hearing/seeing about them in school, but not being actively involved (control group).

The inquiry project intervention

The inquiry project was developed as part of a national initiative in The Netherlands to promote science education and inquiry learning in elementary schools. The project ran for one school year, during which teams of two teachers chose their own subject of inquiry and conducted their own inquiry project. These subjects were very diverse, ranging from action research-type projects in which teachers investigated aspects of their own teaching practices (Kemmis, 2009) to more experiment-like research projects investigating cognitive processes among pupils, such as reading development. An example of an action research-like project was a project investigating why many students who passed on to high school received lower mathematics grades than would be expected, based on their results in primary school. A team that used a more experimental design investigated the hypothesis that physical exercise right before a math lesson would improve blood circulation, attention, and subsequent performance, compared to no physical exercise.

Procedure

The inquiry project started at the beginning of the school year and continued during the entire academic year. Participating in-service elementary teachers conducted the inquiry project alongside their normal teaching activities and were asked to invest a total of around 45 hours in the overall project. The teachers were coached by one of three teacher educators. These supervisors were experienced teacher trainers with experience and expertise in conducting inquiry. They were not part of the research team conducting the current study. Teacher teams were themselves responsible for the progress and content of their inquiry projects. However, they were expected to attend and participate in supervision and coaching activities.

During the course of the project, nine general meetings were organised for the teachers participating in the inquiry projects, in which information about a relevant research-related methodological topic was presented by academic researchers. In addition, each teacher team received, on average, between 3 and 8 hours of individual coaching by the supervisor, such as feedback on their specific research questions and hypotheses, research planning, or use of methods of analysis. Scientific quality of the inquiry projects was assured by having the supervisors check whether the research questions, designs, and statistical analyses met basic research criteria. The teachers wrote their project reports on the basis of a prescribed outline to make sure that all necessary components in the projects would be addressed. The reports were reviewed and provided with feedback twice by a team of academic researchers (other than the authors).

These general and more targeted coaching activities guided teachers with regard to each step of the scientific research cycle, that is, defining an area of interest, literature search, formulating research questions and hypotheses, developing a research design and procedure, collecting data, analysing data, interpreting data, and presenting results. During the entire trajectory, teachers were free to ask the teacher educators questions regarding their projects via email or telephone. The ninth and final meeting was organised as a scientific conference, in which the teacher teams presented their inquiry projects to each other using posters and oral presentations.

The project included key elements that correspond to essential factors in effective professional development (Admiraal, Smit, & Zwart, 2013). It was intended to stimulate teachers' intrinsic motivation by putting teachers in charge of defining their own research questions, designing their research, and collecting, analysing, and interpreting their data. In addition, the project prompted teachers to investigate topics that were closely related to their own school practices, or that arose from their curiosity and experiences in their daily classrooms. Furthermore, the project involved active learning through inquiry activities, took place in a team setting, and over a long period of time.

Measurement instruments

The questionnaire used to measure the different constructs contained a total of 51 items; see the Appendix for an overview of the subscales, example items, and internal consistencies. Note that the table is structured by constructs, but the order of items on the questionnaire was randomised.

Professional attitude towards teaching science

We used the Dimensions of Attitude towards Science questionnaire (DAS) to measure teachers' *attitudes towards teaching science* (for a comprehensive description of the DAS instrument and all the items, see van Aalderen-Smeets & Walma van der Molen, 2013). The DAS is a validated instrument that measures the components of the theoretical framework for professional attitude towards teaching science described in our Introduction. For this study we omitted the component of difficulty, since we did not expect teachers' beliefs about the general difficulty of teaching science (i.e. do you think other teachers find teaching science difficult) to change due to the inquiry project intervention.

We used a Likert-type response scale ranging from 1, *totally disagree*, to 5, *totally agree*, with the middle three options labelled only by their number (*2, 3*, and *4*). The dimension of cognition included two subscales (see the Appendix for an overview of the subscales): relevance, consisting of 5 items, for example, 'I think that science should be anchored in primary education as early as possible' and gender-stereotypical beliefs, consisting of 5 items, such as 'I think that male primary school teachers experience more enjoyment in teaching science than female teachers.' The dimension of affect included two subscales, both consisting of 4 items: enjoyment, for example, 'Teaching science makes me enthusiastic' and anxiety, such as 'Teaching science makes me nervous.' The third dimension, perceived control, included the subscales for self-efficacy, consisting of 4 items, such as 'I have enough knowledge of the content of science to teach this subject well in primary school' and a subscale for context dependency, consisting of 3 items, such as 'For me, the availability of a ready-to-use existing package of materials (e.g. science kits) is essential for teaching science in class.'

Attitude towards conducting inquiry

In order to investigate changes in teachers' *attitudes towards conducting inquiry*, we adapted the original DAS. We modified and rephrased the original items of the DAS within each subscale by replacing what the attitude component is directed towards (teaching science) with a new direction (conducting inquiry), taking into account the readability of the items. We deleted items that could not be rephrased. The new attitude towards conducting inquiry scale consisted of 5 subscales with a total of 19 items, see the Appendix. The subscale of relevance (within the dimension of Cognition) consisted of 3 items, such as 'I believe that conducting inquiry by teachers should be incorporated as a standard element in teacher practices.' Within the dimension of affect, Enjoyment was measured using 4 items, such as 'I feel enthusiastic when conducting inquiry' and anxiety was measured with 4 items, such as 'I feel nervous when conducting inquiry myself.' The dimension of perceived control included two subscales. Self-efficacy was measured with 4 items, such as 'I have sufficient command of conducting inquiries to be able to do valid and reliable inquiry projects at my school.' The fifth subscale, measuring context dependency, consisted of 5 items, such as 'For me, the available support of my colleagues is decisive for whether or not I conduct inquiry at my school.'

We determined the internal consistency of each subscale using Cronbach's alpha (see the Appendix). The internal consistency of the subscales for both attitude towards inquiry and professional attitude towards teaching science proved to be high at both pretest and posttest, as indicated by Cronbach's alpha values that ranged between .71 and .96 (Field, 2009). Only the subscale for context dependency showed a lower alpha, between .55 and .75.

Science teaching behaviour

In addition, we measured self-reported inquiry-based teaching behaviour with a scale including 7 items, such as 'How often do you carry out a research project together with your students?' Response options for the items went from 1 to 5, labelled *seldom or* *never*, *a couple of times a year*, *1–3 times a month*, *weekly*, and *daily*. The internal consistency of this scale was high, with Cronbach's alpha values of .78 (pre) and .75 (post).

Data analysis

The effects of participation in the inquiry project were analysed using GLM (General Linear Model) repeated measures multivariate analysis of variances (MANOVAs), including post-hoc univariate analyses, performed on weighted sum scores for each subscale for attitude towards conducting inquiry and for each subscale for professional attitude towards teaching science. The items within each subscale (component) were aggregated to provide a mean score for each attitude component. We did not compute a total attitude score, since attitude is a multi-dimensional construct (van Aalderen-Smeets et al., 2012). We were interested in interactions that would show that the attitude scores of the experimental group improved more than those of the control group, for each component of attitude. To gain further insight into the effects of the inquiry project on each attitude component individually, we performed additional analyses within each group separately (experimental and control group) using one-sided, paired *t*-tests.

To test the effect of participation in the inquiry project on inquiry-based teaching behaviour, we conducted GLM repeated measures analysis of variances (ANOVAs), concerning the interaction of time and condition for the scores for teaching behaviour.

Results

Initial data checks showed that the distributions of the attitude scores for 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, that is, the interactions between condition (experimental and control groups) and time (pretest and posttest) for each attitude component. The results of the study are presented in Figure 2 and corresponding Table 1. Figure 2(a,c) shows the mean scores of the experimental group and the control group on the pretest of professional attitude (2(a)) and attitude towards conducting inquiry (2(c)). Figure 2(b,d) shows the mean posttest scores of both groups on both measures of attitude. 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. Statistically significant interactions of time and condition for each component are denoted with an asterisk in the figure.

Professional attitude towards teaching science

There was no significant difference between the experimental and control groups on professional attitude scores at the time of the pretest (between-groups MANOVA $\Lambda = .90$, $F(6, 55) = 0.99$, $p = .44$). To investigate the general effects of the inquiry project on teachers' professional attitude towards teaching science, a 2 (experimental versus control group) × 2 (time 1 versus time 2) × 6 (relevance versus gender beliefs versus enjoyment versus anxiety versus self-efficacy versus context dependency) repeated measures MANOVA was conducted, with condition as between-subjects factor, time as a within-

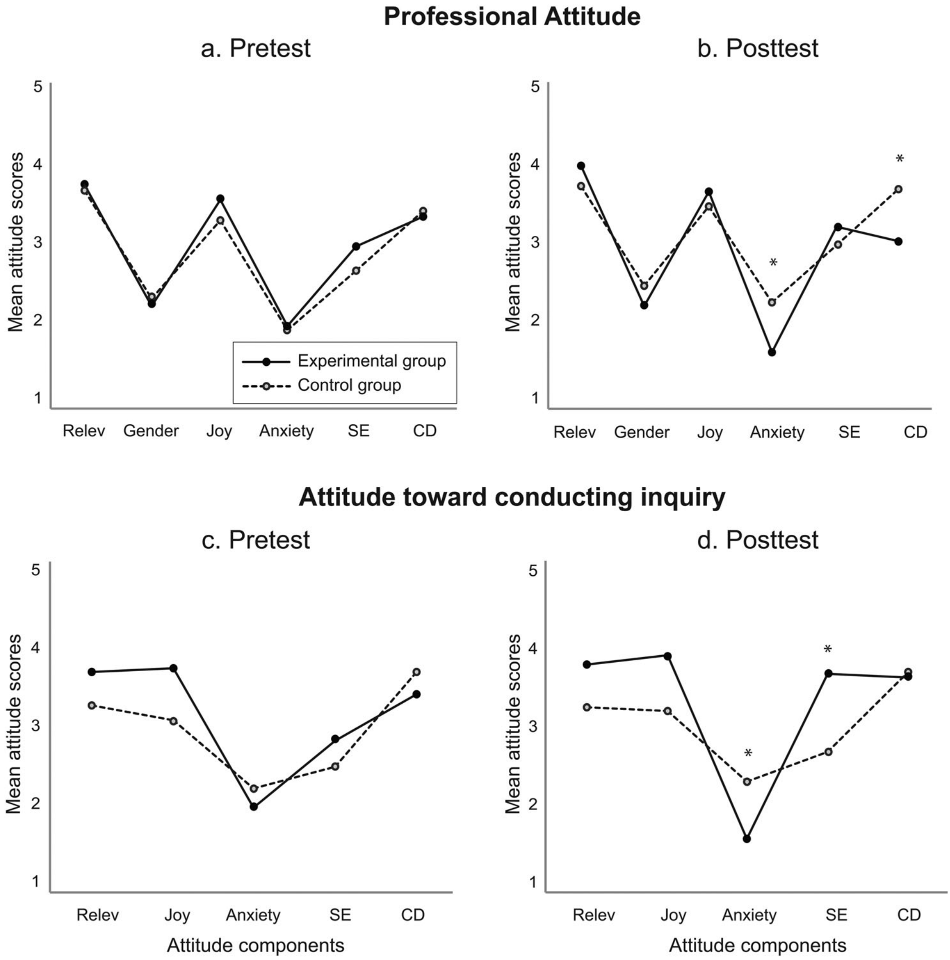

Figure 2. Mean attitude scores of the experimental and control groups before and after the inquiry project for each attitude component: relevance (relev), stereotypical gender beliefs (gender), enjoyment (joy), anxiety, self-efficacy (SE), and context dependency (CD). The figure shows (a) the pretest scores for the experimental and control groups on the components of professional attitude, (b) the posttest scores for the experimental and control groups on the components of professional attitude, (c) the pretest scores for the experimental and control groups on the components of attitude towards conducting inquiry, and (d) the posttest scores for the experimental and control groups on the components of attitude towards conducting inquiry. The connecting lines between the dots are for presentation purposes only and do not depict actual data. *Shows significant interactions (time × condition) from the univariate analyses for each attitude component.

subjects factor, and the six components of teachers' attitude towards teaching science as dependent variables. The test of within-subjects effects using Wilks's statistic revealed a significant overall interaction of time and condition, $\Lambda = .68$, $F(6,\ 55) = 4.25$, $p = .001$, $\eta^2 = .32$. This shows that, across the six attitude components, the change in attitude was larger for the experimental group compared to the control group.

To gain further insight into the origin of this interaction, we looked at the changes in each attitude component separately using post-hoc univariate analyses. Although there

Table 1. Mean scores and the interaction effects (time of measurement * condition) for each attitude component of professional attitude towards science and attitude towards conducting inquiry.

	Trained group				Control group				Time × group interaction		
	Pre		Post		Pre		Post				
	M	SD	*M*	SD	*M*	SD	*M*	SD	*F*	*p*	Partial η^2
Professional attitude towards teaching science											
Cognition											
Relevance	3.69	0.64	3.96[a]	0.53	3.63	0.70	3.72	0.64	1.78	.186	.03
Gender	2.24	0.87	2.26	0.77	2.33	0.77	2.51	0.90	0.86	.368	.01
Affect											
Enjoyment	3.51	0.73	3.64	0.67	3.27	0.76	3.46	0.65	0.19	.666	.00
Anxiety	1.99	0.90	1.68[a]	0.70	1.94	0.77	2.29	0.97	11.71	**.001**	.16
Perceived control											
Self-efficacy	2.95	0.71	3.22[a]	0.84	2.65	0.68	2.99[a]	0.65	0.21	.649	.00
Context dependency	3.32	0.93	3.04[a]	0.95	3.39	0.70	3.70[a]	0.77	13.64	**.001**	.19
Attitude towards conducting inquiry											
Cognition											
Relevance	3.67	0.70	3.76	0.68	3.26	0.79	3.24	0.95	0.55	.460	.00
Affect											
Enjoyment	3.71	0.74	3.87	0.84	3.09	0.75	3.20	0.97	0.10	.759	.00
Anxiety	2.02	0.91	1.65[a]	0.66	2.26	0.96	2.34	1.01	3.91	**.053**	.06
Perceived control											
Self-efficacy	2.84	0.86	3.64[a]	0.76	2.52	0.81	2.71	1.05	9.63	**.003**	.14
Context dependency	3.41	0.75	3.61	0.82	3.68	0.81	3.67	0.95	0.96	.332	.02
Science teaching behaviour											
Teaching science	1.70	0.50	1.88[a]	0.54	1.61	0.44	1.70	0.48	0.792	.377	.013

Note: Mean scores could range between 1 (totally disagree) and 5 (totally agree). *p*-Values printed in bold indicate a significant interaction effect ($p < .05$) between time and condition.
[a]Significant difference between pre- and post-test analysed with a paired *t*-test.

was no significant univariate interaction of time and condition for the component of relevance of teaching science $F(1,60) = 1.78$, $p = .186$, $\eta^2 = .03$, we did observe a trend. There was a significant increase in relevance scores for the experimental group, as indicated by a paired *t*-test, $t(37) = 3.47$, $p = .001$, while this effect was absent in the control group, $t(23) = 0.78$, $p = .443$.

There was a significant interaction of time and condition for the component of anxiety $F(1,60) = 11.71$, $p = .001$, $\eta^2 = .16$. This was supported by paired *t*-tests showing a significant decrease in anxiety within the experimental group, $t(37) = -3.09$, $p = .004$, and a significant increase within the control group, $t(23) = 1.90$, $p = .035$. The effect size, with a partial η^2 of .16, is medium (Cohen, 1988) and accounts for 16% of the overall variance.

The univariate analysis for perceived dependency on contextual factors also showed an interaction of time and condition $F(1, 60) = 13.64$, $p < .001$, $\eta^2 = .19$. This effect size is large and accounts for 19% of the overall variance (Cohen, 1988). A paired *t*-test showed a significant decrease in perceived dependency within the experimental group, $t(37) = -2.54$, $p = .015$, while there was a significant increase in perceived context dependency within the control group, $t(23) = 3.33$, $p = .003$. These results indicate that the experimental group felt less dependent on the availability of materials, methods, and time for teaching science after the inquiry project, while the teachers in the control group felt even more dependent on contextual factors at the time of the posttest. There were no significant univariate interactions for stereotypical gender beliefs and enjoyment when teaching science.

To sum up, the inquiry project had a medium to large effect on the components of anxiety and perceived context dependency; scores on both components decreased within the experimental group and increased in the control group. The component of relevance did show a trend for greater improvement within the experimental group compared to the control group, but the overall univariate interaction was not statistically significant. The components of gender-stereotypical beliefs, enjoyment, and self-efficacy did not show any effect or trend. For self-efficacy, this can be explained by the fact that both the experimental and the control groups showed improvements in self-efficacy beliefs (see Table 1).

Attitude towards conducting inquiry

A between-groups MANOVA at the time of the pretest showed that there was no *overall* significant difference between the experimental and control groups ($\Lambda = .84$, $F(5, 56) = 2.16$, $p = .07$). However, post-hoc univariate tests showed significant differences between the experimental and control groups at the time of the pretest for the components of relevance ($F(1,60) = 4.41$, $p = .04$) and enjoyment ($F(1,60) = 10.05$, $p = .002$). For the component of relevance, the experimental group scored significantly higher ($M = 3.67$) at pretest compared to the control group ($M = 3.26$), see Table 1. The experimental group also scored significantly higher for the component of enjoyment at pretest ($M = 3.71$) compared to the control group ($M = 3.09$). Teachers in the experimental group participated on a voluntary basis in the inquiry project, so they might have already enjoyed (or expected to enjoy) conducting inquiry more than the teachers in the control group and may have believed conducting inquiry to be more relevant compared to the control group.

To investigate the general effects of the inquiry project on teachers' attitudes towards conducting inquiry, a 2 (experimental versus control group) × 2 (time 1 versus time 2) × 5 (relevance versus enjoyment versus anxiety versus self-efficacy versus context dependency) repeated measures MANOVA was conducted, with condition as between-subjects factor, time as a within-subject factor, and the five attitude components as dependent variables. Significant interactions of time and condition in the univariate analyses are denoted with an asterisk.

The results of the repeated measures MANOVA using Wilks's statistic showed a significant difference between the experimental and control groups across the five attitude components over time, $\Lambda = .758$, $F(5, 56) = 3.58$, $p = .007$, $\eta^2 = .24$. To gain further insight into the origin of this interaction of time and condition, we looked at the univariate analyses for each individual attitude component.

The univariate analysis for the component of anxiety showed a significant interaction of time and condition, $F(1,60) = 3.91$, $p = .053$, $\eta^2 = .06$. Paired *t*-tests showed a significant decrease in anxiety from pretest to posttest within the experimental group, $t(37) = -3.48$, $p = .001$, and no such effect within the control group, $t(23) = 0.352$, $p = .728$. The effect size is small to medium with a partial η^2 of .06, meaning that 6% of the overall variance is accounted for by anxiety.

There was also a significant interaction between time and condition for the attitude component of self-efficacy, $F(1, 60) = 9.63$, $p = .003$, $\eta^2 = .14$. Paired *t*-tests showed that there was a significant increase in self-efficacy scores within the experimental group, $t(37) = 6.90$, $p < .001$ and no change within the control group, $t(23) = 1.11$, $p = .277$. The effect size for the univariate analysis (partial $\eta^2 = .14$) was medium to large

(Cohen, 1988), indicating that 14% of the overall variance is accounted for by self-efficacy.

There were no significant interactions for the other three components; Table 1 displays the results for those components. To sum up, the inquiry project had a small to medium effect on the components of anxiety and self-efficacy for attitude towards conducting inquiry. Teachers who participated in the project felt less anxious and more able to conduct inquiry at school. We observed no difference between the experimental and control groups for the components of relevance, enjoyment, and perceived dependency on contextual factors.

Science teaching behaviour

To investigate the effects of the inquiry project on teachers' science teaching behaviour, a 2 (experimental versus control group) × 2 (time 1 versus time 2) repeated measures ANOVA was conducted, with condition as between-subjects factor, time as a within-subject factor, and teachers' self-reported inquiry-based teaching behaviour as dependent variable. We did not find a significant interaction of time and condition for inquiry-based teaching behaviour, $F(1,60) = .792$, $p = .377$, $\eta^2 = .013$. Paired t-tests did show a significant improvement within the experimental condition, $t(37) = 2.70$, $p = .011$, which was absent in the control condition, $t(23) = 0.96$, $p = .349$. However, looking at the data, the improvement within the experimental group, although significant, is very small, from a mean of 1.70 at pretest to 1.88 at posttest, meaning that they still indicated using inquiry-based teaching 'never to seldom' to 'a few times a year'.

Conclusions and discussion

This study investigated the impact of conducting an inquiry project on in-service primary teachers' attitude towards teaching science, their attitude towards conducting inquiry, and their science teaching behaviour. The experience of going through an inquiry project had a positive effect on two out of six components of teachers' attitude towards teaching science; they felt less anxious about teaching science in their classrooms and felt less dependent on contextual factors, such as the availability of pre-structured lesson plans, materials, or available time to teach science. Participating teachers were more convinced of the relevance of teaching science after the project, but this increase was not significantly different from the changes in the control group. There were no effects on gender-stereotypical beliefs, enjoyment, and self-efficacy beliefs when teaching science.

The inquiry project improved two out of five components of teachers' attitude towards inquiry; these teachers reported feeling less anxious and more able to conduct and engage in inquiry in the school context at posttest, compared to their colleagues who did not conduct an inquiry project. There were no changes in relevance beliefs, enjoyment, and feelings of context dependency. The experimental and control groups differed already in their beliefs about the relevance of conducting inquiry and in their enjoyment at the time of the pretest. Teachers who volunteered to participate in the project had more positive relevance beliefs and enjoyed conducting inquiry more. The difference between groups seems therefore likely to be inherent in the procedure of voluntary participation. This difference remained throughout the project and was still present at the time of the posttest. In addition to measuring attitudes, we looked at self-reported science teaching behaviour, but there was no substantial change in this measure.

Previous qualitative research investigating the effects of practitioner research used pre-service teachers as a target group. Familiarising pre-service teachers with the process of inquiry had a positive effect on their personal attitudes towards science and on their understanding of the scientific process and the nature of science (Haefner & Zembal-Saul, 2004; Morrison, 2008; Shapiro, 1996). Consistent with those results, the current findings show that in-service teachers also benefited from the experience they had with the process of inquiry, to a certain extent. Professional attitude towards teaching science and attitude towards conducting inquiry improved in part. This indicates that both pre-service and in-service teachers benefit from experience with inquiry.

In contrast to the previous qualitative studies (Haefner & Zembal-Saul, 2004; Morrison, 2008), we did not find changes in self-reported science behaviour. Teachers did not teach science more frequently and did not use inquiry learning more often; nor did they design scientific inquiry lessons more often. In general, teachers' responses on the science teaching scale indicated that they actually teach science very little, ranging on average between 'never' to 'a few times a year'. The previous studies indicating a positive effect of practitioner research on science teaching behaviour reported teachers' behavioural *intention* to teach science and did not compare pre- and post-measures of self-reported behaviour. A behavioural intention does not necessarily result in actual behaviour (Ajzen & Fishbein, 1980), which might explain the different findings. A prior study on the effects of an introductory research course on pre-service primary teachers' attitude, using similar attitudinal constructs and quantitative instruments, also failed to find effects on behavioural measures (van der Linden, Bakx, Ros, Beijaard, & van den Bergh, 2015).

The marginal effects on teachers' attitudes presented in this current study (improvement on fewer than half of the attitude components) might be due to the content and focus of the intervention. The current inquiry project did not devote explicit attention to attitude change, but attitudes were expected to change as a by-product of increased knowledge about and skills in conducting research. A study by van der Linden et al. (2015), which investigated the effects of an introductory research course on pre-service teachers' attitudes and which failed to find any changes, did not focus explicitly on attitude towards science teaching. This suggests that the mere experience of conducting research and inquiry is not sufficient to change teachers' attitudes.

It may very well be that in order to change teachers' attitudes, an explicit focus on attitude change is necessary. This assumption is supported by a recent study that did focus explicitly on teachers' attitudes (van Aalderen-Smeets & Walma van der Molen, 2015), and used similar measurement methods as the current study. The intervention described in that study also familiarised teachers with conducting inquiry by having them complete small-scale assignments, such as formulating a research question or designing a small-scale experiment. However, the main focus of the intervention was explicitly on attitude change. The intervention included (a) assignments to create awareness about teachers' own attitudes towards science and science teaching, (b) assignments that challenged the merit of negative attitudes, (c) assignments to change potential negative attitudes, and (d) assignments to make teachers reflect upon their feelings of enjoyment or anxiety when completing an inquiry assignment. This explicit focus on attitudes positively affected teachers' self-efficacy beliefs and enjoyment in teaching science. Moreover, it had a large positive effect on teachers' context dependency when teaching science (i.e. teachers felt less dependent on contextual factors) and on their science teaching behaviour. Interestingly, in contrast to the current inquiry intervention, the attitude-focused intervention did not decrease teachers' anxiety for teaching science. This could indicate that the attitude-focused study provided too little actual experience with inquiry for the teachers to decrease feelings of anxiety.

Comparison of the current inquiry project-study and the attitude-focused study by van Aalderen-Smeets and Walma van der Molen (2015) suggests that teacher professional development in science education should combine an explicit focus on teachers' attitudes with sufficient familiarisation with the process of conducting inquiry in order to change the different sub-components of teachers' attitude towards science teaching. We expect, based on our practical experience with professional development, that something along the lines of a larger-scale inquiry homework assignment, spanning 6–8 weeks and with sufficient coaching, within the attitude-focused intervention, might be sufficient.

Practitioner research, that is, research conducted by the practitioners of teaching, is important and serves many different purposes, such as professional and school development, improvement in teacher practices, or development of teacher knowledge about teaching and learning (Goodnough, 2011; Zeichner & Noffke, 2001). However, investigating the effects of practitioner research is difficult. The interventions are implemented within the practices of the school and are therefore subject to large variation in school context, social support, quality of the research, or intensity of the project, which may affect attitude outcomes. It is therefore important to carefully evaluate the quality of any practitioner project. In the current project, we established the internal validity of the research, that is, whether the teachers conducted the research itself in a reliable and valid way (e.g. Oolbekkink-Marchand, van der Steen, & Nijveldt, 2014), by having experienced researchers supervising the projects and by organising multiple meetings in which research methodology and analysis techniques were discussed. All supervisors reported after the project that the different steps within the research projects conducted by the teachers (research questions, research design, used analyses, and so forth) proved to be of good scientific quality.

Although there were changes in some of the attitude components, the majority of the attitude components, such as relevance beliefs, enjoyment, stereotypical beliefs about gender, and self-efficacy showed no significant improvements. There are several factors within the design of the study that might have influenced these findings. First, the study had a rather small number of participants in the experimental and control groups, which may have lowered statistical power. The number of participants in studies such as these is often limited by the large commitment and time investment they require of the participating teachers, often in addition to the teachers' normal teaching activities. Second, the content and amount of individual coaching that teachers received may have varied, producing within-group variance. We tried to circumvent this as much as possible by structuring the coaching and feedback sessions during the project and by providing all teachers with the same information and training during the nine meetings. Nonetheless, it is unclear how much informal contact there was between each teacher and his/her teacher-coach by email or phone, between the formal sessions.

Looking more specifically at professional attitude towards teaching science, the lack of results for four of the six attitude components could be due to the unexpected increase by the control group on these components. For self-efficacy beliefs, there were significant improvements for both the experimental and control groups at posttest. The teachers in the control group worked at the same schools as the teachers from the trained group. Observing your own colleagues conducting an inquiry project, hearing them talking about it, or having discussions with them about the project without actively participating in it might have a positive effect on teachers' attitudes towards science. Alternatively, the lack of results on the professional attitude scale might be explained by an acquiescence response bias within the control group, that is, a tendency to agree with all items, irrespective of the content (Watson, 1992). However, since we do not see this tendency to agree on the attitude towards conducting inquiry scale, this is not likely.

The findings from the current study seem to indicate some merit in the approach of improving attitude by having teachers conduct an inquiry project in their own school context, but the findings also indicate that this is not sufficient. In our view, a better approach for the professional development of primary teachers in science is to focus explicitly on the teacher attitude components and to combine this attitude-focused approach with substantial familiarisation with conducting inquiry, including coaching and supervision. The required time investment for conducting inquiry activities and the amount of and content of supervision are still a subject for investigation. Future research into the details of such a combination of attitude-focused professional development and practitioner research is necessary in order to develop the most efficient professional development approach for primary science teaching.

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