CHARLOTTE VAN CLEYNENBREUGEL, VEERLE DE WINTER, EVELIEN BUYSE, & FERRE LAEVERS

# UNDERSTANDING THE PHYSICAL WORLD: TEACHER AND PUPIL ATTITUDES TOWARDS SCIENCE AND TECHNOLOGY

## AN INTERVENTION STUDY IN PRIMARY EDUCATION

### INTRODUCTION

In this study, an intervention was set up aimed at improving both teachers' attitudes and competences in relation to science and technology, and teaching these subjects. The present report focuses specifically on teacher attitudes and how these evolve throughout the school year. A pre- and posttest design was used to evaluate teacher attitudes in relation to science and technology (and teaching these subjects) before and after the intervention trajectory. Additionally, children's attitudes were investigated to explore the relations between teachers' attitudes (and how these evolve) on the one hand, and (changes in) their pupils' attitudes on the other. At last, we explored the intervention inputs for critical tools/aids to change attitudes.

Trying to foster positive attitudes towards science and technology is a worthy goal in itself. Moreover, a positive attitude towards a certain topic is considered a necessary condition for the development of a broad and in-depth understanding of that topic in several areas (e.g., Cheung, 2009; Ho & Kuo, 2010; Ogbuehi & Fraser, 2007). More positive attitudes towards science and technology may concord with higher involvement in and deeper understanding of the physical world (Laevers, 1993; Laevers, 1998; Walma van der Molen, 2007).

In international literature, attitudes have consistently been described as multidimensional constructs, consisting of a cognitive, affective, and behavioural dimension. The cognitive dimension refers to perceptions and views, the affective component covers feelings with regard to a certain topic and the behavioural dimension captures the intentions to undertake actions in a particular field (e.g., Ajzen, 2005; Vazquez-Alonso, Manassero-Mas, & Acevedo-Diaz, 2006; Walma van der Molen, de Lange, & Kok 2009). In relation to education, teachers' feelings of self-efficacy have often been described as an important additional dimension of teachers' attitudes. Teachers' feelings of self-efficacy have been shown to be powerful predictors of positive teaching behaviour in the classroom, and are therefore also linked with pupil outcomes, such as achievement and motivation (e.g., Pajares, 1996; Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998). It may not surprise that positive attitudes in teachers towards specific *teaching practices* to address certain topics can also be considered important antecedents of their actual teaching behaviour and related pupil outcomes. Although Shrigley and Johnson

*Marc J. de Vries, Hanno van Keulen, Sylvia Peters and Juliette Walma van der Molen (eds.), Professional development for primary teachers in science and technology.*
*The Dutch VTB-Pro project in an international perspective*

already acknowledged this in 1974, attitudes towards teaching have not often been included in research. Chen (2006), for example, stated that “although teachers’ positive attitudes towards teaching are essential for instruction to succeed, a related attitude survey is not available in the literature” (p. 804). With regard to technological and scientific topics in primary classes in particular, recent efforts have been made to stress the importance of positive attitudes towards active teaching strategies to address these topics. Active strategies focus heavily on the development of pupils’ understanding of science and technology in ‘co-construction’. Children are thought to learn the most about technological and scientific issues by designing and actively inquiring things together in class. The active strategies encompass four pedagogical strategies with a positive effect on learning: collaborative, contextual, reflective and project-based learning (Sidawi, 2009). The teachers’ role can then be defined as one of guiding and supporting pupils’ learning processes (Kemmers, Klein Tank, & Van Graft, 2007). According to Jalil, Sbeih, Boujettif and Barakat (2009), teachers who act as a coach with minimal interference and who offer children autonomy in their knowledge building, cause a significant positive attitude shift on pupil level. These teaching strategies also have a positive impact on pupils’ motivation (Barak & Zadok, 2009). The strategies create opportunities for creative thinking and offer pupils the possibility to obtain a better self-image and view glimpses of their potential (Lewis, 2009). The active teaching strategies considered in this study, are intertwined, but address different underlying questions. In ‘learning by design’ a solution for a technical problem is searched; in ‘inquiry-based learning’ a broad and in-depth understanding of science topics is at the centre of attention (Van Graft & Kemmers, 2007).

Positive attitudes towards a certain topic and related teacher practices have been found to foster more positive attitudes in children as well (e.g., Abulude, 2009; Jarvis, 2006; Pell and Jarvis, 2003). Based on these findings, we hypothesise more positive (changes in) teacher attitudes to foster (positive changes in) pupil attitudes in the field of science and technology in particular. Therefore, in the present study, we also examined the relation between teacher and pupil attitudes in these fields.

In the study, an intervention trajectory was set up to promote teachers’ attitudes and competences in relation to the domain of science and technology. The ‘teacher profile’, that served as a basis for the interventions, contains five dimensions: (1) openness to and interest in science and technology (attitude); (2) intuitive understanding of physical phenomena (competence); (3) the capacity to extract knowledge from experience (conceptualisation); (4) the ability to create learning environments where children engage in intense mental activity (didactics enhancing involvement); and (5) the competence to identify the cognitive load of activities, i.e. the developmental domains triggered in pupils through the activity and the mental operations that can be challenged by the activity (critical view on content and material). While teachers implement a module on science and technology in their class during the school year, they are exposed to four specific intervention inputs. These were designed to support development in the five above-mentioned dimensions and respond to the experiential view on learning and development (Laevers, 1993; 1998).

A first input consisted of a half day workshop titled ‘The Eye and the Fire’ (introduction session). In the first part, the teachers responded to pictures (taken in outside areas) which made them aware of the paramount presence of physical phenomena and technological applications. Developing ‘an eye’ for these phenomena can be regarded as one of the main objectives in the domain of science and technology. A broadened view on science and technology gives teachers the opportunity to facilitate transfer between daily life experiences and science and technology activities. This awareness increases teachers’ observational skills: it will be easier for them to recognise and appreciate children’s talents in the science and technology domain. The second part of the workshop offered a framework in which children’s level of involvement is presented as an indicator for the power of learning environments. Here, the active ingredients of an approach that elicits interest and fascination in children are considered. Particular attention is paid to the ‘open framework model’ (Laevers, 2006a) in which both children and teacher take initiative in co-construction of learning. As highlighted above, co-construction is also a key concept in inquiry-based learning and learning by design.

Secondly, a visit to a Science Centre was organised, where an interactive trajectory consisting of ten selected exhibits was laid out for the teachers (interactive visit science centre). With the support of key questions, in groups of four, the teachers concentrated on the perceptions, thoughts and questions that arose while they were experimenting with the materials. They were also invited to formulate a ‘thoughtful’ explanation of the phenomena. This exercise does not only help teachers be receptive to the technological and scientific dimensions in their environment (develop ‘The Eye’) but also helps them identify mental processes within themselves and articulate these in a dialogue with others. This way, they encounter their own limitations in knowledge and insights and try to overcome these with the help of their colleagues. They are put in the position of the learner and therefore experience for themselves how an environment can affect a person’s interest and cognition.

A third input consisted of a training session containing an in-depth analysis of video recordings of children dealing with science and technology activities. These were developed by the Dutch project TalentenKracht [Curious Minds][i] (in-depth session Curious Minds). The guide to view the clips is based on the PaLe (Laevers, 2006b), a tool designed to make a process-oriented analysis of learning environments. Here, well-being, involvement and mental activity are at the centre of attention. Furthermore, the activity is held against several developmental domains to identify the cognitive load, i.e. the domains that are mobilised during the viewed episodes. These domains are not limited to an understanding of the physical world, but may also, for example, refer to social competence, or meta-competences such as entrepreneurship or creativity. Finally, the context factors to enhance involvement in the observed situation are explored, including adult style dimensions (sensitivity, support of autonomy, stimulation), the richness of the materials at hand, and which specific layers of understanding of the physical world are inherent to the material and can hence be triggered by interaction with it.

A fourth intervention consisted of a coaching session, grafted on the science and technology projects in which teachers were already engaged. Reflections in groups started with a specific practice example teachers were proud of, thereby inspiring colleagues and creating a more positive self-concept. Starting from these strong points, weaker points and personal obstructions were explored, followed by an attempt to overcome these in co-construction with teachers who encountered the same challenges.

A closer analysis of the interventions allows to identify which dimensions of teachers' attitudes are likely to be addressed. In general, there is a particular focus on the behavioural dimension (supporting change at the level of planning actions), the affective dimension (enjoying the experimentation and exploration of the physical reality) and the cognitive dimension (offering teachers a view on science and technology that is more linked to daily life experiences, which makes science and technology less difficult and more compelling. Furthermore, feelings of self-efficacy may be mobilised (the feeling to be able to successfully engage in teaching science and technology). Finally, rooted in Experiential Education, the intervention inputs emphasise the importance of a rich learning environment, where activities evolve in interaction or co-construction with the children (Laevers, 2006a). This may lead to more positive teacher attitudes towards learning, also by design and inquiry-based learning, which both adhere to the same essential learning principles.

In sum, four research goals are addressed. Firstly, we evaluated the impact of the intervention on change in teacher and pupil attitudes. Secondly, we investigated the change in attitude scores over the school year for teachers who followed the intervention trajectory, compared to control teachers. We hypothesised a larger growth in every dimension of the attitudes towards science and technology for the teachers who followed the intervention trajectory, as compared to the control group. Thirdly, we evaluated the impact of changes in teacher attitudes (for the teachers who followed the intervention trajectory) on pupil attitudes towards science and technology. We expected a positive change in teacher attitudes resulting in a positive change in their pupils' attitudes as well. Fourthly, we made an exploratory analysis in order to find out which 'tools/aids' offered by the intervention inputs can cause a growth in teacher attitudes. Therefore, at the end of each input, teachers were asked to indicate what they had learned and to rate their level of involvement during each session.

## METHOD

### *Participants*

The study involved schools from Flanders (Belgium) and the Netherlands. In a first stage, teachers were recruited to participate in the intervention, making them part of the ‘trajectory group’. In Flanders, these teachers were involved in an on-going technology project, called ‘Dorp op school’ [‘Village at School’]. Similarly, the Dutch teachers worked at schools that were engaged in integrating science and technology more in their programme (so-called ‘VTB schools’). The 39 colleagues of these (26) teachers, who did not follow the intervention, were assigned to the ‘control group’.

*Table 1. Division of participating teachers over Flemish and Dutch schools*

| | *# Teachers* | |
|---|---|---|
| | *Trajectory group* | *Control group* |
| Flemish schools (n = 9) | 15 | 29 |
| Dutch schools (n = 6) | 11 | 10 |
| | 26 | 39 |

As presented in Table 1, 44 Flemish teachers participated as opposed to 21 Dutch teachers. The trajectory group consisted of 58% Flemish teachers, whereas the proportion of Flemish teachers equalled 74% in the control group. However, these proportions did not differ significantly ($\chi^2(1) = 1.98$, *ns*). There were no significant differences detected between the trajectory and control group with regard to other available background features. Firstly, the proportion of male teachers, equalling 15% and 10% in the trajectory and control group respectively, did not differ between both groups ($\chi^2(1)= 0.38$, *ns*). Secondly, seniority of the teachers (defined as a categorical variable with 1 = < 10 years, 2 = 10-15 years, and 3 = > 15 years of teaching experience respectively) did not differ between both groups ($\chi^2(1) = 1.48$, *ns*).

For the trajectory teacher group, scores on attitude scales were also available for the pupils in their class. In total, 489 children completed the questionnaires, of which 327 were Flemish and 233 were boys. The proportion of boys in Flanders (46%) and the Netherlands (50%) did not differ significantly ($\chi^2(1) = 0.74$, *ns*).

### *Procedure*

The intervention offered to the teachers of the ‘trajectory group’ consisted of four inputs, described in the introduction. Each input was concluded with an evaluation by the teachers (see ‘Instruments’).

During an intake with the participating teachers and their principals, the schools received the teacher and pupil attitude questionnaires for pretesting. These were completed by (a) the ‘trajectory teachers’; (b) the ‘control teachers’; and (c) the pupils of the teachers following the intervention trajectory. The ‘pretest questionnaires’ were handed back before the first intervention input. All intakes took place between October 2009 and January 2010. In June 2010, after the final intervention input, schools received the attitude questionnaires for posttesting, which were completed by the same three groups as described for the pretest.

### *Instruments*

*Teacher attitudes* To measure teachers' attitudes towards science and technology, we used a Dutch questionnaire, developed by VTB. Previous research established that this questionnaire is a comprehensive instrument which operationalises attitude as a set of thoughts, feelings, and behaviours (Walma van der Molen, 2009). We also included the VTB questionnaire on attitudes for pupils, because of its similar design. This would enable us to explore the connection between teacher and pupil attitudes towards science and technology.

The pupil questionnaire consists of scales on two domains, i.e. 'attitudes towards technology' and 'attitudes towards science'. Two other domains were added to the teacher questionnaire, referring to their attitudes towards designing and inquiring as classroom practices to foster learning in the field of science and technology. More specifically, the scales on 'attitudes towards learning by design' and 'attitudes towards inquiry-based learning' were selected from the Oberon study (2009).

Within each domain, a cognitive, affective, and behavioural dimension of attitudes are distinguished, in accordance with the attitude concept. The cognitive component is further divided into two subcomponents: the evaluation of the *difficulty* and the *importance* of science and technology (and inquiry-based learning and learning by design in the teacher form). The affective subscales refer to the *enjoyment* teachers and pupils experience in relation to science and technology (and related practices). The behavioural subscales cover the *intentions* to invest time and energy in these topics. In addition, Oberon (2009) defined a fifth subscale on the teacher questionnaire, *self-efficacy*, which we also included. Here, teachers rate how they perceive their ability to act appropriately in a given area. The respective scales within each domain will be referred to as DIFFICULTY, IMPORTANCE, ENJOYMENT, INTENTIONS and SELF-EFFICACY.

We checked the quality of the teacher attitude questionnaire, using factor[ii] and reliability analysis. Based on the findings, we made a few (small) changes in the composition of the scales. Like Oberon (2009), we omitted the IMPORTANCE and SELF-EFFICACY scales for attitudes towards science and the DIFFICULTY scale for attitudes towards inquiry-based learning and learning by design. We also omitted the DIFFICULTY scale for attitudes towards technology. More details on these analyses can be found in the Appendix (Table A.1) and in the internal report (De Winter & Van Cleynenbreugel, 2010).

Each scale of the final teacher questionnaire contains a series of items to be rated on a five point scale from 'I completely disagree' to 'I completely agree'. Items formulated in a negative sense were inverted and subsequently, scale scores were computed by averaging item scores. Higher scores on each scale indicate that teachers perceive the respective domains (i.e., technology, science, and related practices) as more difficult (DIFFICULTY scales), more important (IMPORTANCE scales), and more enjoyable (ENJOYMENT scales); that they intend to invest more time and energy in the domain (INTENTIONS scales); and that they have more confidence in their own capacities (SELF-EFFICACY scales).

Correlations between the different attitude scales for the four domains were calculated and reported in the internal report (De Winter & Van Cleynenbreugel, 2010) and in the Appendix (Tables A.2, A.3 and A.4). Furthermore, the pretest did not show any differences in attitude scores between countries. At the end of the school year, 2 out of the 15 attitude scales showed a significant difference, i.e. with regard to IMPORTANCE, learning by design ($t(22) = 2.17$, $p < .05$) and ENJOYMENT, inquiry-based learning ($t(13.07) = 3.19$, $p < .01$). More specifically, Flemish teachers describe learning by design as significantly more important than their Dutch counterparts[iii]. Furthermore, Flemish teachers report significantly more enjoyment in inquiry-based learning than Dutch teachers[iv]. Although no significant differences were detected between seniority groups for any of the posttest attitude scales, these were found for INTENTIONS, learning by design ($F(2,23) = 4.28$, $p < .05$) and inquiry-based learning ($F(2,23) = 4.75$, $p < .05$) on the pretest, with the youngest group scoring significantly lower than the oldest[v, vi].

*Pupil attitudes* In accordance with the teacher questionnaire, the pupil questionnaire consists of the DIFFICULTY, IMPORTANCE, ENJOYMENT and INTENTIONS subscales. The GENDER differences subscales were added for attitudes towards science and technology because perception of gender differences, i.e. the idea that boys are better in technology and/or science, is considered an additional element of the cognitive aspect of attitudes (Walma van der Molen, 2009). Similar to the analyses of the teacher questionnaire, a factor[vii] and reliability analysis was performed on the pupil questionnaire. All the original scales were included, except for the science DIFFICULTY scale. More details on these analyses can be found in the Appendix (Table A.5) and the internal report (De Winter & Van Cleynenbreugel, 2010).

Each scale of the final pupil questionnaire contains a series of items to be rated on a four point scale from ‘I completely disagree’ to ‘I completely agree’. Items formulated in a negative sense were inverted and subsequently, scale scores were computed by averaging item scores. Higher scores for the DIFFICULTY, IMPORTANCE, ENJOYMENT and INTENTIONS scales must be interpreted similarly as explained for the teacher questionnaire. Additionally, higher scores on GENDER reflect pupils’ beliefs that boys are better in technology and/or science than girls.

Correlations between the different attitude scales in science and technology were calculated and reported in the internal report (De Winter & Van Cleynenbreugel, 2010) and the Appendix (Table A.6). Moreover, the pretest score of Flemish pupils was significantly higher than the ENJOYMENT and INTENTIONS score for science and technology of the Dutch pupils. However, Flemish pupils perceive technology as significantly more difficult than their Dutch counterparts. On the posttest, all significant differences between the two countries disappear, except for ENJOYMENT and INTENTIONS for science. As on the pretest, both mean attitude scores are significantly higher in Flanders. Detailed information on these group differences can be found in the Appendix (Table A.7). Both on pre- and posttest, pupil gender has a meaningful influence on their attitudes. All differences are significant (see Table A.8 in Appendix for more details), except for the scores on IMPORTANCE of technology in the pretest. Boys enjoy both science and technology more, they find it easier and generally more important, and they are more interested in learning more about it than girls. Furthermore, boys perceive themselves as better at both domains, while girls do not report these gender differences.

*Input evaluation* At the end of each intervention input, all participants were asked to rate their involvement during the session on a five point scale. Score 1 means “I was bored, I only stayed because I had to” and score 5 means “I was interested almost constantly. I felt seriously involved, challenged to think about it and/or engage myself to work with it”. The participants were also asked to report in an open form what they had gained from the sessions for their personal development and/or what they could transfer to their classroom practices.

### *Data-analysis*

To evaluate change in teacher and pupil attitudes after the intervention (first research goal), pre- and posttest scores of trajectory teachers and their pupils were compared by means of paired samples t-tests. For comparison, similar tests were performed on the scores of control group teachers. While we expected these t-tests to indicate significantly positive[viii] changes in attitude scores for trajectory teachers and pupils, we did not expect this for the control teachers. In order to obtain a straightforward comparison between trajectory and control teachers (second research goal) posttest attitude scores were predicted by the variable ‘belonging to the trajectory vs. control group’ (with 0 = control teacher and 1 = trajectory teacher), controlling for pretest scores. As we expected the intervention to have a beneficial effect on teacher attitudes, we hypothesised the regression coefficient of the dummy coded predictor to be positively significant for each outcome (except for DIFFICULTY).

Thirdly, multilevel analyses were performed to predict (changes in) pupil attitudes by means of changes in teacher attitudes. Preliminary, the variance in pupil attitude scores was partitioned into a component at both class and pupil level. Class level variables (i.e. teacher attitude scores) were only added as potential predictors (Hox, 2002; Snijders & Bosker, 1999) for outcomes where a significant amount of variance was situated on class level.

Finally, the hypothesised influence of the intervention inputs on attitude change was explored through the evaluating information gathered after each input (fourth research goal). On the one hand, regression analyses were performed to predict the posttest attitude scores based on the involvement scores related to each input, controlling for pretest attitude scores. On the other hand, the qualitative information obtained from the teachers with regard to their learning gains on a personal and professional level, was clustered and summarised.

## RESULTS

### *Changes in Teacher and Pupil Attitudes over the School Year*

For the 'trajectory teachers', the means, standard deviations, and ranges of attitude scores concerning technology, science, and related practices are presented in Table 2, for the pre- as well as posttest scores[ix].

*Table 2. Paired samples t-tests for mean differences in teacher attitudes for the trajectory group (n = 24-26)*

| | *Posttest scores* | | | | *Pretest scores* | | | | *t-test*[(a)] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *Min.* | *Max.* | *M* | *SD* | *Min.* | *Max.* | *df* | *t* | *p* |
| **Attitude Technology** | | | | | | | | | | | |
| Importance | 4.37 | .35 | 3.83 | 5.00 | 4.28 | .35 | 3.50 | 4.83 | 24 | 1.09 | .286 |
| Enjoyment | 3.85 | .70 | 2.33 | 4.83 | 3.60 | .84 | 1.67 | 4.83 | 24 | 1.89 | .071 |
| Intentions | 3.86 | .45 | 3.00 | 4.75 | 3.69 | .52 | 2.75 | 5.00 | 25 | 2.41* | .024 |
| Self-efficacy | 3.33 | .65 | 1.71 | 4.29 | 3.17 | .74 | 1.57 | 4.86 | 23 | 1.73 | .097 |
| **Attitude Science** | | | | | | | | | | | |
| Difficulty | 3.25 | .74 | 1.50 | 4.00 | 3.56 | .68 | 1.50 | 5.00 | 25 | -2.96** | .007 |
| Enjoyment | 3.76 | .54 | 2.50 | 4.50 | 3.68 | .55 | 2.75 | 5.00 | 24 | 0.56 | .578 |
| Intentions | 3.47 | .66 | 2.00 | 4.50 | 3.34 | .73 | 2.00 | 5.00 | 25 | 1.33 | .195 |
| **Attitude Learning by design** | | | | | | | | | | | |
| Importance | 4.18 | .47 | 3.00 | 5.00 | 4.03 | .41 | 3.00 | 5.00 | 23 | 0.76 | .454 |
| Enjoyment | 4.19 | .41 | 3.50 | 5.00 | 3.96 | .34 | 3.00 | 5.00 | 23 | 2.04 | .053 |
| Intentions | 3.99 | .44 | 3.00 | 4.67 | 3.96 | .34 | 3.00 | 5.00 | 23 | 0.29 | .775 |
| Self-efficacy | 3.35 | .59 | 2.33 | 4.33 | 3.14 | .66 | 2.00 | 4.67 | 23 | 1.46 | .158 |
| **Attitude Inquiry-based learning** | | | | | | | | | | | |
| Importance | 4.22 | .45 | 3.25 | 5.00 | 4.10 | .37 | 3.25 | 4.75 | 22 | 1.05 | .307 |
| Enjoyment | 4.22 | .45 | 3.67 | 5.00 | 3.96 | .36 | 3.33 | 5.00 | 22 | 2.49* | .021 |
| Intentions | 4.02 | .50 | 3.00 | 5.00 | 4.06 | .48 | 3.00 | 5.00 | 23 | -0.33 | .747 |
| Self-efficacy | 3.43 | .48 | 2.00 | 4.33 | 3.23 | .56 | 2.33 | 4.67 | 22 | 1.27 | .217 |

$^{*}p < .05$. $^{**}p < .01$.

[(a)] two-tailed paired samples t-tests for mean differences.

Table 2 further reveals that the posttest scores for the 'trajectory teachers' are beneficially higher[x] than the pretest scores on all comparable scales, with one exception (i.e. slightly reduced intentions to include more inquiry-based learning in their school practices). Paired samples t-tests for mean differences revealed that three of these changes in mean attitude scores over the year reached significance. In more detail, we found that after the intervention trajectory teachers significantly (a) intend to learn more about technology; (b) perceive science as less difficult; and (c) find inquiry-based learning more pleasant, as compared to the pretest measure.

Additionally, three mean differences are borderline significant, indicating that after the intervention, teachers also tend to (a) enjoy technology more; (b) enjoy learning by design more; and (c) feel more self-efficient in the technology domain.

For the pupils, the means, standard deviations, and ranges of attitude scores concerning science and technology are presented in Table 3, for the pre- as well as the posttest[xi].

*Table 3. Paired samples t-tests for mean differences concerning pupil attitudes (n = 478 – 485)*

| | *Posttest scores* | | | | *Pretest scores* | | | | *t-test*[(a)] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *Min.* | *Max.* | *M* | *SD* | *Min.* | *Max.* | *df* | *t* | *p* |
| **Attitude Technology** | | | | | | | | | | | |
| Difficulty | 1.99 | .66 | 1.00 | 4.00 | 2.07 | .66 | 1.00 | 4.00 | 483 | -2.75* | .006 |
| Importance | 2.84 | .50 | 1.14 | 4.00 | 2.90 | .46 | 1.43 | 4.00 | 484 | -2.80* | .005 |
| Gender | 2.12 | .94 | 1.00 | 4.00 | 2.23 | .91 | 1.00 | 4.00 | 484 | -2.83* | .005 |
| Enjoyment | 3.15 | .64 | 1.00 | 4.00 | 3.27 | .55 | 1.00 | 4.00 | 484 | -4.50** | .000 |
| Intentions | 2.11 | .83 | 1.00 | 4.00 | 2.17 | .84 | 1.00 | 4.00 | 479 | -1.70 | .089 |
| **Attitude Science** | | | | | | | | | | | |
| Importance | 2.85 | .54 | 1.00 | 4.00 | 2.93 | .51 | 1.00 | 4.00 | 483 | -3.12* | .002 |
| Gender | 1.80 | .89 | 1.00 | 4.00 | 1.86 | .92 | 1.00 | 4.00 | 484 | -1.85 | .065 |
| Enjoyment | 3.00 | .65 | 1.00 | 4.00 | 3.14 | .61 | 1.00 | 4.00 | 483 | -4.92** | .000 |
| Intentions | 1.99 | .77 | 1.00 | 4.00 | 2.02 | .81 | 1.00 | 4.00 | 477 | -0.98 | .327 |

* $p < .01$. ** $p < .001$.
[(a)] two-tailed paired samples t-tests for mean differences.

As for the teachers, pre- and posttest attitude scores were also compared with paired samples t-tests for the pupils in the ‘trajectory classes’ (see Table 3). In accordance with the expectations, we found a decrease in stereotypical thinking about gender in technology. Although not significant, a similar result was found for gender stereotypes in science. Pupils also find technology less difficult at the end of the school year, compared to the beginning of the year. However, unexpectedly, we also detected significant decreases in ENJOYMENT and IMPORTANCE of both science and technology over the course of the school year. Pupils’ intentions towards science and technology also decreased over the year, but not significantly.

### *Comparison of Trajectory and Control Group Teachers*

Preliminary analysis on pretest scores, comparing the initial attitudes of trajectory and control group teachers, only revealed significant initial differences in mean scores for two scales (see Table 4). On average trajectory teachers score higher on the ENJOYMENT scales for technology as well as learning by design[xii]. No significant differences were detected between the control and trajectory teachers for the other 13 attitude scales.

*Table 4. Pretest comparison of mean attitude scores between trajectory and control group teachers*

| | *Control group (N =38 -39)* | | | | *Trajectory group (N = 25-26)* | | | | *t-test*[(a)] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *Min.* | *Max.* | *M* | *SD* | *Min.* | *Max.* | *df* | *t* | *p* |
| **Attitude Technology** | | | | | | | | | | | |
| Importance | 4.12 | .39 | 3.00 | 5.00 | 4.28 | .35 | 3.50 | 4.83 | 62 | 1.71 | .092 |
| Enjoyment | 3.35 | .78 | 1.83 | 4.67 | 3.60 | .84 | 1.67 | 4.83 | 63 | 1.23 | .222 |
| Intentions | 3.45 | .54 | 2.25 | 4.75 | 3.69 | .52 | 2.75 | 5.00 | 63 | 1.82 | .074 |
| Self-efficacy | 2.91 | .64 | 1.71 | 4.57 | 3.17 | .74 | 1.57 | 4.86 | 62 | 1.49 | .141 |
| **Attitude Science** | | | | | | | | | | | |
| Difficulty | 3.60 | .58 | 2.00 | 5.00 | 3.56 | .68 | 1.50 | 5.00 | 63 | -0.29 | .776 |
| Enjoyment | 3.40 | .51 | 2.25 | 4.25 | 3.68 | .55 | 2.75 | 5.00 | 62 | 2.10* | .039 |
| Intention | 3.01 | .74 | 1.00 | 4.50 | 3.34 | .73 | 2.00 | 5.00 | 63 | 1.74 | .087 |
| **Attitude Learning by design** | | | | | | | | | | | |
| Importance | 3.91 | .32 | 3.00 | 4.67 | 4.03 | .41 | 3.00 | 5.00 | 63 | 1.22 | .227 |
| Enjoyment | 3.68 | .52 | 2.50 | 5.00 | 3.96 | .34 | 3.00 | 5.00 | 63 | 2.63* | .011 |
| Intentions | 3.89 | .47 | 2.00 | 5.00 | 3.96 | .34 | 3.00 | 5.00 | 62 | 0.70 | .484 |
| Self-efficacy | 3.22 | .52 | 2.33 | 4.00 | 3.14 | .66 | 2.00 | 4.67 | 62 | -0.53 | .597 |
| **Attitude Inquiry-based learning** | | | | | | | | | | | |
| Importance | 4.03 | .30 | 3.25 | 4.50 | 4.10 | .37 | 3.00 | 5.00 | 62 | 0.88 | .382 |
| Enjoyment | 3.86 | .42 | 2.67 | 4.67 | 3.96 | .36 | 3.00 | 5.00 | 62 | 0.94 | .351 |
| Intentions | 3.96 | .45 | 3.00 | 5.00 | 4.06 | .48 | 3.00 | 5.00 | 63 | 0.83 | .413 |
| Self-efficacy | 3.30 | .53 | 2.00 | 4.00 | 3.23 | .56 | 2.00 | 4.67 | 62 | -0.52 | .605 |

***** $p < .05$.
[(a)] two-tailed, independent samples *t*-test for mean differences.

Paired sampled t-tests to evaluate changes in attitude scores over the year for the control group of teachers only revealed a significant change in positive attitudes for the DIFFICULTY scale of science, indicating that also control group teachers perceive science as less difficult over the course of one school year (with $t(38) = 2.71$, $p < .05$).

However, to obtain a straightforward comparison between trajectory and control teachers, regression analyses were performed, including type of intervention (i.e. intervention followed vs. not followed) as well as pretest scores as predictor variables for posttest scores. Results of the regression analyses, comparing estimated posttest scores for control and trajectory teachers, are reported in Table 5. Estimated posttest scores are significantly higher for the trajectory teachers than for the control teachers, for the same five attitude scales where the trajectory teachers have grown (marginally) significantly over the course of the trajectory school year. Furthermore, it must be noted that the significant decrease in perceived difficulty of science over the year, which we detected for both trajectory and control teachers, does not differ significantly between both groups.

*Table 5. Predicting posttest attitude scores by pretest scores and 'control vs. trajectory group' (n = 61-65)*

| | | *Regression coefficient*[a] | | *Estimated posttest score* | |
|---|---|---|---|---|---|
| | $M_{pretest}$ | $\beta_{group}$ | *P* | *Control group* | *Trajectory group* |
| **Attitude Technology** | | | | | |
| Importance | 4.18 | .19 | .078 | 4.15 | 4.31 |
| Enjoyment | 3.45 | .18* | .027 | 3.43 | 3.70 |
| Intentions | 3.55 | .23** | .008 | 3.51 | 3.76 |
| Self-efficacy | 3.01 | .22* | .014 | 2.99 | 3.26 |
| **Attitude Science** | | | | | |
| Difficulty | 3.58 | -.05 | .585 | 3.34 | 3.27 |
| Enjoyment | 3.51 | .10 | .379 | 3.54 | 3.65 |
| Intentions | 3.14 | .11 | .262 | 3.19 | 3.35 |
| **Attitude Learning by design** | | | | | |
| Importance | 3.96 | .21 | .095 | 3.96 | 4.16 |
| Enjoyment | 3.79 | .28* | .021 | 3.80 | 4.11 |
| Intentions | 3.92 | .17 | .153 | 3.81 | 3.97 |
| Self-efficacy | 3.19 | .08 | .477 | 3.26 | 3.36 |
| **Attitude Inquiry-based learning** | | | | | |
| Importance | 4.05 | .25 | .055 | 4.01 | 4.21 |
| Enjoyment | 3.90 | .26* | .035 | 3.95 | 4.19 |
| Intentions | 4.00 | .22 | .090 | 3.78 | 3.90 |
| Self-efficacy | 3.27 | .11 | .354 | 3.31 | 3.43 |

[a] Regression coefficient of the dummy coded variable, with 0 = control group and 1 = trajectory group.

### *Associations Between (Changes in) Teacher and Pupil Attitudes*

Table 6 shows the estimation and significance of the class level variance in pupil attitude scores for pretest, posttest and changes over the school year. Overall, the proportion of variance on class level for the outcomes as presented in Table 6 ranges between 0% and 13%. Class level features matter the most for gender stereotypical attitudes (significant class level variances ranging between 9% and 13%).

*Table 6. Estimation of class level variance in attitude scores, concerning the pre- and posttest measurement, and changes over the school year (n = 478-490)*

| | *Pretest scores* | | | *Posttest scores* | | | *Change scores* | | |
|---|---|---|---|---|---|---|---|---|---|
| | *B* | *SE* | *p* | *B* | *SE* | *p* | *B* | *SE* | *p* |
| **Attitude Technology** | | | | | | | | | |
| Difficulty | .03* | .02 | .033 | .00 | .00 | 1.00 | .02 | .01 | .093 |
| Importance | .03* | .01 | .025 | .02* | .01 | .023 | .01 | .01 | .208 |
| Gender | .04 | .02 | .087 | .09* | .04 | .014 | .06* | .03 | .022 |
| Enjoyment | .01 | .01 | .181 | .05* | .02 | .017 | .02 | .01 | .057 |
| Intentions | .04* | .02 | .046 | .02 | .02 | .189 | .02 | .02 | .286 |
| **Attitude Science** | | | | | | | | | |
| Importance | .01 | .01 | .113 | .02* | .01 | .040 | .01 | .01 | .588 |
| Gender | .08* | .03 | .016 | .10** | .04 | .008 | .05* | .02 | .018 |
| Enjoyment | .02 | .01 | .060 | .04* | .02 | .026 | .02 | .01 | .079 |
| Intentions | .02 | .02 | .154 | .01 | .01 | .470 | .02 | .01 | .261 |

*****$p < .05$. **$p < .01$.

To explain significant class level variances in pupil attitude scores, teacher attitude scores were added as predictors of pupil scores. More specifically, teacher scales of technology and learning by design were used as predictors of pupil scores on attitudes towards technology, and teacher scales of science and inquiry-based learning as predictors for pupil attitudes towards science. Pretest, posttest, and change scores of teachers were included as predictors of pretest, posttest, and change scores of pupils, and were not mixed.

No significant predictors were found concerning pretest scores. With regard to posttest scores, pupils' enjoyment of technology can be predicted by the self-efficacy teachers experience for technology ($\beta$ = -0.15, $p < .01$), and for design-based learning ($\beta$ = -0.20, $p < .001$). However, the associations are negative, indicating that higher feelings of self-efficacy in teachers at the end of the school year are associated with lower feelings of enjoyment in children with regard to technology.

### *The Impact of the Intervention Inputs: An Exploratory Analysis*

As shown in Table 7, self-reported mean involvement scores during the inputs range from 4.13 to 4.61 on a five-point scale. Significant correlations are found between involvement scores for the introduction session on the one hand, and the science centre visit and the in-depth session about talents on the other hand. Scores for the latter also significantly correlate with involvement scores for the coaching session.

*Table 7. Descriptive statistics and correlations of the involvement scores (n=23-46)*

| | *Involvement scores* | | | | *Correlations* | | | |
|---|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *Min.* | *Max.* | *1.* | *2.* | *3.* | *4.* |
| 1. Introduction session | 4.13 | .61 | 3.00 | 5.00 | | .57* | .69** | .35 |
| 2. Interactive visit science centre | 4.61 | .50 | 4.00 | 5.00 | | | .38 | .42 |
| 3. In-depth analysis Curious Minds | 4.52 | .51 | 4.00 | 5.00 | | | | .59* |
| 4. Coaching session | 4.21 | .57 | 3.00 | 5.00 | | | | |

*****$p < .05$. **$p < .01$.

Using regression analysis, involvement scores for each input were linked to changes in teacher attitude scores. Involvement during the introduction session was found to operate as a predictor of growth in SELF-EFFICACY with regard to technology ($\beta = 0.38$, $p < .05$). Secondly, involvement during the interactive visit to a science centre predicted the growth in INTENTIONS with regard to technology ($\beta = 0.31$, $p < .05$). No other attitude changes could be predicted based on involvement for the different intervention inputs.

Finally, table 8 contains an overview of the learning experiences participants report to have encountered for each of the four intervention inputs.

Although the content of the different inputs highlights different aspects of science and technology and teaching it (see introduction), most of the learning experiences teachers mentioned hold to some extent for several inputs.

*Table 8. Overview of self-reported learning experiences for each intervention input*

| *Introduction Session ($N^1$=88)* | *%* | *(N)* |
|---|---|---|
| Broader view on science and technology/recognising science and technology in daily life | 23.86% | (21) |
| Self-knowledge: strong and weak points, personal obstructions | 20.45% | (18) |
| Providing autonomy and being sensitive to the child's exploratory drive | 12.50% | (11) |
| Stimulation: the teacher as source of enrichment in communication and engagement in activities | 11.36% | (10) |
| Domains of development: the development of fundamental schemes and the importance of intuition | 12.50% | (11) |
| Importance of a rich learning environment: based on reality, challenging to different levels of competence, with focus on process instead of result | 10.23% | (9) |
| Attentiveness to pupils' involvement, their competences and talents | 9.09% | (8) |

*Table 8 (continuation). Overview of self-reported learning experiences for each intervention input*

| *Interactive visit science centre (N=101)* | *%* | *(N)* |
|---|---|---|
| Importance of a rich learning environment: with room for experimenting (in co-construction), starting from wonderment, with focus on process instead of result | 26.73% | (27) |
| Self-knowledge: strong and weak points, personal obstructions | 22.77% | (23) |
| Knowledge about science and technology and inspiration for the classroom practices | 17.82% | (18) |
| Broader view on science and technology/recognizing science and technology in daily life | 12.87% | (13) |
| Enjoyment of science and technology | 5.94% | (6) |
| Attentiveness to the nature of cognitive processes mobilised through the activity | 5.94% | (6) |
| Stimulation: the teacher as source of enrichment in communication and engagement in activities | 2.97% | (3) |
| Importance of science and technology for pupils | 2.97% | (3) |
| Attentiveness to pupils' involvement, their competences and talents | 1.98% | (2) |
| *In-depth session about talents (N=60)* | *%* | *(N)* |
| Providing autonomy and being sensitive to the child's exploratory drive | 30.00% | (18) |
| Stimulation: the teacher as source of enrichment in communication and engagement in activities | 28.33% | (17) |
| Attentiveness to pupils' involvement, their competences and talents | 23.33% | (14) |
| Importance of a rich learning environment: challenging to different levels of competence, with focus on the process instead of the results | 8.33% | (5) |
| Attentiveness to the nature of cognitive processes mobilised through the activity | 6.67% | (4) |
| Broader view on science and technology/recognizing science and technology in daily life | 3.33% | (2) |
| *Coaching session (N=54)* | *%* | *(N)* |
| Self-knowledge: strong and weak points, personal obstructions | 38.89% | (21) |
| Inspiration for classroom practices | 22.22% | (12) |
| Confirmation of self-efficacy | 12.96% | (7) |
| Providing autonomy and being sensitive to the child's exploratory drive | 11.11% | (6) |
| Broader view on science and technology recognizing science and technology in daily life | 5.56% | (3) |
| Attentiveness to pupils' involvement, their competences and talents | 5.56% | (3) |
| Attentiveness to the nature of cognitive processes mobilised through the activity | 3.70% | (2) |

[1] Total number of remarks of the participants.

Over the different inputs, teachers' specific learning experiences can be combined into three categories. The first category concerns a broader view on science and technology, which (a) helps teachers recognise science and technology in daily life; and (b) helps see connections with their own knowledge and image of the physical world more easily. Related to this, teachers indicate to have learned about how specific science and technology issues can be translated into classroom practices. In this regard, they refer to the importance of a rich learning environment, with room for exploring and experimenting, based on reality. In a second (related) category, teachers indicate to have learned about specific teacher competences that are highly relevant in guiding children's learning processes with regard to science and technology. Here, providing autonomy and stimulating thoughts, communication and creativity are specifically stressed. Furthermore, according to what teachers have learned, attentiveness to pupils' involvement, competences and talents is an important teaching skill in this domain. Finally, knowledge of different developmental domains and the capability to recognise (possible) mental loads in an activity is considered an important additional competence for teaching science and technology. In a third category, personal feelings and notions can be grouped together. Teachers pointed out that they gained better insight into themselves through the input sessions. They mentioned their strong and weak points and the personal obstructions they encountered. This was, for example, translated into a more accurate and overall more positive perception of their self-efficacy. Apart from the three main content categories teachers mentioned, particularly with regard to the interactive science centre visit, teachers indicated that they experienced enjoyment during activities in science and technology domains.

## DISCUSSION AND CONCLUSION

The main purpose of this article was to examine the impact of an intervention trajectory on changes in teacher and pupil attitudes towards science and technology. Furthermore, we explored whether, and if so, which elements of the intervention inputs could provide an explanation for these changes.

With regard to the effectiveness of the intervention, our goal to enhance positive teacher attitudes has especially been reached in relation to the technology domain. By the end of the year, compared to the beginning, teachers who followed the intervention (a) intended to learn more about technology; (b) felt more self-efficient about their capacities in the field, and (c) enjoyed it more. Their attitudes in these three aspects evolved to a significantly stronger extent than was the case for the teachers who did not follow the intervention. For two out of these three effects, self-attributed involvement scores of teachers evaluating the inputs can offer some insight into the specific active ingredients of the intervention. Firstly, higher involvement scores for the visit to the science centre predicted a larger growth in intentions with regard to technology. The interactive visit to a science centre primarily aimed at allowing the teachers to experience what a wondering child experiences in relation to science and technology in a rich and open context. The qualitative analysis on the evaluation sheets showed that teachers especially reported to have learned from this visit that a rich environment is an important basis for children to learn about science and technology in co-construction. Furthermore, confronting teachers with rich environments, i.e., the exhibits at the centre, offers a lot of inspirational material that teachers can translate into their classroom practices. For teachers who were more involved during the visit, this may consequently evoke more intentions to implement more science and technology activities in their classrooms. Secondly, higher involvement scores during the introduction session predicted a larger growth in feelings of self-efficacy with regard to technology. In the introduction session, participants were confronted with the principles of experiential education and the link to a science and technology implementation that starts from a rich context and daily life experiences. Furthermore, teachers receive the message that an intuitive understanding is very important and that as a teacher, you can make a difference by stimulating and coaching your pupils, and hence finding a solution in co-construction with your pupils. This may give teachers more grip on how to conduct a science or technology activity and may make it more achievable. In accordance with the aims of the input, many teachers mentioned these items in the evaluation forms as learning experiences: they gained a broader view on science and technology and better self-knowledge. Teachers also mentioned the importance of 'providing autonomy' and 'stimulation' to children. As teachers may experience these aspects of good teaching behaviour as feasible, the combination of the above elements may lead to higher estimated feelings of self-efficacy. With regard to the growth in enjoyment of technology over the year, the involvement during the inputs does not operate as a significant predictor. However, the enjoyableness of science and technology is mentioned by six teachers during the visit to a science centre. Part of the goal of this visit was getting teachers to wonder (again). Moreover, the possibility to operate in active co-construction with their pupils during the science and technology module in their classroom, might have given teachers the chance to become acquainted with a more enjoyable way of working with science and technology. Additionally, the intervention had similar effects on teachers' enjoyment of teaching practices related to science and technology (learning by design and inquiry-based learning), which are stressed as good practices in these domains throughout the intervention inputs. Also with regard to these two attitude scales, teachers who followed the intervention trajectory have grown significantly more than their control group counterparts.

With respect to pupil scores, attitudes with regard to gender stereotypes and the perception of difficulty of science and technology improved over the year, whereas pupil attitudes decreased concerning (a) their perceptions of importance of both domains; (b) their enjoyment in both domains; and (c) their intentions to invest more time and effort in these domains. The latter results were unexpected and deserve future research attention. As there were no data available on pupil attitude scores in the control group, findings are however hard to interpret. However, the pupil results suggest that although intervention efforts may aim at improving teacher attitudes and related teacher practices, this does not necessarily improve pupil attitudes directly. This idea was also confirmed by the (striking) finding that more feelings of self-efficacy in teachers (with regard to technology and design-based learning) are related to less enjoyment of technology by pupils at the end of the school year. As one possible explanation, it may not be unlikely that through the intervention, teachers become 'too' self-confident and consequently tend to impose new content on pupils, rather than building knowledge in co-construction with them. In line with experiential education, this lack of autonomy and self-initiative for children may result in less enjoyment of tasks related to technology (Laevers, 2005). Alternatively, as innovation in teacher practices does not go without adaptation, this may cause some friction and drops in satisfaction and enjoyment for the pupils confronted with it. Perhaps if the intervention was spread over a longer period, and/or we conducted a follow-up measure on pupil attitudes, we might have discovered an increase in enjoyment again. Therefore, finding significant improvements in positive attitudes over the period of only one year in pupils, and especially in teachers, holds a strong promise for the future. However, further (in depth) study is certainly necessary based on the unexpected findings on pupil attitudes, as additional and/or alternative explanations may be equally valuable. Perhaps intentions to learn more about science and technology as well as enjoyment in both domains drop by the end of the school year, because it is traditionally a period with a lot of testing, close to the holidays, for example.

With respect to gender, it is also interesting to note that gender-stereotypic beliefs may be determined by class and/or teacher features, as the amount of class level variance was meaningful. Fairly straightforward, it is possible that equivalent teacher attitudes about gender stereotypes play a significant role here. This could however not be evaluated, as this scale was omitted in the version of the teacher questionnaire we used. Other (possibly related) determinants of the detected decrease in gender stereotypic beliefs of pupils may lay in the 'active ingredients' of the intervention we imposed, such as a focus on hidden talents and intensified working with science and technology. This offers pupils and teachers a chance to appreciate the skills of their feminine counterparts, even more when using co-construction and working in a rich environment that provides many opportunities to explore and experiment. Further study would be useful to determine tools and aids to positively affect pupils' views on gender in relation to science and technology, as this is a major issue, especially in the Netherlands (Joukes, 2010).

In general, three remarks are at stake. First, comparison of effects between trajectory group and control group teachers may hold an underestimation of effects, as the control group teachers belonged to the same schools as the teachers who followed the intervention. As these teachers shared the same school environment, this may have led to communication and interaction about the interventions, restoring an influence on the attitudes of the control teachers as well. However, on five attitude scales, we still detected a significant difference in growth on attitude scales in favour of the trajectory group teachers, underscoring the effectiveness of the intervention. Second, it may not surprise that the intervention seems to have a more meaningful influence on attitudes towards technology vs. attitudes towards science. After all, interventions were imbedded in a *technology* module which was implemented through the school year. Third, concerning attitudes towards teacher practices in the field of science and technology, only teachers' enjoyment was fostered through the intervention. Yet, as the correlation analysis showed, both for teachers and pupils, enjoyment of science and technology are associated with all other attitude scales, except for the gender scales. This may indicate that enjoyment in science and technology activities hold a key to improve attitudes on both domains, not only concerning the affective component, but also concerning the cognitive and behavioural components in an indirect way as well.

Finally, we note that next to the fact that effects on (teacher and especially pupil) attitudes may be underestimated due to the limited period of active intervention mentioned above, some other limitations have to be articulated with regard to the present study. First, the aim of the larger study was broader, and hence, future analyses including different outcomes, may show a larger impact of the intervention on the actual competence, behaviour and involvement in science and technology practices of pupils and/or teachers, compared to the impact on their attitudes. As gathering all data through questionnaires, interviews, and observations during the intervention year was very time-consuming, the limited number of participating teachers in the study has to be acknowledged as a downside as well. Consequently, if in future studies the statistical power could be enhanced by enlarging the teacher sample, this may lead to more significant effects on a broader variety of subscales concerning teacher attitudes. We may expect this, because the changes in teacher attitude scores after the intervention year, although not statistically significant for each single outcome, all go in the expected direction.

## NOTES

i http://www.talentenkracht.nl; for English: http://www.talentenkracht.nl/content/files/SITE1765/Brochure_CuriousMinds_eng.pdf

ii We made use of factor analysis with Oblimin rotation, while Oberon used Varimax rotation.

iii With mean scores of 4.36 and 3.97 for Flemish and Dutch teachers respectively.

iv With mean scores of 4.44 and 3.97 for Flemish and Dutch teachers respectively.

v With mean scores for learning by design of 4.12 and 3.71 for the oldest and youngest group of teachers respectively, and mean scores for inquiry-based learning of 4.27 and 3.69 for the oldest and youngest group of teachers respectively.

vi Due to the small number of male participants, gender differences were not calculated.

vii We made use of factor analysis with Oblimin rotation, while Walma van der Molen used Varimax rotation.

viii Except for DIFFICULTY and GENDER, for which scales we expected significantly negative t-values, because we expected the posttest scores to be lower than the pretest scores on these subscales.

ix The reported t-statistics in Table 2 will be discussed later.

x Or lower, concerning DIFFICULTY.

xi The reported t-statistics in Table 3 will be discussed later.

xii With mean scores for technology of 3.68 and 3.40 for the trajectory and control teachers respectively, and mean scores for learning by design of 3.96 and 3.68 for the trajectory and control teachers respectively.

## REFERENCES

Abulude, F. (2009). *Students' attitudes towards chemistry in some selected secondary schools in akure south local government area, Ondo State.* Post graduate thesis, the national teachers institute, Kaduna, Nigeria. Retrieved from http://www.scribd.com/doc/34545165/students%E2%80%99-attitudes-towards-chemistry-in-some-selected-secondary-schools-in-akure-south-local-government-area-ondo-state.

Ajzen, I. (2005). *Attitudes, personality and behavior.* Berkshire, United Kingdom: Open University.
Barak, M. & Zadok, Y. (2009). Robotics projects and learning concepts in science, technology and problem solving. *International Journal of Technology and Design Education*, *19*(3), 289-307.
Chen, S. (2006). Development of an instrument to assess views on nature of science and attitudes toward teaching science. *Science Education, 90,* 803-819.
Cheung, D. (2009). Students' attitudes chemistry lessons: The interaction effect between grade level and gender. *Research in Science Education*, *39*, 75-91.
De Winter, V., & Van Cleynenbreugel, C. (2010). *Leerkrachtprofielen en onderwijs in wetenschap en techniek in het basisonderwijs: Werkzame bestanddelen voor deskundigheidsbevordering en attitudeverandering (VTB-Pro aanvullend onderzoek).* [Teacher profiles and education in science and technology in primary education: Active ingredients to promote professionalism and a positive change in attitudes (VTB-Pro complementary research).] Internal report (draft), Centre for Experiential Education, Catholic University Leuven, Belgium.
Ho, L., & Kuo, T. (2010). How can one amplify the effect of e-learning? An examination of high-tech employees' computer attitude and flow experience. *Computers in Human Behavior*, *26*, 23-31.
Hox, J. (2002). *Multilevel analysis: Techniques and applications.* Mahwah, NJ: Erlbaum.
Jalil, P.A., Sbeih, A.M.Z., Boujettif, M., & Barakat, R. (2009). Autonomy in science education: a practical approach in attitude shifting towards science learning. *Journal of Science Education and Technology*, *18*(6), 476-486.
Jarvis, T. (2006). *Guide for the seed city trainer.* Barcelona, Spain: P.A.U. Education.
Joukes, G. (2010). *Meiden en wetenschap & techniek: Van tegenpolen tot aantrekkingskracht*. [Girls and science & technology: From opposites to attraction.] Maarssen, the Netherlands: Kaldenbach Grafische Producties.
Kemmers, P., Klein Tank, M., & Van Graft, M. (2007). *Onderzoekend en ontwerpend leren bij natuur en techniek: Evalueren van brede ontwikkeling van leerlingen in open onderwijsvormen.* [Inquiry-based learning and learning by design in science and technology: Evaluation of the broad development of pupils in open education forms.] Enschede, the Netherlands: Institute for Curriculum Development (SLO).
Laevers, F. (1993). Deep level learning: an exemplary application on the area of physical knowledge. *European Early Childhood Research Journal, 1*, 53-68.
Laevers, F. (1998). Understanding the world of objects and of people: Intuition as the core element of deep level learning. *International Journal of Educational Research, 29*, 69-85.
Laevers, F. (2005). The curriculum as means to raise the quality of ECE. Implications for policy. *European Early Childhood Education Research Journal*, *13*, 17-30.
Laevers, F. (2006a). Onderwijs op een nieuwe leest. Een reconstructie van de actuele paradigma-shift. [A new approach for education. A reconstruction of the actual paradigma-shift]. In: F. Laevers, en E. Bertrands (Eds.), *Draagkracht geven. Uitkomst voor de toekomst*. (pp.5-24). Leuven: CEGO.
Laevers, F. (2006b). *Kijkwijzer voor een Procesgerichte Analyse van Onderwijsleersituaties*. [Monitoring system for a process-oriented analysis of learning situations in education]. Leuven: Centrum voor Ervaringsgericht Onderwijs.
Lewis, T. (2009). Creativity in technology education: providing children with glimpses of their inventive potential. *International Journal of Technology and Design Education*, *19*(3), 255-268.
Oberon (2009). *Een selectie uit de tussenrapportage effectstudie VTB-Pro. Schooljaar 2008/09.* [A selection from the interim rapport effectstudy VTB-Pro. 2008/09]. Utrecht, the Netherlands: Platform Bèta Techniek.
Ogbuehi, P., & Fraser, B. (2007). Learning environment, attitudes and conceptual development associated with innovative strategies in middle-school mathematics. *Learning Environments Research*, *10*, 101-114.
Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research*, *66*, 543-578.
Pell, A., & Jarvis, T. (2003). Developing attitude to science education scales for use with primary teachers. *International Journal of Science Education, 25*, 1273-1295.
Shrigley, R., & Johnson, T. (1974). The attitude of inservice elementary teachers toward science. *School Science and Mathematics, 74,* 437-446.
Sidawi, M.M. (2009). Teaching science through designing technology. *International Journal of Technology and Design Education*, *19*(3), 269-287.

Snijders, T. A. B., & Bosker, R. J. (1999). *Multilevel analysis: An introduction to basic and advanced multilevel modeling.* London, United Kingdom: Sage.

Tschannen-Moran, M., Woolfolk Hoy, A., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research, 68,* 202-248.

Van Graft, M., & Kemmers, P. (2007). *Onderzoekend en ontwerpend leren bij Natuur en Techniek.* [Inquiry-based learning and learning by design in science and technology]. Den Haag, the Netherlands: Platform Bèta Techniek.

Vazquez-Alonso, A., Manassero-Mas, M. A., & Acevedo-Diaz, J. A. (2006). An analysis of complex multiple choice science technology items: Methodological development and preliminary results. *Science Education, 90,* 681-706.

Walma van der Molen, J. (2007). *Eindrapportage VTB attitude monitor. De ontwikkeling van een attitude-instrument op het gebied van wetenschap en techniek voor leerlingen in het basisonderwijs.* [Final rapport VTB attitude monitor. The development of an attitude instrument on the domain of science and technology for pupils in primary education.] Den Haag, the Netherlands: Platform Bèta Techniek.

Walma van der Molen, J. (2009). Wat vinden leraren basisonderwijs van wetenschap en techniek? De attitudemonitor maakt hun gevoelens, gedachten en gedrag inzichtelijk. [What do teachers in primary education think about science and technology? The attitude-monitor makes their feelings, thoughts and behaviour visible.] In H. van Keulen en J. W. van der Molen (Eds.), *Onderzoek naar wetenschap en techniek in het Nederlandse basisonderwijs.* (pp. 157-163). Den Haag, the Netherlands: Platform Bèta Techniek.

Walma van der Molen, J., de Lange, J., & Kok, J. (2009). Theoretische uitgangspunten bij de professionalisering van leraren basisonderwijs op het gebied van wetenschap en techniek. [Theoretical starting points at the professionalisation of primary education teachers on science and technology domains.] In H. van Keulen, en J. W. van der Molen (Eds.), *Onderzoek naar wetenschap en techniek in het Nederlandse basisonderwijs.* (pp. 29-39). Den Haag, the Netherlands: Platform Bèta Techniek.

## AFFILIATIONS

*Charlotte Van Cleynenbreugel*
*Veerle De Winter*
*Evelien Buyse*
*Ferre Laevers*
*Research Centre for Experiential Education*
*Katholieke Universiteit Leuven*

# APPENDIX

The appendix contains more detailed information on instruments and statistical analysis.

*Table A.1. Overview of scales, example items and study results concerning the teacher questionnaire on attitudes towards science, technology, and related practices*

| | | *Oberon study*[a] | | *Present study* | |
|---|---|---|---|---|---|
| *Subscales* | *Example item* | *# items* | *α*[b] | *# items* | *α*[b] |
| **Attitude Technology** | | $R^2$ [c] = 59% | | $R^2$ [c] = 57% | |
| Difficulty | The technology course can only be given by specially trained teachers. | 2 | .67 | /[d] | / |
| Importance | Technology is important for the community. | 7 | .75 | 6[e] | .77 |
| Enjoyment | I like to repair things myself. | 6 | .87 | 6 | .89 |
| Intentions | I would like to learn more about technology in primary school. | 4 | .81 | 4 | .78 |
| Self-efficacy | I wonder whether I have the necessary skills to teach technology. | 5 | .78 | 7[d] | .84 |
| **Attitude Science** | | $R^2$ [c] = 59% | | $R^2$ [c] = 57% | |
| Difficulty | Science is complicated. | 2 | .60 | 2 | .67 |
| Importance | Researchers do important work. | /[f] | .46 | /[f] | .52 |
| Enjoyment | I like to invent things. | 4 | .79 | 4 | .72 |
| Intentions | I like to read about new inventions, for example in the newspaper or on the Internet. | 4 | .72 | 4 | .68 |
| Self-efficacy | | /[g] | | /[g] | |
| **Attitude Learning by design** | | $R^2$ [c] = 55% | | $R^2$ [c] = 58% | |
| Difficulty | It seems difficult to me to apply learning by design in primary school. | /[f] | (.57) | /[f] | (.22) |
| Importance | Learning by design in primary school is necessary to prepare children for secondary school. | 3 | .62 | 3 | .71 |
| Enjoyment | It appeals to me to let children solve technical problems. | 5 | .84 | 2[h] | .70 |
| Intentions | I would like to learn more about how to conduct children with learning by design. | /[h] | / | 3[h] | .85 |
| Self-efficacy | When children can't figure out a technical problem, I can help them. | 3 | .62 | 3 | .68 |

*Table A.1 (continuation). Overview of scales, example items and study results concerning the teacher questionnaire on attitudes towards science, technology, and related practices*

| | | *Oberon study*[(a)] | | *Present study* | |
|---|---|---|---|---|---|
| *Subscales* | *Example item* | *# items* | *α*[(b)] | *# items* | *α*[(b)] |
| **Attitude Inquiry-based Learning** | | $R^{2\,(c)}$ = 60% | | $R^{2\,(c)}$ = 62% | |
| Difficulty | It seems difficult to me to apply inquiry-based learning in primary school. | /[(f)] | (.55) | /[(f)] | (.49) |
| Importance | It is important that even young children learn how to do research (at their level). | 4 | .75 | 4 | .77 |
| Enjoyment | It appeals to me to let children unravel things. | 3 | .74 | 3 | .75 |
| Intentions | I would like to learn more about inquiry-based learning at primary school. | 3 | .78 | 3 | .84 |
| Self-efficacy | I know how to motivate pupils for inquiry-based learning. | 3 | .60 | 3 | .64 |

[(a)] Extracted from the interim report on an effect study VTB-Pro (school year 2008-2009) by Oberon (2009).
[(b)] Cronbach's alpha coefficients.
[(c)] Explained variance in attitudes towards technology, science, learning by design, and inquiry-based learning respectively, based on factor analysis.
[(d)] Based on factor and/or reliability analysis, the items of the DIFFICULTY scale, i.e., *'The course technology can only be taught by specially trained teachers'* and *'To be able to be a good teacher in technology, you need a specialised training'* were added to the 'self-efficacy' scale. This adaptation is theoretically defendable.
[(e)] Compared to the Oberon study, the item '*The government should spend more money on technology'*, was excluded.
[(f)] Based on factor and/or reliability analysis, this subscale was excluded.
[(g)] In the interim report of Oberon (2009, p. 6), it is stated that the 'self-efficacy' scale is not applicable for attitude towards science.
[(h)] Other than in the Oberon study, the items on the INTENTIONS scale were not added to the ENJOYMENT scale.

*Table A.2. Correlations between teacher attitude scales concerning science and technology (posttest, n = 25-26)*

| | *2.* | *3.* | *4.* | *5.* | *6.* | *7.* |
|---|---|---|---|---|---|---|
| **Attitude Technology** | | | | | | |
| 1. Importance | .06 | .18 | -.09 | -.29 | .11 | .05 |
| 2. Enjoyment | | .34 | .49* | -.15 | .70** | .62** |
| 3. Intentions | | | .36 | -.20 | .42* | .37 |
| 4. Self-efficacy | | | | -.47* | .61*** | .43* |
| **Attitude Science** | | | | | | |
| 5. Difficulty | | | | | -.50** | -.20 |
| 6. Enjoyment | | | | | | .59** |
| 7. Intentions | | | | | | |

*****$p < .05$. **$p < .01$.

*Table A.3. Correlations between technology related teacher subscales (posttest, n = 23-24)*

| | ***Attitude Learning by design*** | | | |
|---|---|---|---|---|
| | *Importance* | *Enjoyment* | *Intentions* | *Self-efficacy* |
| **Attitude Technology** | | | | |
| Importance | .47 * | .48 * | .08 | -.07 |
| Enjoyment | .38 | .24 | .23 | .05 |
| Intentions | .18 | .27 | .26 | .14 |
| Self-efficacy | .03 | -.04 | .22 | .33 |

*****$p < .05$.

*Table A.4. Correlations between science related teacher subscales (posttest, n = 24)*

| | ***Attitude Inquiry-based learning*** | | | |
|---|---|---|---|---|
| | *Importance* | *Enjoyment* | *Intentions* | *Self-efficacy* |
| **Attitude Science** | | | | |
| Difficulty | -.16 | -.04 | -.16 | -.34 |
| Enjoyment | .07 | .42 * | .35 | .28 |
| Intentions | .23 | .16 | .19 | .09 |

*****$p < .05$.

*Table A.5. Overview of scales, example items and study results concerning the pupil questionnaire on attitudes towards science and technology*

| | | Design study[a] | | Present study | |
|---|---|---|---|---|---|
| *Subscales* | *Example item* | *# items* | $\alpha^{(b)}$ | *# items* | $\alpha^{(b)}$ |
| **Attitude Technology** | | $R^{2\,(c)}$ = 51% | | $R^{2\,(c)}$ = 54% | |
| Difficulty | I find it hard to learn about technology. | 4 | .50 | 3[d] | .66 |
| Importance | Technology has a big influence on people. | 7 | .73 | 7 | .70 |
| Gender | Boys are better car-mechanics than girls. | 3 | .76 | 3 | .77 |
| Enjoyment | I enjoy fixing things myself. | 6 | .78 | 6 | .80 |
| Intentions | Later, I want to follow a technical profession. | 3 | .92 | 3 | .84 |
| **Attitude Science** | | $R^{2\,(c)}$ = 56% | | $R^{2\,(c)}$ = 56% | |
| Difficulty | I find science difficult. | 3 | .60 | /[e] | (.36) |
| Importance | People who figure out new ideas are important to society. | 7 | .70 | 7 | .76 |
| Gender | Boys are better scientists than girls. | 3 | .85 | 3 | .88 |
| Enjoyment | I like to figure out new ideas. | 7 | .88 | 7 | .82 |
| Intentions | Later, I would like to have a job in science. | 3 | .84 | 3 | .83 |

(a) Extracted from the design report of the pupil attitude monitor (Walma van der Molen, 2007).
(b) Cronbach's alpha coefficients.
(c) Explained variance in attitudes towards science and technology respectively, based on factor analysis.
(d) Compared to the design study, the item *'Technology is only for smart people'*, was excluded.
(e) Based on factor and/or reliability analysis, this subscale was excluded.

*Table A.6. Correlations between pupil attitude scales (post-test, n = 480-487)*

| | *2.* | *3.* | *4.* | *5.* | *6.* | *7.* | *8.* | *9.* |
|---|---|---|---|---|---|---|---|---|
| **Attitude Technology** | | | | | | | | |
| 1. Difficulty | -.07 | .00 | -.36*** | -.18*** | -.09* | -.06 | -.26*** | -.18*** |
| 2. Importance | | -.02 | .29*** | .32*** | .65*** | .07 | .27*** | .17*** |
| 3. Gender | | | .02 | .13** | .07 | .76*** | .03 | .11* |
| 4. Enjoyment | | | | .45*** | .27*** | .10* | .68*** | .28*** |
| 5. Intentions | | | | | .34*** | .21*** | .41*** | .45*** |
| **Attitude Science** | | | | | | | | |
| 6. Importance | | | | | | .15*** | .43*** | .33*** |
| 7. Gender | | | | | | | .12* | .17*** |
| 8. Enjoyment | | | | | | | | .52*** |
| 9. Intentions | | | | | | | | |

*****$p < .05$. **$p < .01$. ***$p < .001$.

*Table A.7. Comparison of mean attitude scores between Flemish and Dutch pupils*

| | *Flanders (N = 320-327)* | | *The Netherlands (N = 158-163)* | | *t-test*[(a)] | | |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *df* | *t* | *p* |
| **PRETEST** | | | | | | | |
| **Technology** | | | | | | | |
| Difficulty | 2.19 | .65 | 1.86 | .64 | 487.00 | 5.32*** | .000 |
| Importance | 2.90 | .44 | 2.90 | .49 | 488.00 | -0.13 | .895 |
| Gender | 2.17 | .87 | 2.33 | .98 | 291.96 | -1.69 | .092 |
| Enjoyment | 3.32 | .52 | 3.17 | .58 | 488.00 | 2.85** | .005 |
| Intentions | 2.25 | .82 | 2.03 | .86 | 485.00 | 2.75** | .006 |
| **Science** | | | | | | | |
| Importance | 2.94 | .47 | 2.90 | .59 | 265.67 | 0.63 | .531 |
| Gender | 1.82 | .87 | 1.94 | 1.00 | 282.24 | -1.32 | .188 |
| Enjoyment | 3.22 | .55 | 2.97 | .70 | 260.19 | 4.00*** | .000 |
| Intentions | 2.10 | .80 | 1.87 | .80 | 482.00 | 2.93** | .004 |
| **POSTTEST** | | | | | | | |
| **Technology** | | | | | | | |
| Difficulty | 2.02 | .66 | 1.93 | .65 | 483.00 | 1.47 | .141 |
| Importance | 2.81 | .46 | 2.88 | .56 | 278.07 | -1.26 | .208 |
| Gender | 2.18 | .91 | 2.01 | .98 | 483.00 | 1.82 | .069 |
| Enjoyment | 3.18 | .63 | 3.09 | .65 | 483.00 | 1.50 | .134 |
| Intentions | 2.15 | .83 | 2.03 | .83 | 481.00 | 1.56 | .119 |
| **Science** | | | | | | | |
| Importance | 2.85 | .49 | 2.84 | .63 | 260.27 | 0.25 | .804 |
| Gender | 1.77 | .83 | 1.86 | .98 | 277.00 | -0.96 | .338 |
| Enjoyment | 3.05 | .62 | 2.89 | .71 | 485.00 | 2.65** | .008 |
| Intentions | 2.04 | .76 | 1.88 | .79 | 482.00 | 2.04* | .042 |

***** $p < .05$. **$p<.01$. ***$p<.001$.

[(a)] two-tailed independent samples *t*-test for mean differences.

*Table A.8. Comparison of mean attitude scores between boys and girls on the pupil questionnaire*

| | *Boys (N = 230-233)* | | *Girls (N = 250-256)* | | *t-test*[(a)] | | |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *df* | *t* | *p* |
| **PRETEST** | | | | | | | |
| **Technology** | | | | | | | |
| Difficulty | 1.97 | .69 | 2.18 | .63 | 486.00 | -3.51** | .001 |
| Importance | 2.94 | .43 | 2.86 | .48 | 487.00 | 1.87 | .063 |
| Gender | 2.74 | .89 | 1.75 | .63 | 414.65 | 14.04*** | .000 |
| Enjoyment | 3.40 | .53 | 3.15 | .54 | 487.00 | 5.11** | .001 |
| Intentions | 2.48 | .88 | 1.90 | .70 | 486.00 | 7.98*** | .000 |
| **Science** | | | | | | | |
| Importance | 3.01 | .53 | 2.85 | .48 | 484.00 | 3.361** | .001 |
| Gender | 2.40 | .98 | 1.36 | .49 | 333.06 | 14.61*** | .000 |
| Enjoyment | 3.23 | .62 | 3.05 | .59 | 484.00 | 3.31** | .001 |
| Intentions | 2.19 | .89 | 1.88 | .69 | 432.70 | 4.26*** | .000 |
| **POSTTEST** | | | | | | | |
| **Technology** | | | | | | | |
| Difficulty | 1.84 | .69 | 2.12 | .60 | 457.83 | -4.65*** | .000 |
| Importance | 2.90 | .52 | 2.78 | .47 | 482.00 | 2.57*** | .000 |
| Gender | 2.58 | .98 | 1.70 | .65 | 393.83 | 11.54*** | .000 |
| Enjoyment | 3.29 | .64 | 3.02 | .62 | 482.00 | 4.77*** | .000 |
| Intentions | 2.37 | .89 | 1.87 | .70 | 435.24 | 6.79* | .011 |
| **Science** | | | | | | | |
| Importance | 2.97 | .53 | 2.74 | .53 | 484.00 | 4.81*** | .000 |
| Gender | 2.27 | .96 | 1.36 | .51 | 348.39 | 12.79*** | .000 |
| Enjoyment | 3.12 | .64 | 2.88 | .64 | 484.00 | 4.15*** | .000 |
| Intentions | 2.14 | .84 | 1.83 | .67 | 442.33 | 4.49*** | .000 |

***** $p < .05$.**p<.01.***p<.001.

[(a)] two-tailed, independent samples *t*-test for mean differences.