# Equipping pre-service teachers to improve science education at primary schools:

## The impact of a science professional development program on pre-service teachers' subject matter knowledge, teachings strategies, self-efficacy, and attitude

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**Tables & Figures**

*Tables*



*Figures*

**Abstract**
International studies as well as Dutch studies have shown that Dutch elementary school teachers face several challenges in teaching science. In addition to their lack of subject matter knowledge, they have low self-efficacy, a negative attitude towards science, and they are unable to utilize effective teaching strategies during science lessons. This study investigated the effects of a science teaching professional development (PD) program on pre-service teachers facing these challenges. It investigated the extent to which the science teaching PD program alleviated these challenges in teaching science. The research followed a pre-test and post-test design with an experimental group ($n$=23) and comparison group ($n$=51). The experimental group received the science PD program, while the comparison group followed the regular science program. All respondents were third year pre-service teachers. Results indicated that the science PD program significantly improves pre-service teachers' subject matter knowledge and self-efficacy. The program had little or no effect on the utilization of teaching strategies and pre-service teachers' attitude towards science.

To improve the science PD program, pre-service teachers answered a questionnaire on how they perceived the four main elements of the program, which were based on a review of the literature on teacher professional development. These elements are: collaborative learning, observing and reflecting, analysing student work, and having a space for teachers' own professional development focus. Pre-service teachers perceived that focusing on their own professional development had a moderately positive effect on pre-service teacher professional development. The other elements were considered valuable for becoming good at teaching science.

**Contents**

## Chapter 1 Introduction

### 1.1. The need for improvements in science education

The Netherlands is regarded as a world-class player in innovation, scientific research, and education (Techniekpact, 2013). To retain and strengthen this position, Dutch society needs creative, innovative, and highly educated people, including sufficiently skilled technicians (Techniekpact, 2013). By 2020, more than 70,000 construction workers, installers, electricians, metal workers, engineers, and system analysts will have retired. The education system produces only 10,000 technicians per year to take their places (Velthuis, 2014). In addition, every year 30,000 additional technicians are needed to meet the growing need for technical workers (ROA, 2011). Therefore, the Netherlands will have to deal with a growing shortage of workers in the field of Science, Technology, Engineering and Mathematics (STEM). To reduce this shortage, action is needed in the Dutch education system (Techniekpact, 2013).

Since 2000, several initiatives have been taken in the Netherlands to increase students' interest in STEM. For example, the Ministry of Education, Culture, and Science created the platform 'Bèta Techniek' to guide primary schools in focusing on science in the curriculum (Verkenningscommissie wetenschap en technologie primair onderwijs, 2013). These initiatives are appearing to pay off: more students are choosing to study in STEM fields. Whereas in 2009 39% of Dutch secondary education students chose a study in technical direction, in 2013 this number rose to 45%. Despite this growth, the amount of STEM students in secondary education is still far below the total number of students required to meet the shortages in STEM fields (Ministerie van Economische Zaken en Platform Bèta Techniek, 2015). The outflow of highly educated technical employees is especially worrisome in light of these shortages (Rijksoverheid, 2013). According to Volkerink, Berkhout, Bisschop & Heyma (2013), 38% of the highly educated STEM students choose non-technical jobs in non-technical sectors. In addition, Volkerink, Berkhoud and De Graaf (2010) concluded that the outflow of higher-educated technical students is even higher than the outflow of lower-educated technical students.

Research suggests that these problems can be solved with science education (Osborne, Simon & Collins, 2003; Techniekpact, 2013; Van Aalderen-Smeets, Walma van der Molen & Asma, 2012). According to a review study of Osborne, Simon and Collins (2003), science education, especially in primary education, can have a big impact on student interest in STEM. Dutch students in primary schools often develop negative and stereotypical images of science as dirty, dangerous, or masculine (Platform Bèta Techniek, 2008). As a result, many students, particularly girls, exclude study in and/or a career in STEM (Platform Bèta Techniek, 2008).

### 1.2. Science education in Dutch primary school

Review study, conducted by Osborne, Simons & Collins (2003) suggests that students develop their interest and attitudes towards science before the age of fourteen. Hence, primary school plays an important role in developing interest in science. According to van Aalderen-Smeets, Walma van der Molen & Asma (2012), a major determinant of student interest in science and related occupations is the quality of science education. The Trends in International Mathematics and Science Study (TIMSS) showed that Dutch science education in fourth grade of primary school consists, to a large extent of reading a textbook or other learning materials (Meelissen, Netten, Drent, Punter, Droop & Verhoeven, 2012). It seems that Dutch elementary school teachers pay little attention to self-exploring knowledge in physics, such as observing natural phenomena or using fieldwork experiments in their science lessons. In fact, only 6% of the teachers in at least half of the science lessons let their students perform a science experiment. 13% Of Dutch elementary school teachers never use experiments in their science lessons. It would appear that Dutch elementary school teachers are not very confident using experiments in their lessons. Only 24% of the teachers feel ‘very confident’ to provide the instruction and 15% of the teachers indicated they were ‘not confident’ (Meelissen et al., 2012).

By doing science, students can develop skills to propose hypotheses, ask questions, organize their ideas and to experience with their ideas. However, TIMSS results showed that only 5% of the Dutch elementary school teachers teach science by inquiry in at least half of the science lessons. On average, the Netherlands almost pays the least attention of all TIMSS-countries to this way of science teaching. The international average is 40% (Meelissen et al., 2012).

According to the research of Osborne and Dillon (2008), the use of experiments stimulates active learning and can positively affect student learning outcomes. A review study of Davis, Petish and Smithey (2006) offer an explanation as to why teachers hold on to traditional education, such as hands-off activities and instruction-based learning with textbooks. This is, namely, that teachers face several concerns, such as lacking subject matter knowledge and not understanding how to put science teaching strategies into practice.

Another problem in Dutch science education is the limited time elementary school teachers spend on teaching science. Per week, the students obtain one hour of science education. That equates to only 42 hours of science per year, which is far below the international average of 85 hours (Martin, Mullis, Foy & Stanco, 2012). These results indicate that science education in fourth grade in Dutch primary schools has a smaller role than in other TIMSS-countries. Additionally, most of the time in Dutch science lessons is spent on ‘biology’, namely 47% of the time. Only 15% of the time is spent on ‘physics and chemistry’. Generally, Dutch elementary school teachers feel less equipped to teach about this topic (Meelissen et al., 2012).

Other research stated that Dutch primary school teachers in general have little affinity with science and lack necessary subject matter knowledge to teach science (Van Aalderen-Smeets, Walma van der Molen & Asma, 2012; Van Uum & Gravemeijer, 2012). TIMSS results also showed that only 45% of the students obtain science lessons with a ‘very well’ prepared teacher to teach TIMSS science topics (Martin, Mullis, Foy & Stanco, 2012). The TIMSS topics are about biology, physics and chemistry and physical geography. However, in 2011 Dutch elementary school teachers felt better equipped to teach science than in 2007. So, a growth is made in comparison to previous results. Nevertheless, these averages for science education are lower than for mathematics (Meelissen et al., 2012), which is also a STEM subject.

The many challenges Dutch elementary school teachers face in teaching science is worrisome, because teachers play a crucial role in science education: they need to integrate science in their curricula and be able to provide high-quality science lessons. Though much is known about how to improve science education from international research, this knowledge is applied in Dutch primary education only to a limited extent (Van Keulen, 2009; Van Keulen & Walma van der Molen, 2009). High-quality science education in primary school can positively influence students’ attitudes towards science. Students who have more often been in contact with science in primary school have a more realistic view of science in comparison with children who received less science education (Velthuis, 2014).

The Ministry of Education, Culture, and Science recognizes that the Netherlands is behind in science education and wants to improve the quality of and place more importance on science education in primary school. As a reaction to the aforementioned problems, the Dutch government made it obligatory for primary schools to systematically provide science lessons from 2020 (Techniekpact, 2013). The goal of this plan is to remain, in the long-term, one of the most competitive countries in the world in innovation, scientific research, and education. Therefore, great effort should be invested to improve science education in primary school (Ministerie van Onderwijs, Cultuur en Wetenschap, 2009).

### 1.3. Problem statement: Scientific and social relevance

A possible explanation for the lack of time and attention in science education in Dutch primary schools are the competencies of teachers (Rohaan, Taconis & Jochems, 2012; Van Aalderen-Smeets, Walma van der Molen & Asma, 2012; Van Uum & Gravemeijer, 2012; Velthuis, 2014). According to Davis, Petish and Smithey, beginning primary school teachers in particular, face many challenges in teaching science. These researchers conducted a review of the research on the challenges teachers face when they teaching science. The researchers stated that these challenges were: 1) little science subject matter knowledge, 2) difficulties implementing effective science teaching strategies, 3) a low self-efficacy regarding science teaching, and 4) a lack of a positive attitude towards science. The challenges will be explained in more detail in the theoretical framework of this study.

The challenges teachers face in teaching science and technology indicate a need for professional development (PD). The research group 'Science and Technology in Education' at Saxion Academy (Deventer), University of Applied Sciences, focuses on how to prepare pre-service teachers to teach science in primary education. During the 2014-2015 academic year the research group developed and tested the first evidence-based science PD program for pre-service teachers in the Netherlands (Kroek, 2016). The aim of the science PD program is to prepare pre-service teachers to provide effective science education in primary school.

The science PD program has been designed based on four effective program elements, which contribute to the effectiveness of a PD program. Based on research literature, these elements have shown to be effective in PD programs (Kroek, 2016). Currently, little is known about the effects of the science PD program on pre-service teacher professionalism in teaching science and the effects of the elements on teacher professionalism in teaching science. In this study, professionalism in teaching science refers to subject matter knowledge about science topics, science self-efficacy, teaching strategies in science education, and a positive attitude towards science. Davis, Petish, and Smithey (2006) conclude that these aspects are necessary to teach science, but these are also experienced as challenges in teaching science.

The outcomes of this study contribute in various ways to improve PD programs for (pre-service) teachers. On national and international level, there is still much to learn about how teachers can be best prepared to teach science. Also the research group 'Science and Technology in Education' can use the findings of this research to improve and adapt the science PD program.  v

*Structure of the thesis*

The effective elements of the PD-program are explained in more depth in chapter 2, the theoretical framework. Additionally, the challenges that teachers face in teaching science will be explained and the term 'professionalism in teaching science' will be defined. From here, the research questions will be presented. Chapter 3 provides information about the science PD program and how the four effective elements are used in the program. Subsequently, the research methods to answer the research questions will be explained in chapter 4. The research results are presented in chapter 5, followed by the conclusions and discussion in chapter 6.

## Chapter 2 Theoretical framework

In this chapter the theoretical foundation of the study is described. First, in section 2.1 the current position and situation of science education in the Netherlands is described. After this, the effective elements of a PD program will be explained in section 2.2. Then, in section 2.3, the challenges facing elementary school teachers in teaching science are described. This section contains information about science subject matter knowledge, teaching strategies in science, self-efficacy in teaching science, and attitude towards science. In section 2.4, the literature will be integrated and an analytical framework will be presented. Based on the findings in literature, the research questions will be formulated in section 2.5.

### 2.1. Science education in the Netherlands

In contrast to other countries such as England, Sweden, and Australia, the Netherlands has no strong tradition regarding science education in primary schools (Van Keulen & Walma van der Molen, 2009). In 2003, the Dutch government launched 'Deltaplan Bèta Techniek' (Delta Plan for Science) to address the shortage of scientists and engineers. The aim of this plan was to obtain 15% more graduates for studies in science and engineering (Kuijpers, Noordam & Peters, 2009). In order to achieve this goal, many institutions, like Saxion Academy and Platform Bèta Techniek, are working on improving the effectiveness of science education. These institutions find that primary education in the Netherlands should focus more attention on inquiry and design-based learning, because research suggests that this way of learning improves students understanding of relevant science concepts, as well as design and inquiry skills (Fredrick & Shaw, 1999).

In the Netherlands, science education is divided into science and technology (Walma van der Molen, De Lange & Kok, 2009). Science focuses on explanations of natural phenomena and generalizations of statements. Technology focuses on design solutions for specific (technical) problems. Both subjects require scientific knowledge; laboratory skills; graphing skills; interpreting data; critical thinking; vocabulary knowledge; and fostering scientific literacy, understanding of scientific processes and conceptual understandings (Haury, 1993). The Dutch core objectives (Dutch: kerndoelen) state what all students must have learned at the end of primary education. The core objectives related to science education have the heading 'Nature and Technology' (SLO, 2015). The use of the term 'nature' allows many teachers to focus on instilling wonder and respect for living nature in their students (Van Keulen, 2009). Studies show that many teachers are confident about the nature components (Jarvis & Pell, 2004; Pell & Jarvis, 2003; Plourde, 2002), but these are not the only aims of science education. To avoid possible confusion, it is important to be explicit about the topics of science education this study focuses on. The focus of this study is physical science and technology. In this study these fields of study are described as 'science'.

### 2.2. Effective elements in a PD program

Kroek (2016) developed a science PD program for pre-service teachers at Saxion Academy to enhance the professionalism of pre-service teachers in science education at primary schools. This program has been developed on the basis of reviews of effective PD programs. Kroek (2016) reviewed the reviews on the effectiveness of PD programs, focusing on identifying effective program elements.

Kroek (2016) concluded that four specific elements contribute to the effectiveness of PD programs. These elements are: 1) student assessment, 2) collaborative learning, 3) observing oneself and others, and 4) a personal professional development focus. According to Kroek (2016), the elements have the greatest impact when they are related to the content and focus of the PD program. For this reason, Kroek (2016) included these elements in the science PD-program. The following sub-sections provide insight into these four effective elements, which are used to build the science PD program.

### *2.2.1. Student assessment*

The first effective element of a PD program for pre-service students is *student assessment* (Blank & de las Alas, 2009; Van Veen, Zwart, Meirink & Verloop, 2010). This implies that pre-service teachers have to practice with student data, such as by analysing student data, reviewing students' work, and developing assessments. It provides pre-service teachers insight into student performance (Blank & de las Alas, 2009; Van Veen, Zwart, Meirink & Verloop, 2010). Student assessment enables teachers to choose an appropriate remedial for students, so that children will be taught at suitable levels (Dewals & Rodwell, 1988). Student data also provides a deeper understanding of the relationship between the education teachers provide and student learning (Langer, Colton & Goff, 2003; Van Veen, Zwart, Meirink & Verloop, 2010). It is an indicator of what the students learned about a certain concept or skill and how the student learning process proceeded (Langer, Colton & Goff, 2003).

Some teachers have a natural tendency to assume the students have completely understood the lesson (Cautreels & Van Petegem, 2008). However, this is not always the case. A teacher can gain insight into student achievement with a reflective analysis of student work. A reflective analysis implies a focused examination of student work to gain insight into the learning process of students. Subsequently, the teacher can make adaptations in the following lessons (Cautreels & Van Petegem, 2008). Additionally, Cautreels and Van Petegem (2008) argue that student data also can provides insight into teacher quality. A weak student performance can be (partially) caused by a teacher. For example, a teacher's lack of instructional skills may result in students not understanding how to carry out an inquiry experiment during a science class. By analysing student data, the teacher obtains insight into his teaching strengths and weaknesses. This provides teachers with the opportunity to identify new professional development goals (Cautreels & Van Petegem, 2008).

According to Timperley, Wilson, Barrar and Fung (2007), active engagement of pre-service teachers with 'student assessment' in PD programs could have a positive influence on teachers' attitude towards science subjects. When teachers are more engaged, they feel more committed to teaching and learning of pupils. Examining and discussing student work can help teachers to design their lessons at an appropriate level of difficulty and it helps to develop new skills in diagnosing pupil problems (Garet, Porter, Desimone, Birman & Yoon, 2001).

### *2.2.2. Observation and reflection*

The second effective element of a PD-program is *observation and reflection* (Blank & de las Alas, 2009; Cordingley, Bell, Thomason & Firth, 2005; Garet, Porter, Desimone, Birman, Yoon, 2001; Timperley, Wilson, Barrar & Fung, 2007). Observation refers to the opportunity for teachers to observe expert teachers, observe themselves, and observe others. Reflection refers to the opportunity to *reflect* on their own practice.

Observation and reflection includes providing advice and information about new ideas across a broad spectrum of teaching and learning issues (Cordingley, Bell, Thomason & Firth, 2005). These activities can take a variety of forms, such as providing feedback on videotaped lessons; teachers visiting each other's classroom to observe lessons; or having activity leaders, lead teachers, mentors and engage in reflective discussions about the goal of a lesson, teaching strategies, and student learning (Garet, Porter, Desimone, Birman, Yoon, 2001). According to Timperley, Wilson, Barrar & Fung (2007), by providing these opportunities, teachers are more actively engaged in learning.

Research suggests that observation is an effective element in PD programs, because expert teachers and videos can be used for modelling, a method of skills transference. Modelling can be used to learn a specific behaviour to another. The desired behaviour is encountered several times, so the behaviour becomes ingrained to the other (Haston, 2007). This way, teachers who observe another teacher can analyse qualitative sample lessons or behaviour, with the aim to model it in their own practices (Vrieling, Stijnen, Besselink, Velthorst & van Maanen, 2015).

According to research results of Kroek (2016), pre-service teachers indicated that they felt more confident after observing other teachers, because this gives them an idea on how they can perform science lessons themselves. The research of Kroek (2016) also found that reflection on science lessons was effective in professional development. Pre-service teachers felt more confident in science teaching when they reflect on their own lessons, because then they gain more insight in how to manage a science lesson and how to improve behaviour or the quality of their own lessons.

*2.2.3. Collaborative learning*

The third effective element of a PD program is *collaborative learning (*Blank & de las Alas, 2009; Cordingley, Bell, Thomason & Firth, 2005; Timperley, Wilson, Barrar & Fung, 2007; Van Veen, Zwart, Meirink & Verloop, 2010). According to Gerlach (1994), collaborative learning is an educational approach in which students or pre-service teachers work together in small groups towards a common goal. It gives pre-service teachers the opportunity to exchange ideas and knowledge.

Collaborative learning can occur in several ways, such as through peer support or by stimulating professional dialogues (Blank & de las Alas, 2009; Cordingley, Bell, Thomason & Firth, 2005; Timperley, Wilson, Barrar & Fung, 2007; Van Veen, Zwart, Meirink & Verloop, 2010). A central aim of collaborative learning is collective knowledge. Collective learning makes individual knowledge explicit; as a result, that knowledge can be shared and discussed with others, and used by others (Verbiest, 2003).

Kroek (2016) stated that pre-service teachers experience collaborative learning as a valuable addition in a PD program, because they gain more insight into (didactic) knowledge. Collaborative learning also can contribute to attitudes and behaviours. Several studies suggests that collaborative interventions positively changed teachers' attitudes and behaviours towards subjects (Blank & de las Alas, 2009; Cordingley, Bell, Thomason & Firth, 2005; Cordingley, Bell, Rundell & Evans, 2003; Timperley, Wilson, Barrar & Fung, 2007).

Powerful collaboration strategies are professional dialogues (Van Veen, Zwart, Meirink & Verloop, 2010) and peer coaching (Cordingley, Bell, Thomason & Firth, 2005). Craig (2004) stated that teachers not only have to discuss their teaching experience with others, but have to engage in critical dialogues about their work and teaching circumstances, because that is the most important element to improve teaching and learning. In addition, professional dialogues can move pre-service teachers towards higher-level cognition. Peer coaching can be used for professional learning through a mutual process of support and challenge. It ensures that pre-service teachers will not only feel responsible for their own learning, but also for the learning of others (Van Veen, Zwart, Meirink & Verloop, 2010).

In short, research suggests that collaborative learning in a PD program contributes to pre-service teachers' shared knowledge. Pre-service teachers can exchange knowledge, discuss topics and exchange ideas with others with professional dialogues and peer coaching. Collaborative activities, like student assessment or exchanging ideas about the content of a science class, ensures that teachers are more engaged in their own and others' learning processes, because they are aware of the mutual dependency (Verbiest, 2003).

*2.2.4. Teachers' own professional development focus*

The last effective element of a PD-program is identifying a *teacher's own professional development focus* (Cordingley, Bell, Thomason & Firth, 2005). According to Jano (2015), motivation of teachers can be affected by autonomy. The factor 'autonomy' refers to the need of the teacher to act on his- or herself (Jano, 2015). Autonomy is linked to intrinsic motivation. Research has shown that the sense of autonomy is important for intrinsic motivation (Gagné & Deci, 2005; Guay, Boggiano & Vallerand, 2001). The sense of autonomy and the space for teachers' own development focus is positively related to intrinsic motivation. Teachers are often not involved in educational innovation; they only have to perform the innovation (Ketelaar, Beijaard, Boshuizen & Den Brok, 2012). This can lead to less intrinsic motivation (Pelletier, Seguin-Levesque & Legault, 2002).

Pelletier, Seguin-Levesque and Legault (2002) suggest that teachers have less intrinsic motivation when they have to perform the primary school curriculum as it has been described, and don't have the freedom to adapt it. Intrinsic motivation can be enhanced when teachers are more involved in the curriculum and teachers can choose their own professional development focus.

Teachers with their own development focus could be more involved in the development of lessons and change processes at school (Bergen & Van Veen, 2004). Thereby, it is important that teachers obtain guidance in their own professional development focus, because otherwise it can result in uncertainty in how to act or design lessons or a curriculum in the right way (Kroek, 2016).

### 2.4. Challenges for pre-service teachers in teaching science

Based on review study it is concluded that teachers, especially beginning teachers, face many challenges in teaching science (Davis, Petish and Smihey, 2006). As mentioned before, the main challenges that teachers face in teaching science are: 1) little science subject matter knowledge, 2) difficulties implementing effective science teaching strategies, 3) low self-efficacy regarding science teaching, and 4) lack of a positive attitude towards science. In the following subsections, the teacher challenges are described. Also an explanation why the challenges should be tackled is presented.

*2.3.1. Subject matter knowledge in teaching science*

One challenge teachers face in teaching science is their limited amount of subject matter knowledge (SMK). SMK is knowledge about the content to be taught. Teacher knowledge can be defined as 'the whole of knowledge and insight that underlie teachers' action in practice' (Verloop et al. 2001, p. 446). SMK can be divided into conceptual knowledge and procedural knowledge (Rohaan, Taconix & Jochems, 2012). Conceptual knowledge includes knowledge about theories, principles, and facts, such as scientific knowledge about air pressure, constructs, sinking and floating, or electronics. Procedural knowledge is mainly concerned with knowledge of how to solve scientific or technological design problems, which is simply 'know how to do it' knowledge (McCormick, 1997).

Many pre-service teachers in the Netherlands did not receive any teacher training for giving science lessons (Rohaan, Taconis & Jochems, 2012). Therefore, Rohaan, Taconis & Jochems (2012) recommended that PD programs for pre-service teachers should initially focus on the development of teachers' SMK, because it is an important predictor for student achievement. Research suggests that teachers with more science SMK achieve better student results in comparison to teachers with less science SMK (Sadler, Sonnert, Coyle, Cook-Smith & Miller, 2013). According to Rohaan, Taconis and Yochems (2012) SMK is also an important prerequisite for self-efficacy. Teachers with more science SMK have a higher personal self-efficacy in teaching science, because they feel more confident about their knowledge (Velthuis, 2014).

Research showed that many teachers are struggling with their SMK. Many teachers exhibit deficiencies in their SMK (Leonard, Boakes & Moore, 2009) and use alternative or misconceptions in their science lessons. Teachers with a low level of SMK are also less able to ask pupils good questions and develop additional inquiries (Lederman, 1999; Leung & Park, 2002). Therefore, teachers need comprehensive SMK in order to teach science correctly. Teachers with more SMK are more likely to present science topics in familiar contexts, to make relationships between concepts and those teachers are more able to connect lessons to pupils' knowledge level (Lee, Hart, Cuevas & Enders, 2004; Leonard, Boakes & Moore, 2009).

Van Uum and Gravemeijer (2012) conducted a research at four teacher training colleges in the Netherlands ($n$=110). The results suggested that many teachers exhibit deficiencies in science SMK. 48% Of the Dutch pre-service teachers did not feel confident enough about their SMK to provide science lessons. 34% Of the respondents assessed their SMK as 'neutral' and only 17% felt confident about their SMK. According to Van Uum and Gravemeijer (2012), Dutch pre-service teachers feel the need for more SMK courses at their teacher training college.

Research also suggests that pre-service teachers' science SMK can be increased when pre-service teachers work collaboratively (in groups) on a practical activity. This contributes to a better understanding of science concepts, especially when pre-service teachers can discuss the concepts (McRobbie, Ginns & Stein, 2000). In addition, repeating and naming the concepts is important for a deeper understanding of science concepts (Parkinson, 2001). Moreover, it is not possible to teach pre-service teachers all the science concepts they will encounter in teaching science in primary school.

Therefore, it is important to teach pre-service teachers how they can obtain the necessary science knowledge on their own (Lloyd, Smith, Fay, Khang, Wah & Sal, 1998).

In the science PD program, SMK is systematically offered by collaborative learning activities (for example by professional dialogues). It is expected that that this will enhance pre-service teachers SMK about science topics and that pre-service teachers will feel more confident about their SMK to provide science lessons.

### *2.3.2. Teaching strategies in science education*

Schroeder et al. (2007) conducted a meta-analysis on effective science teaching to identify the most effective science teaching strategies. They studied the effects of specific strategies on student achievement in science and identified eight teaching strategies that are proven to be effective: enhanced context strategies, collaborative learning strategies, questioning strategies, inquiry strategies, manipulation strategies, testing strategies, instructional technology strategies, and enhanced material strategies. Pupil science achievement was used as the dependent variable and the eight teaching strategies as the independent variable. Table 2.1 provides a ranked overview of the strategies, based on their effect size.

Table 2.1
*Ranking of Teaching Strategies*

| Strategies | Effect Size | Rank |
|---|---|---|
| Enhanced Context Strategies | 1.48 | 1 |
| Collaborative Learning Strategies | .96 | 2 |
| Questioning Strategies | .74 | 3 |
| Inquiry Strategies | .65 | 4 |
| Manipulation Strategies | .57 | 5 |
| Testing Strategies | .51 | 6 |
| Instructional Technology Strategies | .48 | 7 |
| Enhanced Material Strategies | .29 | 8 |

*Note.* Adapted from 'Meta-analysis of national research regarding science teaching' by Schroeder et al., 2007, Texas Science Initiative of the Texas Education Agency.

Although the strategies are proven to effectively contribute to pupil learning, several studies have shown that teachers have difficulties with applying the strategies, and some teachers not use them at all (Davis, Petish & Smithey, 2006; Eick, 2002; Harlen & Holroyd, 1997). The following sub-sections explain the purpose and importance of the strategies.

#### *Enhanced context strategies*

Enhanced context strategies have the greatest impact on pupil learning. Learning begins with contextualization of the learning goal or activity (Wason & Johnson-Laird, 1972). Enhanced context strategies make tasks that pupils will face meaningful situations and stimulates them to action, so students can immediately begin to investigate (Kimbell, Stables & Green, 1996).

It is important for pupils to learn subjects in a context, because it makes it more likely for pupils to make a relationship between theory and real-world situations (Bjork, Richardson-Kavhen, 1989). One example of a lesson where a context strategy is applied, is one in which pupils have to construct a bridge for their city. Such a context gives students the opportunity to struggle with real-world and meaningful situations (Fortus, Dershimer, Krajcik, Marx & Mamlok-Naaman, 2004). Research also suggests that pupils who learn with different contexts extend their science learning beyond school to a greater degree than pupils without. It has been found that pupils of the former group engage in more community activities than pupils who are learning science with a focus on pure knowledge (Yager, 1989).

*Collaborative learning strategies*

In collaboration strategies, pupils have a mutual task and work together to achieve something that neither member could have independently produced without difficulty. Pupils' deployment and the effort of every pupil in class is required to be successful in science learning. This is a positive dependence, because joint efforts yield more effects than individual performances (Casteren, Broek, Hölgens & Warps, 2014).

Moreover, Roychoudhury and Roth (1992) stated that collaborative learning environments give rise to a number of benefits beyond achievement. First, when a teacher provides pupils the opportunity for collaborative problem solving, pupils will obtain shared insight and solutions that would not have come about without the others. Second, collaborative learning strategies give pupils the chance to alternate in interactional roles and to reflect on their achievements in their roles. For example, one fulfils the role of tutor and one other take the role of executor. In such divisions of roles, there needs to be a difference in knowledge between the individuals, so more knowledgeable pupils can act as tutor to those less knowledgeable. Third, collaborative strategies decrease pupils' science misconceptions, because pupils have to explain, elaborate, or defend their findings to other pupils. Lastly, through collaboration, pupils can develop social skills which are necessary in today's rapidly changing society (Roychoudhury & Roth, 1992; Thijs, Fisser & van der Hoeven, 2014).

Another important aspect of collaborative learning strategies is that they reduce fear concerning science course content, particularly for female students. Learning in heterogeneous and interdisciplinary groups promotes learning and decreases science preconceptions. It creates space for pupils to ask questions without exposing themselves to the teacher (Cooper & Mueck, 1990).

Although research has shown that working together in science classes has a positive influence on pupils' attitude towards science, many teachers avoid collaborative learning. Many teacher prefer a traditional way of science teaching, involving reading textbooks, listening to lectures, and pupils working by themselves, because they are afraid that they lose control (Casteren, Broek, Hölsgens & Warps, 2014; Davis, Petish & Smithey, 2006; Harlen & Holroyd, 1997; Johnson, Johnson, Scott & Ramolae, 1985).

*Questioning strategies*

One aim of science teaching is the development of higher—level thinking in pupils. To achieve this goal, teachers need to facilitate communication with and amongst pupils. An important way to stimulate thinking in the science classroom is by using questioning strategies (Blosser, 1990; Neeley, 2005).

Questioning strategies can stimulate pupils to develop a thorough understanding of science content. Teacher questions are a frequent component in science lessons and play an essential role in discourse during science instruction. Both the type of questions and how teachers ask questions influences the cognitive processes that pupils engage in (Chin, 2007). Teacher questions can be categorized into higher-order and lower-order questions. Lower-order questions include cognitive-memory thinking and often result in a limited number of acceptable responses (for example: 'What do we call this phenomenon?'). Higher-order questions include convergent thinking, divergent thinking and evaluative thinking. These questions result in a greater number of acceptable responses (for example: 'What might have happened if you replaced it with wood?') (Blosser, 1990).

Lower-order and higher-order questions can be classified further relative to the type of thinking stimulation they cause. For higher-order questions, these are divergent and evaluative thinking, while lower-order questions stimulate cognitive memory or convergent thinking. Teachers can improve the science comprehension of pupils with a combination of these type of questions (Blosser, 1990).

After asking a question most teachers only wait a second for a pupil's response. Teachers are concerned about giving a longer wait time, because they fear pupils will become bored or the class will become noisy (Rowe, 1996). However, according to Rowe (1996), sufficient wait time, allowing five or more seconds of silence after asking a question, is a highly effective strategy for making students think and respond to questions. Research has shown that a wait time of five or more seconds reveals many interesting pupil responses. For instance, when a teacher uses a longer wait time, a pupil will give more elaborate answers and fewer pupils will say they do not know the answer. Furthermore, longer wait times allows pupils to use evidence to support their ideas or findings. Another finding is that pupils who normally do not respond to questions from the teacher will be more inclined to volunteer and participate in science lessons (Rowe, 2003).

*Inquiry strategies*

According to Flick and Lederman (2006), inquiry-based teaching is a main principle of modern science. Scientific inquiry refers to a variety of processes and ways in which pupils can investigate the everyday world and propose explanations based on evidence derived from their work. Knowledge of isolated scientific facts is not sufficient to participate in a society increasingly dominated by science and technology. Pupils need to understand the opportunities and limits of scientific knowledge (Driver, Newton & Osborne, 2000). Inquiry strategies in science education can contribute to discovering and developing new knowledge in science, understanding scientific ideas, and making understandable how scientists conduct research about the natural world. In inquiry-based learning, pupils learn many of the same thinking processes and activities as scientists who are engaged in developing human knowledge in the natural world (NRC, 2000).

Pupils at all grades should have the opportunity to use inquiry methods in science lessons. Inquiry is a basic element for science education. Inquiry activities can promote reasoning as well as development of exploration processes (Ash & Klein, 2000). Scientific inquiry includes hands-on activities, asking questions, setting hypotheses, planning and conducting investigations, using appropriate tools and techniques for data collection, building critical and logical relationships between evidence and explanations, analysing alternative explanations, and finding scientific arguments. The teacher has the important task of making a selection of pupils' activities and guiding pupils' inquiry process (NRC, 1996).

Research has shown that pupils have a need for personalization in their learning environment, that is, they desire personal relevance in learning activities (Osborne & Collins, 2001). Inquiry activities can contribute to such successful learning settings. Pupils experience more opportunities to make decisions about their own learning processes and enjoy more active involvement. Therefore, inquiry in science education provides authentic and challenging learning situations, based on student agency. It enhances pupils' motivation to learn science (Carvalho et al., 2009).

*Manipulation strategies*

Manipulation strategies are integrated in inquiry science. Such science strategies that involve direct experiences with natural phenomena have become known as hands-on science (Fredrick & Shaw, 1999). Hands-on science includes activities that allows pupils to handle, manipulate, and observe scientific processes (Lumpe & Oliver, 1991). Science teachers should provide pupils the opportunity to work or practice with physical objects and manipulate equipment to gather data (Neeley, 2005). Manipulating devices ensures that pupils will establish relationships between concepts and draw conclusions about different science topics (Neeley, 2005). Research suggests that the use of manipulation strategies in science education has positive effects, such as increasing positive attitudes towards science, scientific subject matter knowledge, motivation to learn science, development of scientific skills and strategies for learning, and scientific insight for inquiry (Fredrick & Shaw, 1999; Weinburgh, 1999).

Manipulation activities also promotes peer interactions, where pupils feel free to discuss, make mistakes, and challenge each other (Glasson, 1989). Pupils can learn more from the errors they made than pupils who only listen to lectures or watch films (Martin, 2007). Pupils observing the teacher are more likely to be passive learners and are often less motivated to solve problems independently (Glasson, 1989). This is often the case, because teachers often prefer to demonstrate an experiment by themselves rather than have students perform it (Glasson, 1989). Another problem in the use of manipulation strategies, is that teachers have concerns about discipline and management, which can lead to traditional hands-off teaching practices (Eick, 2002). As a result, a lack of manipulation strategies cause a negative effect on students' mastery of science concepts (Fredrick & Shaw, 1999; Weinburgh, 1999).

*Testing strategies*

Teachers can use different testing strategies to assess pupils' understanding of science content or skills (Neeley, 2005). Teachers have to adapt the content of the curriculum to differences in levels of pupils. A teacher needs to know whether pupils understand the learning objectives and if additional instruction is needed (Blok, 2004). Differences between pupils can be taken into account by testing. Testing can inform about the level of pupils and based on pupil work, teachers can differentiate in their lessons.

In literature, two types of assessment are distinguished, namely formative and summative assessment (Struyf, 2000). Both assessments require different tests: formative and summative testing. Teachers should use both types of testing in their science lessons. Summative tests can be used for determining pupil results (Nieveen, 1995; Struyf, 2000). The aim of summative testing is to gain insight into the final performance of pupils. The results of a summative test summarize the learning goals that a pupil obtained at the end of a curriculum. Typical for this type of assessment is that information is collected over a longer period and about a larger amount of material (Struyf, 2000).

Formative assessment aims to optimize the learning process of pupils (Tessmer, 1994). Formative tests can provide insights into which topics pupils require additional instruction or guidance. The feedback that is provided by the teacher to pupils is crucial (Struyf, 2000). Formative tests provide information about what learning goals pupils have achieved. Teachers can determine whether there is a limitation in the learning process of a pupil, and hence adjust the learning process (Struyf, 2000; Tessmer, 1994). For example, teachers can use pupil worksheets to assess whether the pupils understood that objects' buoyancy was related with mass, volume, and density. In this situation, the worksheets are used as a formative test. If it appears that a pupil did not understand the content, the teacher can develop an appropriate adaptation to help the pupil understand the content knowledge. This contributes to a higher level of learning.

According to Sluijsman, Joosten-Ten Brinke and Van Der Vleuten (2013), formative assessment leads to better learning outcomes of pupils, but this type of assessment is rarely used by teachers. Teachers find it difficult to use pupils' test results in their lessons, because they do not know exactly how to use them.

*Instructional technology strategies*

Studies have shown that pupils are more motivated to learn when they use technology, like computers, iPads or simulations (Heemskerk, Eck, Van Volman & Dam, 2013; Kennisnet, 2012). Pupils learn faster by using technology. In addition, pupils obtain better results and the learning process becomes more efficient. Also teachers can benefit from the use of technology in science lessons. Technology can provide time savings, better classroom management and teachers can better follow the progress of pupils (Heemskerk, Eck, Van Volman & Dam, 2013; Kennisnet, 2012).

Despite the fact that technology can be a valuable addition in education, studies have shown that male teachers use more technology (like computers, iPads or ICT) in their lessons than female teachers (Stubbe, 2015). Study also has shown that male teachers have a more positive attitude towards technology (Stubbe, 2015). According to Van Braak, Tondeur and Valcke (2004) female teachers do have a positive attitude towards technology, but they have less experience with technology. Therefore, they are less likely to use technology in their lessons, because they do not exactly know how to use it (Kusano, et al., 2013; Stubbe, 2015).

*Enhanced materials strategies*
Different types of materials can enhance pupils' achievement in science. This strategy implies that the teacher creates or modifies materials which help to improve science learning. It requires the teacher to adopt a more pupil-centred approach and encourages pupils to take ownership over the procedures and outcomes of a practical activity (Neeley, 2005). McManus, Dunn and Denig (2003) examined learning through material strategies in science lessons. They conclude that pupils were more actively involved in science lessons when they worked with teacher- and pupil-constructed materials, like task cards, floor games and worksheets. In addition, the pupils scored significantly higher on science achievement tests when they worked with these instructional resources. Also the attitude of pupils towards science was positively improved when they worked with these materials.

### *2.3.3. Teachers' self-efficacy in science education*
Self-efficacy is defined as one's belief in one's ability to perform an action leading towards a specific goal (Bandura, 1977). In the context of education, self-efficacy can be defined as a teacher's personal belief in their ability to perform teaching tasks at a certain level of quality in a classroom environment. Self-efficacy has a major impact on the motivation to carry out tasks and achieve goals. Studies have shown that teachers' belief in their self-efficacy affects their resilience and the way in which they teach (Schwartzer & Schmitz, 2005).

Review study has shown that teachers with a high self-efficacy are better able to deliver high-quality science lessons (Davis, Petish & Smithey, 2006). These teachers set higher goals for themselves (Bandura, 1977), have less fear of failure, will try out other strategies when the familiar approach appears to have no effect (Velthuis, 2014), will more often adopt a hands-on approach using various activities, and will spend more time in designing their science lessons (Czerniak & Schriver, 1994). Teachers with low self-efficacy often spend less time on a task, give traditional, teacher-centred lessons, and offer little variation in teaching methods or student challenges (Czerniak & Schriver, 1994).

Studies have shown that many teachers experience a lack of self-efficacy in teaching science (Osborne, Simon & Collins, 2003; Velthuis, 2014). This can be explained by a low level of SMK and a lack of didactic knowledge, like teaching strategies (Ellis, 2001; Palmer, 2006; Settlage, 2006). Teachers with low self-efficacy choose more often a traditional teaching method, in which they feel more comfortable. They avoid effective science teaching approaches, which are inquiry-oriented (Alfieri, Brooks, Aldrich & Tennenbaum, 2011; Schroeder, Scott, Tolson, Huang & Lee, 2007). A low degree of self-efficacy also can cause teachers to spend little time on science (Jarvis & Pell, 2004).

TIMSS results showed that Dutch elementary school teachers do not feel confident about several components in teaching science (Martin, Mullis, Foy & Stanco, 2012). It seems that Dutch primary teachers have a lower self-efficacy in teaching science, in comparison to other TIMSS countries. Table 2.2 provides an overview of the percent of students whose teachers feel confident to several components of teaching science. It is remarkable that Dutch elementary school teachers score on each component lower than the international average.

Table 2.2. Components of confidence in teaching science scale.

| | **Percent of students whose teachers feel very confident to** | | | | |
|---|---|---|---|---|---|
| | Answer student questions about science | Explain science concepts or principles by doing science experiments | Provide challenging tasks for capable students | Adapt teaching to engage student interest | Help students appreciate the value of learning science |
| The Netherlands average | 46 | 21 | 16 | 53 | 51 |
| International average | 62 | 51 | 43 | 63 | 68 |

*Note.* Adapted from 'TIMSS 2011 International Results in Science' by Martin, M., Mullis, I., Foy, P. & Stanco, G., 2012, TIMSS 2011 International Results in Science. Chestnut Hill, MA: Boston College, TIMSS & PRILS International Study Center.

In the science PD program, attention is paid on SMK and science teaching strategies. SMK will be systematically offered, so this can positively influence pre-service teachers' self-efficacy. Also teaching strategies will be treated during the science PD program and pre-service teachers will use them in their science lessons. So, this also can have a positive influence on self-efficacy.

Many studies have shown that a higher level of self-efficacy contributes to the quality of science education (Velthuis, 2014; Davis, Petish & Smithey, 2006). However, there are studies contradicting these conclusions. Research indicates that teachers with a low degree of self-efficacy are still able to provide high-quality science education (Ginns & Walters, 1999). Boone and Gabel (1998) offer a possible explanation for this finding. The study measured the level of self-efficacy of pre-service teachers after following a science teacher preparation program. The scores of pre-service teachers were compared with the scores of pre-service teachers who did not follow the program. It appeared that pre-service teachers who had followed the science preparation program had a lower degree of self-efficacy. The teachers felt less prepared to teach elementary students. Boone and Gabel (1998) concluded that the teacher had gained a more realistic conception of what they needed to teach science, such as subject matter knowledge and teaching strategies. Avery and Meyer also (2012) stated that an inquiry-based science course showed different outcomes. For some pre-service teachers it resulted in self-efficacy gains, but for others it had a negative effect on self-efficacy in teaching science. It is probable that pre-service teachers find teaching science difficult and becoming aware of the difficulties can result in a lower sense of self-efficacy. However, this does not necessarily mean that these teachers are not able to provide qualitative science lessons (Boone & Gable, 1998).

*2.3.4. Attitude towards science*

According to Pajares (1992, p. 314), attitudes are 'clusters of beliefs which are organized around an object or situation and predisposed to action, this holistic organization becomes an attitude'. Attitude can be divided into three components: cognitive, affective, and behavioural components (Walma van der Molen, De Lange & Kok, 2009). The *cognitive component* consists of thoughts and ideas about science. The *affective component* consists of feelings and moods, such as enjoying science teaching. The *behavioural component* consists of changes in behaviour or the intention to do so, such as pre-service teachers' intentions to give science classes in the future. These three components refer to one's attitudinal responses in relation to the attitude object (cognitive response, affective response, and behavioural response) and to the various processes underlying the formation of an attitude (Walma van der Molen, de Lange & Kok, 2009).

Van Uum and Gravemeijer (2012) conducted a research to obtain in insight in Dutch pre-service teachers attitude towards science ($n$=98). The results of this study indicated that only 54% of the pre-service teachers find it important to give science education in primary school. In addition, 20% of the respondents indicated that they lack the enthusiasm to teach science. In respect to the behavioural component of attitude, only 53% of the pre-service teachers is planning to give science at primary school when they start working (Van Uum & Gravemeijer, 2012).

A possible explanation for a negative attitude towards science of teachers, is that they had negative experiences during their own science education. During their pre-service teacher training, they continue to associate science with these negative experiences. Therefore, there is no change is made in their attitude towards science. These teachers also have lower confidence and belief in their self-efficacy, meaning they are less able to influence the attitudes of their students positively (Rohaan, Taconis & Jochems, 2012; Van Aalderen-Smeets, Walma van der Molen and Asma, 2011). Therefore, Casteren, Broek, Hölsgens and Warps (2014) emphasize that especially pre-service teachers' attitudes towards science should be positively stimulated before they start to work as teachers.

According to Van Aalderen-Smeets, Walma Van Der Molen and Asma (2012), teachers are better able to improve their students' attitudes towards science when they have more confidence in their SMK and science teaching skills. Attitude-focused professional development programs especially have positive effects on primary teachers' professional and personal attitudes towards science.

Attitude-focused professional development programs include three key elements. The first component is *attitude toward (teaching) science*. This includes assignments or discussions that challenge awareness about the components of attitude towards (teaching) science. The second component *is scientific attitudes*. This refers to collection of trainable attitudes that characterize scientific thinking, such as curiosity, wondering about the environment, and being critical about several statements. The last component is *knowledge about (teaching) science and scientific skills*. This refers to knowledge about the process of science and the required skills to perform scientific inquiry. It includes knowledge about the inquiry cycle and the phases of an inquiry cycle, like formulating research questions, data analysis, and results presentation. Knowledge about scientific skills refer to teachers' knowledge about skills, which teachers need to coach their pupils with an investigation, like higher-order thinking (Bloom's taxonomy) and applying inquiry-based learning methods.

The third component, knowledge about (teaching) science and scientific skills, is particularly emphasized in the science PD program because pre-service teachers are taught about effective teaching elements. The effective elements correspond to knowledge about teaching science. In addition, the pre-service teachers also are taught about the inquiry cycle, which they will use in their class. The last component is included in the science PD program. Therefore, it is expected that the science PD program will positively influence pre-service teachers' attitude towards science.

### 2.4. Professionalism in teaching science

Important elements of teacher professionalism in teaching science are SMK, the utilization of teaching strategies, self-efficacy in teaching science and attitude towards science (Davis, Petish & Smithey, 2006). Teachers with a higher level of SMK, a higher level of self-efficacy in teaching science, a positive attitude towards science and utilize teaching strategies, are more professional in teaching science. Therefore, in this study the term 'professionalism in teaching science' will refer to SMK, the utilization of teaching strategies, self-efficacy in teaching science and attitude towards science. As mentioned in section 2.2, four elements need to be included in a PD program to enhance the effectiveness of the learning of pre-service teachers. These elements are related to the content and focus of the science PD program. Figure 2.2 shows how the effective elements of the science PD program are expected to influence teacher professionalism in teaching science.

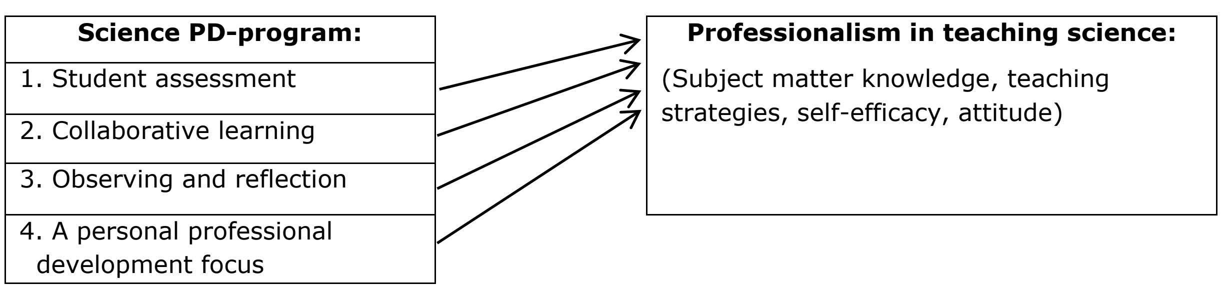


*Figure 2.1.* Contribution of effective PD program elements on professionalism in science teaching.

### 2.5. Research questions

This research study aims to investigate whether pre-service teachers who followed the science PD program are better equipped to teach science in primary education. The goal of the science PD program is to enhance science SMK, the use of teaching strategies, the level of self-efficacy, and promote a more positive attitude towards science. To investigate the effect of the science PD program, the first research question of this study is:

1. To what extent are pre-service teachers who participated in the science PD program improved to teach science?

This will be evaluated by investigating the following sub-questions:

a. To what extent has the science PD program effect on pre-service teachers' science SMK?
b. To what extent has the science PD program effect on the pre-service teachers' utilization of effective science teaching strategies?
c. To what extent has the science PD program effect on pre-service teachers' science teaching self-efficacy?
d. To what extent has the science PD program effect on pre-service teachers' attitude towards science?

Besides gaining insights in the effectiveness of the science PD program, this study aims towards a better understanding of the program by investigating the relationship between the elements of the science PD program and the professional development of the pre-service teachers. To investigate this goal, the second research question is:

2. What is, according to the pre-service teachers, the contribution of the four elements to the development of pre-service teacher professionalism in teaching science?

To answer this question, the following sub-questions will be investigated:

a. To what extent do pre-service teachers asses *student assessment* as a contribution to teacher professionalism in teaching science?
b. To what extent do pre-service teachers assess *observing and reflection on their practice* as a contribution to teacher professionalism in teaching science?
c. To what extent do pre-service teachers assess *collaborative learning* as a contribution to teacher professionalism in teaching science?
d. To what extent do pre-service teachers assess *a personal development focus* as a contribution to their teacher professionalism in teaching science?

## Chapter 3 The intervention

This chapter contains information about the science PD program. Section 3.1. provides a general description of the science PD program. The science PD program at Saxion Academy contains the four effective elements, which were described in the theoretical framework. In each meeting, the effective elements were taken into account. Section 3.2. provides an overview of each meeting and how the effective elements were integrated in the program.

### 3.1. Description of the science PD program

The science PD program consisted of five meetings of two hours per meeting. The content of the meetings were a combination of several activities, including information transfer to enhance learning contexts, professional dialogues, observations, reflection on their selves and others, inquiry assignments, and analysis of student work. The effective elements were included in the program, for example: observing video material of another pre-service program which conducted a science lesson in the primary school (effective element: observing) or analysing student work from the science lessons to determine which pupils need additional instruction (effective element: student assessment).

Another part of the science PD program was practical assignments. Participants had to conduct science lessons at their primary school. They were student-oriented science lessons, to let the participants experience science teaching in primary school. In this way, the participants learned to apply acquired knowledge from the science PD program in practice. After the execution of the science lessons in primary school, the lessons were reflected upon during the course meetings. The science PD program included assignments, which aimed to improve pre-service teachers' professionalization in teaching science. The assignments during the meetings required higher—order and reflective thinking skills from the participants.

The participants received a reader about the science PD program, written by the teacher, which contained information about the meetings, theoretical background information, assignments for each meeting, take-home assignments, and websites. The Powerpoints and worksheets, used in the meetings, were placed on 'Blackboard,' the virtual learning platform of Saxion.

During the meetings the pre-service teachers were taught about didactic knowledge (effective teaching strategies) and were prepared for the science lessons they had to teach their primary school class. These science lessons consisted of three phases (orientation, experimentation and deepening phase). In total, the pre-service teachers had to perform four science lessons about air, constructions, levers, and one on a science topic of one's choice. The pre-service students had to film the last science lesson. Finally, the pre-service students had to submit the film and preparation forms (a form, filled in by pre-service teachers, to describe the structure of a lesson) to obtain study credits.

### 3.2. Effective elements addressed in the science PD program

The four effective elements were underpinned in the content of lessons and activities of the science PD program and contributed to the effectiveness of the program. Table 3.1. provides an overview of how the effective elements were integrated in the science PD program.

Table 3.1.
*Overview of effective elements addressed in the science PD program*

| Meeting | Processes |
|---|---|
| 1 | *Observation and reflection*<br>- Pre-service teachers observed the teacher. The teacher showed how a lesson about floating and sinking can start (orientation phase) in third and fourth grade of primary school. After, the pre-service teachers reflected on this example. |

| | |
|---|---|
| | *Collaborative learning*<br>- The meeting started with an experiment. The pre-service teachers conducted this experiment in groups and had to think about the following question together: '*Do you think this is effective science and technology education?', 'Why or why not?'.* When the different groups formulated an answer, the teacher led the dialogue and summarized pre-service teachers' answers.<br>- In the following activity, students had to formulate what they think effective science education constitutes. First, they had to individually write catchwords down on post-its. Second, they collaborative (in groups of 3-4) had to group these post-its in groups and formulate headings. After, the teacher led the dialogue and summarized pre-service teachers' findings. |
| | *Teachers' own professional development focus*<br>- The science teacher introduced the preparation form, which is necessary for the science lessons at primary school. An example preparation form about 'floating and sinking' is used to explain how to fill in the form. The preparation form was filled in for third and fourth grade. The pre-service teachers obtained the assignment to think about how they could adapt the lesson into their own class. For example: pre-service teachers of $5^{th}$ or $6^{th}$ grade had to think about and explain the content of the lesson on how to make it more difficult. After each meeting, the pre-service teachers have more room to fill in their own lessons |
| | *Student assessment*<br>- Not a part of this meeting |
| 2 | *Observation and reflection*<br>- Pre-service teachers observed five fragments from an example lesson of a primary school teacher about floating and sinking in third/fourth grade. This primary school teacher knows the strategies and applied the strategies in her lesson. Pre-service teachers had to indicate sequential what the teacher did in the different fragments, why it is important that the teacher does that, what the reactions of the students were and which strategies the teacher applied. |
| | *Collaborative learning*<br>- The science concept 'air' was introduced. The teacher showed two experiments about the concept and pre-service teachers themselves also conducted some experiments. After the experiments, the pre-service teachers had to complete the following sentence in groups: 'primary school students learn by means of this experiment that air ……'. Pre-service teachers can use some of the experiments and the knowledge gained of this meeting by developing their *experimentation phase* for the lesson they had to give. |
| | *Teachers (partially) identify their own focus*<br>- The pre-service teachers have to give a science lesson about 'air' at primary school. For the lesson about 'air', the pre-service teachers were presented with a lesson preparation form which was partially filled in. They had to develop their own experiments (*experimentation phase*) and the first part of the *deepen phase*: presentation part and reflection and discussion part. They also got examples of sites where they could look for inspiration. |
| | *Developing assessments and analyzing students work*<br>- Not part of this meeting. |
| 3 | *Observation and reflection*<br>- Pre-service teachers form groups and reflect on their lessons about 'air' by means of the following questions: 'How did you give meaning to the experimentation phase?' and 'How did you check if your students reached the lesson goals?' After, various answers were discussed classical. |

| | |
|---|---|
| | - Based on the new science concept ‘levers’ the preservice teachers observe three situations were context is used in different ways and had to answer two questions: ‘Which context is used?’ and ‘in which way is the context used?’ . After each example, the teacher and the pre-service teachers reflected on the answers together. |
| | *Collaborative learning*<br>- The knowledge about the science concept air of the pre-service teachers was tested. Individually, they had to answer seven questions about this concept. After, the answers are discussed and pre-service teachers are reminded about why it is important to have knowledge about science concepts. Finally, the teacher led a dialogue about which ‘air’ subjects can be discussed in preschool, first/second/third grade and in fourth, fifth and sixth grade and if and why it is important that a preschool teacher also has knowledge about the subjects which will be addressed in sixth grade.<br>- After reflection on pre-service teachers’ lessons about ‘air’, the teacher introduced the *Testing Strategies* by means of the following question: ‘Why is it important that you systematically check if your students are reaching the lesson goals?’ Then, the teacher led a professional dialogue about this subject and provided the pre-service with theory about this strategy.<br>- The new science concept ‘levers’ was introduced. Based on three different situations where context was used in a science lesson, the science teaching strategy *Enhanced Context Strategies* was introduced. The teacher led a dialogue why working from a context is important in science teaching and provided the pre-service teachers with theory about this strategy.<br>- The teacher provided the pre-service teachers with theory about levers and with examples of different levers. Also, the pre-service teachers can share their own knowledge about the subject.<br>- The pre-service teachers formed groups (of 3-4) and conducted on of the experiment about ‘levers’. During the activity they had to answer the following questions: ‘What is the lesson goal of the experiment?’ and ‘Which problems will the students encounter?’. After the experiments, the different answers are discussed classical. Also, the pre-service teachers had to explain which experiments they think fit their primary school classes and which do not. |
| | *Teachers (partially) identify their own focus*<br>- For their following lesson about ‘levers’, the pre-service teachers were presented with a lesson preparation form which was partially filled in. They had to develop the *experimentation phase* and the *deepen phase* themselves. They also got examples of sites where they could look for inspiration |
| | *Analyzing student work*<br>- Pre-service teachers had to bring students work from their lesson about air. In pairs, they analyze the work. They had to answer three questions: ‘What stands out?’, ‘Which remediation can you think of for your next lesson?’ and ‘What are the advantages of analyzing students work and/or observing your students during activities?’ After, different answers were discussed classical. For their next lesson, they will apply their contrived remediation. |
| 4 | *Observation and reflection*<br>- Pre-service teachers observe and reflect on an example of the *orientation phase* of a lesson about constructions.<br>- Pre-service teachers observe and reflect on an example of the *experimentation phase* of a lesson about construction.<br>- The teachers reflects with the pre-service teachers on what they have learned so |

| | |
|---|---|
| | far: four strategies (*Enhanced Context Strategies, Questioning Strategies, Testing Strategies and Collaboration Strategies*). |
| | *Collaborative learning*<br>- The knowledge about the science concept levers of the pre-service teachers was tested. In pairs, they had to answer several questions about this concept. After, the answers are discussed and pre-service teachers are reminded about why it is important to have knowledge about science concepts.<br>- In this meeting, the *Questioning Strategies* is introduced by means of the new science concept '*constructions'*. First, the pre-service teachers watch a movie clip. Second, they carry out an assignment. Both can be used in the *orientation phase* in a lesson about constructions. During both the movie clip and the assignment, pre-service teachers formed pairs and formulated questions that can be asked. After this, the teacher provided the pre-service teachers with theory about the questioning strategy: goals of questions differ, difficulty of questions vary. The pre-service teachers grouped their own questions based on the formats and discussed why it is important to ask questions with different goals and with various difficulty. Last, the pre-service teachers had to read to transcripts in which a primary school teacher interact with a student. The subject was air pressure. The pre-service teachers had to answer two question: 'What are the differences between the dialogues regarding the use of language?' and 'What differenced do you see in the reactions of the students?'. After they answered these questions, the teacher led a discussion about why asking the right questions is important.<br>- The pre-service teachers had to form groups (of 3-4) and had to buid a solid bridge of paper. They only could use 10 A4 papers, a scissor, tape, glue, and a ruler. During the assignment, the pre-service teachers have to think about how to construct a solid construction together.<br>- After the assignment (build a solid bridge with only paper), the teacher introduced the *Collaboration Strategies*. He led a dialogue about why it is important that students work together and why this is not easy. Also, the teacher provided the pre-service teachers with theory about collaboration. |
| | *Teachers (partially) identify their own focus*<br>- For their following lesson about 'constructions', the pre-service teacher were only presented with the first page of the lesson preparation form (e.g. lesson goals). They had to fill in the rest, namely orientation phase, experimentation phase and deepen phase. They also got examples of sites where they could look for inspiration<br>- For their last lesson, pre-service teachers have to choose their own theme. This can be any subject within the field of science. |
| | *Analyzing student work*<br>- Pre-service teachers had to bring students work from their lesson about levers. In pairs, they analyze the work. They had to answer three questions: 'What stands out?', 'Which remediation can you think of for your next lesson?' and 'What are the advantages of analyzing students work and/or observing your students during activities?' After, different answers were discussed classical. For their next lesson, they will apply their contrived remediation. |
| 5 | *Observation and reflection*<br>- In preparation for this meeting, the pre-service teachers had to evaluate on their last lesson (constructions) by means of a 'checklist asking questions'. On this list, they could indicate which questions they did or did not ask during their lesson. In the meeting, pre-service teachers formed pairs and reflected on their lesson |

| | |
|---|---|
| | about construction by means of a 'checklist asking questions'. They had to answer the following questions: 'What stands out?', 'Which question did I or did I not aks?', 'What goes well?' and 'Which questions could I ask more?'. After, various answers were discussed classical.<br>- In the meeting, pre-service watch an example lesson about lesson of another pre-service teacher. This pre-service teacher attempt to apply the effective science strategies in her lesson. The pre-service teacher all had to focus on two of the eight strategies. After, the teacher and the pre-service teachers reflect on the example. |
| | *Collaborative learning*<br>- The knowledge about the science concept constructions of the pre-service teachers was tested. In pairs, they had to answer several questions about this concept. After, the answers are discussed and pre-service teachers are reminded about why it is important to have knowledge about science concepts.<br>- In this meeting, the last four science strategies are being discussed (*Inquiry Strategies, Manipulation Strategies, Instructional Technology Strategies, Enhanced Material Strategies*). Teacher led a dialogue about why the use of these strategies is important in science teaching. |
| | *Teachers (partially) identify their own focus*<br>- In this meeting, the pre-service teachers are told that they can get feedback during designing their final lesson. |
| | *Analyzing student work*<br>- Not part of this meeting |

*Note.* Adapted from "Preparing pre-service teachers for high-quality science teaching: the development and effectiveness of an evidence-based professional development program" by Kroek, M., 2016, University of Twente.

## Chapter 4 Method

To answer the research questions, an empirical quantitative study has been conducted. In this chapter, the methods of the study are described. First, the research design is explained. Second, a description of the respondents is provided. Third, the instruments this study uses are described. Fourth, an explanation of the data collection procedures, data types, and analysis methods is given.

This research contains two research questions. Therefore, some sections will be divided into two sub-sections to clarify how the first and second research question will be answered.

### 4.1. Research design

To establish the average effects of the science PD program on pre-service teachers' self-efficacy, SMK, attitude towards science and the utilization of effective teaching strategies, a quasi-experimental pre-test, post-test design with a comparison group is used. A fully randomized controlled study in which participants are randomly assigned to conditions was impossible to utilize due to fixed groups. The participants belong to a permanent class and courses are scheduled for the whole class. Therefore, a quasi-experimental design was chosen. The experimental group received the science PD program, while the comparison group followed the regular science program.

To investigate the effects of the science PD program on pre-service challenges, pre-tests and post-tests were administered in both the experimental and comparison group. The tests measured participants' development on their SMK, utilization of effective teaching strategies, self-efficacy and attitude towards science education. The type of program is the predictor variable and SMK, utilization of teaching strategies, self-efficacy in teaching science, and attitude towards science are dependent variables.

To gain insights into pre-service teachers' opinions about the extent to which the effective elements of the science PD program contributed to pre-service teachers' professional development in science teaching, a questionnaire was administered in the experimental group. The four elements were predictor variables and pre-service teacher professionalism in teaching science was the dependent variable. Figure 4.1 visualizes the research model of this study.

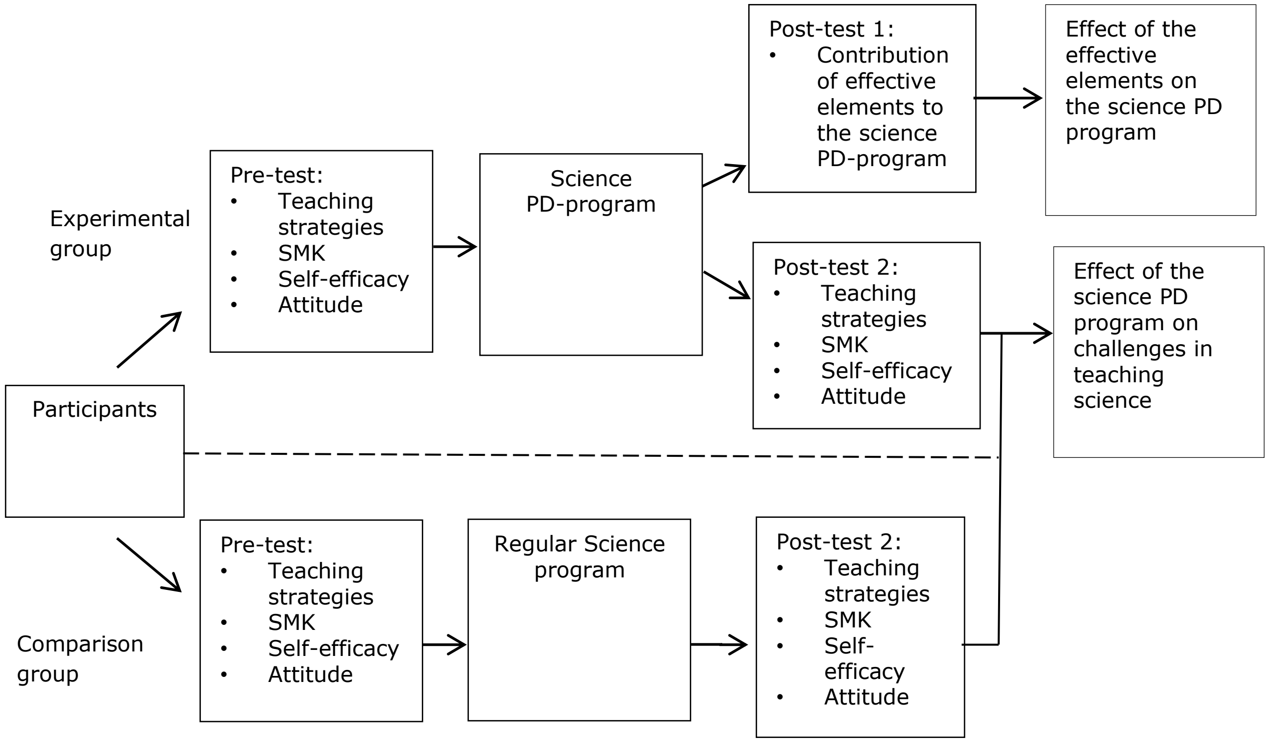


*Figure 4.1.* Research model of the study.

**4.2. Participants**

In total, 74 pre-service teachers took part in the study. The participants are third year students in teacher training education at Saxion Academy (Deventer), University of Applied Science. Science is an obligatory course in the third semester of the third study year for pre-service teachers at Saxion Academy. The experimental group followed the newly-developed science PD program and the comparison group followed the regular science program.

The experimental group consisted of 23 pre-service teachers from one class. The experimental group consisted of 5 male pre-service teachers (21.7%) and 18 female pre-service teachers (78.3%). The average age was 20.48, ranging from 19 to 24. The researcher of this study gave the lessons for the science PD program. The comparison group, which followed the regular science program, consisted of 51 pre-service teachers divided over two separate classes. This group consisted of 11 male pre-service teachers (21.6%) and 40 female pre-service teachers (78.4%). The average age of the comparison group was 21.29, ranging from 19 to 26. Table 4.1 provides an overview of characteristics of both groups. The permanent science teacher of Saxion academy provided the regular science lessons for the comparison group.

Gender is almost equally distributed in both groups. No significant differences were found between the groups, $t(72)=-.02$, $p=.97$. The mean age in the comparison group is 1.38 year higher than in the experimental group. The independent samples t-test showed a significant difference between the groups, $t(72)=.-2.05$, $p=.04$. The statistic chi-square showed that the groups did not significantly differ on educational background, $X^2(3)=6.44$, $p=.09$. The total number of study credits differ in the groups. Independent samples t-test showed a significant difference between the two groups on number of study credits, $t(72)=-2.82$, $p=.00$. The comparison group has on average 7.05 more study credits.

Table 4.1
*Background information participants*

| | Gender | Age | Educational background | Study credits |
|---|---|---|---|---|
| Experi-mental group (*n*=23) | Male= 21.7% (*n*=5) Female= 78.3% (*n*=18) | *M*=20.48 *SD*=1.31 | Intermediate vocational education (Dutch: MBO)= 13.0% (*n*=3) Higher general secondary education (Dutch: HAVO)= 82.6% (*n*=19) Pre-university education= (Dutch: VWO) 0% (*n*=0) Not-Dutch education= 4.4% (*n*=1) | *M*=132.13 *SD*=11.62 |
| Compari-son group (*n* =51) | Male= 21.6% (*n*=11) Female= 78.4% (*n*=40) | *M*=21.29 *SD*=1.69 | Intermediate vocational education (Dutch: MBO)= 33.3% (*n*=17) Higher general secondary education (Dutch: MBO)= 62.8% (*n*=32) Pre-university education (Dutch: VWO) = 3.9% (*n*=2) Not-Dutch education= 0% (*n*=0) | *M*=139.18 *SD*=9.14 |

**4.3. Instruments**

Multiple instruments for gathering data were used in this study. In the following sub-sections, the instruments for each research question are described. All the questionnaires were administered on paper while participants attended their first and last science classes.

*4.3.1. Instruments used for teacher challenges*

In the following sub-sections the instruments are described, which are used to measure the effect of the science PD program on teacher challenges (research question 1). First, the multiple-choice test for SMK will be described. Then, the questionnaire to measure the use of teaching strategies will be described. Third, the STEBI-NL will be described, which measures the self-efficacy towards science teaching, followed by the DAS instrument that measures teachers' attitude towards science.

*4.3.1.1. SMK*

A multiple-choice test was used to measure the science PD program's effect on pre-service teachers' science SMK with pre-test and post-test measurement. The SMK test aims to obtain insight into how the type of science program has contributed to the SMK of science topics. The test questions were based on two science source books for pre-service teachers. These source books contain science SMK, which pre-service teachers need to know before they begin the teacher training program. The Dutch science core objectives (Dutch: kerndoelen) for primary education form the subject matter for these science source books (Oostendorp-Bourgonjon & Oostendorp, 2002). On the basis of these science source books, specific SMK objectives for pre-service teachers have been formulated.

The science SMK test was developed with the aid of a test matrix. A test matrix is a blueprint of a test and ensures a proper distribution of questions and points for the question. As a result, the test is representative for the content that is measured. A test matrix offers structure in the design of the test and development of the questions. The developed test matrix is based on the taxonomy of Bloom for closed questions (Teelen, 2015). It provides an overview of the key objectives and related specific objectives, number of items per specific objective, the percentage of the specific objective and, finally, shows the item's purpose (knowledge, application, or insight). See appendix 1 for the test matrix.

Thereafter, the researcher of this study developed a science SMK test to assess pre-service teachers' science SMK. The test was categorized with two scales: treated and untreated science topics in the science PD-program. The treated topics consist of air, constructions, and levers. The untreated topics consist of floating and sinking, light and electricity. These topics are chosen, based on the Dutch core objectives (SLO, 2015). The untreated topics were included in order to make a comparison between the SMK level of treated and untreated topics after following the science PD program. It will be examined whether only SMK about treated topics is enhanced or whether the science PD program also stimulated pre-service teachers to learn about untreated topics.

In the first stage, the science SMK test consisted of 69 questions. A science expert from the research group 'Science and Technology in Education' checked the SMK test to check the content of the questions. Then, a discussion between the researcher and the science expert took place, after which the final items from the science expert were formulated. Next, an assessment committee member of teacher training (from Saxion Academy, Deventer) was asked to give feedback on the clarity of the phrasing. Based on that feedback, textual changes were made to the problems. After this, the resulting instrument consisted of 62 items for measuring SMK level of pre-service teachers with two scales.

The SMK-test was administered for pilot-testing to pre-service teachers at Saxion Academy in Deventer. The pilot group enrols first-, second-, and fourth-year pre-service students ($n$=61). Respondents obtained one point for a correct answer and no points for a wrong answer. The internal consistency of the SMK-test was measured using Cronbach's Alpha. According to De Vellis (2003), the interpretation of Cronbach's Alpha is <.60 unacceptable; between .60 and .65 undesirable; between .65 and .70 minimally acceptable; >.70 respectable, and >.80 very good. After analysing the reliability of the SMK-instrument, 33 items were removed. The treated topics scale consisted of 13 items and showed a Cronbach's Alpha of .70. The untreated topics scale consisted of 16 items and showed a Cronbach's Alpha of .73. See Appendix 2 for the science SMK test.

*4.3.1.2. Teaching strategies*

A questionnaire was used to measure the extent in which the participants applied the eight teaching strategies. The questionnaire used a five-point Likert-scale, ranging from 1 (strongly disagree) to 5 (strongly agree), to indicate their usage of the science teaching strategies in science lessons. In total, the questionnaire contains 18 items. The items relate to the eight effective teaching strategies (Kroek, 2016). The mean scores are calculated with a minimum of 1 (strongly disagree) and a maximum of 5 (strongly agree). A higher score indicates a more frequent usage of the science teaching strategies in science lessons.

Kroek (2016) developed a questionnaire to obtain more insight into the extent pre-service teachers believe they utilize the eight teaching strategies. The questionnaire was based on a theoretical understanding of the eight teaching strategies (Kroek, 2016; Schroeder, et al., 2007). This provides content validity of the instrument. Table 4.2 presents the relation between the items of the questionnaire and theoretical findings. The questionnaire proved to be reliable, with a Cronbach's Alpha of .84. In this study, the Cronbach's Alpha was .86 on pre-test and .78 on post-test. See Appendix 3 for the teaching strategies questionnaire.

Table 4.2

*Relation between items of the questionnaire and theoretical background*

| Content effective science teaching strategies | Item questionnaire |
|---|---|
| *Context strategies* | |
| Teachers use the context to illustrate the concept and the underlying processes of the subject-matter. | 'I work from a meaningful context to the goal' |
| *Collaborative learning strategies* | |
| Cooperative learning situations can improve science achievement and non-cognitive skills when well organized | 'I let students work together during the lesson' |
| When working together, collaboration skills must be developed. The teacher cannot assume students themselves are good collaborators | 'I stimulate the collaboration skills of the students' |
| All students must have an equal share during collaboration | 'I make sure all students have an equal share in the collaboration process' |
| *Questioning strategies* | |
| Combination of low-level and high-level questions can enhance science 'achievement | 'I ask low-level questions'<br>'I ask high-level questions' |
| Low-level questions should have a wait-time of 3 seconds<br><br>High-level questions should have a wait-time of 5 seconds | 'I apply enough wait-time after asking a questions (>3 seconds with a lower-level question, <5 seconds with a higher-level question) |
| *Inquiry strategies* | |
| Students have to answer scientific questions by means of concrete instruction. This teaching procedure consists of three steps. First, the teacher provides the right material to the students, which will lead them to form the concept when they interact with those materials (exploration). Second, the teacher summarizes the information which the students gained from the interaction with the material and provides them with the language of the concepts (conceptual intervention). Third, the students have the opportunity to use the learned concept in additional settings and with different material (expansion of ideas). | I follow the inquiry cycle during teaching the lesson'<br><br>*Note: this item is also based on the developed science teaching model. This model consist of an inquiry cycle which helps the students to shape their science lessons* |
| Teachers have a big responsibility for making inquiry successful. For example, students have to be supported when they formulate questions, design experiments, and collect and analyze data. | 'I stimulate the science process skills of students' |
| Teachers  must integrate learning experiences into a coherent whole instead of presenting each learning activity as a discrete activity | 'I make a clear connection with a previous lesson' |

| | |
|---|---|
| *Manipulation strategies*<br>Students have to manipulate the apparatus to gather experimental data (for example, by controlling variables), or have to draw or construct something. | 'I make sure the students interact with the material'<br>'I make sure that students can control variables (differs per concept if this is possible)' |
| Students have to set up their own experiences using hand-outs | 'I make sure students can set up their own experiments through hand-outs' |
| *Enhanced material strategies*<br>Teachers have to modify or create material to enhance students' achievement in science | 'I let students work with materials to stimulate students' understanding of the subject-matter (for example, games, worksheets/hand-outs and other material)' |
| *Instructional technology strategies*<br>The use of educational videos or simulations are intended to enhance instruction | 'I use technology to stimulate students' understanding of the subject-matter |
| *Testing strategies*<br>For a teacher it is important to know if students have achieved the learning objectives and if additional instruction is needed | 'I can devise a remediation based on students' work (preschoolers: by observing)'<br>'During the lesson, I use students' work to adjust the learning (preschoolers: by observing)' |

*Note*. Reprinted from "Preparing pre-service teachers for high-quality science teaching: the development and effectiveness of an evidence-based professional development program" by Kroek, M., 2016, University of Twente.

*4.3.1.3. Self-efficacy*

Science teaching self-efficacy was measured by the Science Teaching Efficacy Belief Instrument (STEBI)-NL (Velthuis, 2014). This instrument was translated from an existing English instrument: the STEBI-A, which was based on Bandura's self-efficacy and specifically aims at the beliefs of teachers about teaching and learning science (Velthuis, Fisser & Pieters, 2013). The instrument can be used for pre-service teachers, because Dutch pre-service teachers teach primary students from their first study year of teacher training (Velthuis, Fisser & Pieters, 2013).

The STEBI-NL measures self-efficacy with two scales: Personal Science Teaching Efficacy (PSTE) and Science Teaching Outcome Expectancy (STOE). PSTE refers to teachers' self-assessment of teaching competence. STOE refers to teachers' expectation that teachers will influence student learning. The STEBI-NL includes 23 items and contains items, like 'I understand science concepts well enough to be effective in teaching elementary science' (PSTE, 12 items total) and 'When a low achieving child progresses in science, it is usually due to extra attention given by the teacher' (STOE, 11 items total).

The instrument uses a five-point Likert scale, ranging from 'strongly disagree' (1) to 'strongly agree' (5) to indicate pre-service teachers' opinions on the statements. A higher score on the survey indicates a higher level of self-efficacy. See appendix 4 for the STEBI-NL. Velthuis (2014) has shown that the STEBI-NL is a valid instrument. A factor and reliability analyses for the STEBI-NL was conducted. The STEBI-NL instrument was used in previous study. Then, the PSTE showed a Cronbach's Alpha of .84 and STOE showed a Cronbach's Alpha of .74. In this study, the internal consistency of the STEBI-NL was also measured with Cronbach's Alpha. Cronbach's Alpha on pre-test PSTE scale was .94, and the post-test showed a Cronbach's Alpha of .92. Cronbach's Alpha for the STOE scale on pre-test measurement was .73. After removing item 11 ('*Good science teaching has little effect on the performance of students with low motivation*), the reliability increased to .78 on the pre-test. The Cronbach's Alpha for STOE scale on the post-test also increased from .81 to .82.

#### *4.3.1.4. Attitude*

Attitude towards teaching science was measured by using the Dimensions of Attitude towards Science (DAS) questionnaire, a validated questionnaire to assess primary teachers' attitude towards teaching science (Van Aalderen-Smeets & Walma van der Molen, 2013). The questionnaire was based on a theoretical framework of attitudes towards teaching science. The DAS instrument consists of four scales: personal attitude, professional attitude, teachers' view of science, and science teaching behaviour. In this study, only *personal attitude* and *professional attitude* were used to measure teachers' attitude towards science. In total, these scales consist of 67 items. Cronbach's Alpha on pre-test was .88 and Cronbach's Alpa on the post-test was .86. The instrument uses a five point Likert scale, ranging from 'strongly disagree' (1) to 'strongly agree' (5).

The first scale, *professional attitude,* is measured with 37 items and seven subscales. The first subscale is *relevance of teaching science* and investigates whether pre-service teachers find it important to teach science in primary school. This subscale is measured by statements such as: 'I think that science education is essential for primary school children's development'. The second subscale is labelled *difficulty in science* and measures to what extent teachers think that science is more difficult than other topics in primary school. It is measured with statements such as: 'I think that most primary school teachers find science a difficult subject to teach in terms of content'. The third subscale is *gender-stereotypical belief regarding teaching science* and includes items that question teachers about gender-related beliefs. It measures teachers' belief about potential differences between male and female teacher's ability, interest, and enjoyment in teaching science. An example of an item is: 'I think that male primary school teachers can do an investigation or technical assignment with pupils more easily than female teachers'.

The fourth and fifth subscales measure the positive and negative experiences of teachers related to teaching science. These subscales are *enjoyment in teaching science* and *anxiety in teaching* science, for example, 'I feel happy while teaching science' and 'I feel tense while teaching science in class'. The sixth subscale investigates *self-efficacy* and measures teachers' perceived ability to teach science and to what extend they can handle problems that may occur in teaching science. The last subscale is labelled *PD on context factors*, which investigates how teachers feel about teaching science in primary school depends on several context factors, for example: 'For me, the availability of a science teaching textbook (e.g. Natuniek, Leefwereld) is decisive for whether or not I will teach science in class'. Some subscales contribute positively to attitude (e.g. self-efficacy, enjoyment) and others negatively (anxiety, gender and context dependency). In this study, these three subscales were scored in reverse to obtain one score for attitude.

The second scale, *personal attitude,* refers to science in teachers' personal lives. This personal attitude survey consisted of seven subscales (relevance, gender, difficulty, enjoyment, anxiety, self-efficacy, and context dependency). It consists of 32 items. Personal attitude items include statements like: 'I enjoy finding out how things work' (enjoyment), 'I get nervous if someone is watching while I try to repair something' (anxiety) and 'I think that for me, knowledge of science and technology is necessary to be able to live healthily' (relevance). Negative subscales (anxiety, gender and context dependency) were reverse scored. This provides one score for (professional and personal) teacher attitude and that means a higher score on the survey indicates a more positive attitude towards science.

### *4.3.2. Instrument effective elements*

To investigate the extent to which the effective elements contribute or constrain pre-service teachers' professional development in science teaching, Kroek (2016) developed a questionnaire of 12 items. The questionnaire used a five-point Likert-scale, ranging from 'strongly disagree' (1) to 'strongly agree' (5). The items were based on the literature about the effective elements for PD programs, so content validity is reached. Kroek (2016) established the characteristics and specific activities of the four elements and translated them into items for the questionnaire. Table 4.3 provides an overview of the effective elements and the items which belong to each element.

The developed instrument aims to indicate the extent to which the pre-service students experienced how the elements influenced their professionalism in teaching science. See appendix 5 for the questionnaire.

Because the instrument was used in the last meeting, it was not possible to measure untreated elements before the experiment. However, the instrument showed a respectable Cronbach's Alpha of .73. The elements will be analysed on item level, to gain more specific insight into pre-service perceptions of the activities in the program.

Table 4.3
*Oversight effective elements addressed in the science PD program*

| Effective elements in the science PD program | Items |
|---|---|
| Student assessment (Blank & de las Alas, 2009; Van Veen et al., 2010) | 'Test developing to check whether the students achieved the goals contributes to my professionalism in science teaching'<br>'Analysing student work to check whether the students achieved the goals contributes to my professionalism in science teaching' |
| Observation and reflection (Blank & de las Alas, 2009; Van Veen et al., 2010) | 'Reflecting together with others on my lessons contributes to my professionalism in science teaching'<br>'Reflecting on possible experiments contributes to my professionalism in science teaching'<br>'Reflecting on possible experiments contributes to my professionalism in science teaching' |
| Collaborative learning (Blank & de las Alas, 2009; Cordingley et al., 2005; Van Veen et al., 2007; Timperley et al., 2007) | 'Thinking about and defining science concepts together contributes to my professionalism in science teaching'<br>'Discussing the subject matter knowledge tests contributes to my professionalism in science teaching'<br>'Thinking about and defining effective teaching strategies contributes to my professionalism in science teaching' |
| Teachers' own professional development focus (Cordingley et al., 2005) | 'Obtaining more freedom to design the phases in science lessons contributes to my professionalism in science teaching' |

*Note.* Adapted from 'Preparing pre-service teachers for high-quality science teaching: the development and effectiveness of an evidence-based professional development program' by Kroek, M., 2016, University of Twente.

### 4.4. Procedure

The science PD program was obligatory for the experimental group, because it was a part of the curriculum for third-year pre-service students. In total, there were three classes of pre-service students in the third year. One class followed the science PD program (experimental group) and the other two classes followed the regular science program (comparison group). The researcher of this study provided the lessons for the science PD program in the experimental group. The permanent science teacher of Saxion academy provided the regular science lessons for the comparison group.

Two weeks before the first meeting, participants were informed about the research and received explanations as to why they were asked to participate. The pre-test surveys were delivered to students in paper by the researcher during the first meetings of both the experimental and comparison groups. The reason for collecting data at this time was that all the students were present. This would yield a higher response rate than asking pre-service teachers to fill in a survey sent by mail. There was additional time scheduled for the first meeting to fill in the surveys. The surveys were distributed to the pre-service teachers in February 2016. The science PD program consisted of five meetings. A sixth meeting was organized, to complete the post-test surveys. The post-test took place in March 2016. The researcher collected the questionnaires and gave the participants an explanation for each questionnaire.

To ensure that the study meets the ethical rules and norms, the research activities were submitted to and approved by the Ethics Commission of the University of Twente.

### 4.5. Data analysis

The data analysis per research question will be explained in the next sub-sections.

*4.5.1. Data analysis teacher challenges*

The questionnaires about the learning strategies, the SMK test, the DAS questionnaire, and the STEBI-NL questionnaire provided information about the effects of the science PD program on teacher challenges (research question 1). The quantitative data from the surveys has been analysed using SPSS. To check whether the average level of SMK, utilization of teaching strategies, self-efficacy, and attitude between the groups is equal, independent sample t-tests has been used.

One-tailed paired samples t-test has been used to compare the means of both groups before and after the intervention. It is expected that the results from both groups will go in one direction, namely a higher level of SMK, utilization of teaching strategies, self-efficacy and attitude towards science.

Furthermore, difference scores between means have been calculated and compared between groups with an one-tailed independent samples t-test, because it was expected that the experimental group made more growth than the comparison group. Chapter 5, the results of this research, will particularly focus on these scores, because the difference scores indicate to what extent the groups made progress in SMK, utilization of teaching strategies, self-efficacy and attitude and whether the progress significantly differ between groups after following the science PD program or regular science program.

*4.5.2. Data analysis effective elements in PD programs*

The questionnaire about the effective elements provided information on what pre-service teachers assessed as successful elements of the PD program with positive effects on their professionalism in teaching science (research question 2). The questionnaire consisted of 13 items. All the respondents' scores on the items were added up and the mean score was calculated. Items were separated in five dimensions. Each dimension represented an effective element for PD programs. Descriptive statistics can describe to which extent the different elements have or not have contributed to respondents' professionalism in teaching science. The conclusions of these data analyses provided insight in the contribution, according to the pre-service teachers, of the elements of the science PD program to their professionalism in teaching science.

# Chapter 5 Results

This chapter reports the results of the study. First, the contribution of the science PD program on teacher challenges will be presented. The instruments and data of the challenges were analysed separately and a comparison is made between the experimental and comparison group. Second, this chapter presents how pre-service students believe to which extent the effective elements of the PD program contribute to their professionalism in teaching science in primary school.

## 5.1. Teacher challenges

In this section the results are described to answer the first research question: 'To what extent are pre-service teachers who followed the science PD program better equipped to teach science?'. Therefore, the results on the questionnaires for the four main challenges will be described. First, the results of the SMK test will be described. Second, the results of the questionnaire on the teaching strategies will be described. Then, the results on self-efficacy will be presented. Last, it is described how pre-service teachers' attitude towards science developed.

The results of the challenges are presented according to a fixed structure. First, the descriptive statistics are presented. Second, the paired samples t-test of both groups is presented. Third, a comparison between groups is made with an independent samples t-test. Finally, the difference score is presented in a separate paragraph, because these results provide the most insight into the effect of the type of program on the challenges.

### *5.1.1. Subject Matter Knowledge*

In this section, the results of the SMK-test are provided to answer the sub-research question what the effect of the PD-program was on pre-service teachers' science SMK. The SMK test consists of two scales. First, the results of the scale 'treated topics' will be described. Then, the scale 'untreated topics' will be described. Average results on the SMK-test will be displayed in percentages.

#### 5*.1.1.1. Scale: treated topics*

The treated topics are air, levers, and constructions. Table 5.1 provides an overview of the obtained scores on average. The mean scores show what percentage of this scale was correctly answered. Based on descriptive statistics, it seems that the experimental group made more growth than the comparison group.

Table 5.1
*Results SMK about treated topics*

| | Experimental group | | | Comparison group | | |
|---|---|---|---|---|---|---|
| | Pre-test *M (SD)* | Post-test *M (SD)* | Difference score in % | Pre-test *M (SD)* | Post-test *M (SD)* | Difference score in % |
| Air | 55.7%(.18) | 63.5%(.22) | +7.8% | 47.5%(.23) | 42.4%(.22) | -5.1% |
| Levers | 52.1%(.21) | 67.0%(.14) | +14.8% | 41.7%(.26) | 52.4%(.27) | +10.7% |
| Constructions | 80.4%(.20) | 87.0%(.15) | +6.5% | 75.0%(.24) | 79.2%(.18) | +4.7% |
| Total treated topics | 64.2%(.16) | 74.9%(.13) | +10.7% | 55.8%(.18) | 59.4%(.21) | +3.7% |

The paired samples t-test in the experimental group showed that SMK about treated topics significantly increased after following the science PD program, $t(22)=-4.54$, $p=.00$. The paired samples t-test showed no significant difference in the comparison group, $t(41)=-1.51$, $p=.07$.

To test whether the experimental group scored higher on these topics before the intervention, an independent samples t-test was conducted. No significant difference was found on pre-test, $t(69)=1.92$, $p=0.06$, which means that the average level of knowledge about air, lever and construction between the groups was the same before the intervention. Post-test results showed that the groups significantly differ from each other, $t(63)=2.88$, $p=.00$. The experimental group achieved a higher score on average on pre-test. See Table 5.1 for the average scores of both groups.

*Difference scores on treated topics*

In Figure 5.1 it is represented how the scores of both groups were developed on treated topics. The experimental group had a higher growth rate than the comparison group. The difference scores showed that the experimental group obtained a higher difference score between pre-test and post-test than the comparison group. The comparison group showed a difference score of +3.1%, while the experimental group had a difference score of +10.7%. The independent samples t-test between the groups showed a significant difference between the groups, $t(58.36)=2.08$, $p=.04$. So, this results indicated that SMK after following the science PD program had a higher growth than the regular science program.

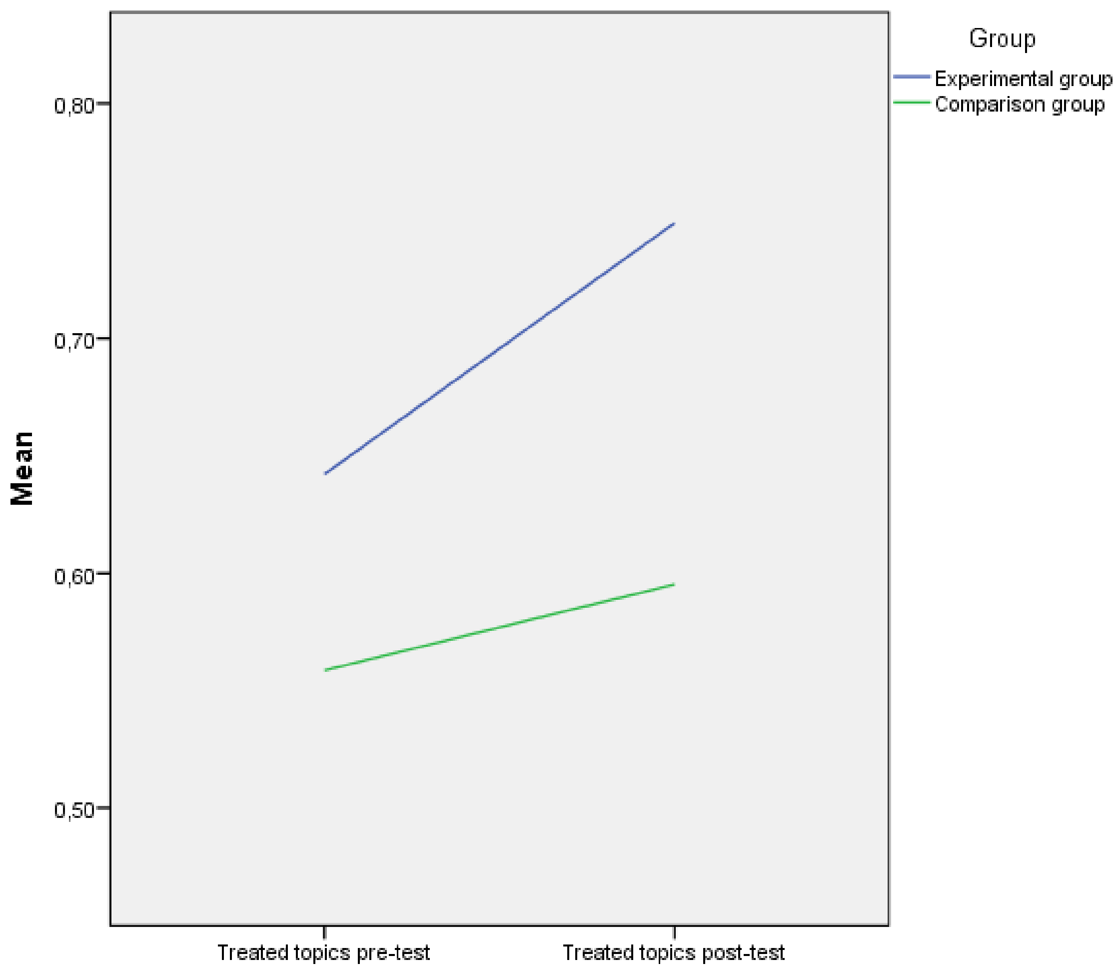


*Figure 5.1.* Mean scores on treated topics (significant effect on difference scores).

*5.1.1.2. Scale: untreated topics*

The untreated topics consisted of floating and sinking, electricity, light. Table 5.2 provides an overview of the mean pre-test and post-test scores in percentage per topic. The mean scores show what percentage of the test was correctly answered. It is remarkable that the comparison group scored lower on post-test than on pre-test results.

Table 5.2
*Results SMK about untreated topics*

| | Experimental group | | | Comparison group | | |
|---|---|---|---|---|---|---|
| | Pre-test *M (SD)* | Post-test *M (SD)* | Difference score in % | Pre-test *M (SD)* | Post-test *M (SD)* | Difference score in % |
| Water | 55.7%(.19) | 51.3%(.20) | -4.4% | 49.8%(.21) | 45.1%(.21) | -4.6% |
| Electricity | 76.8%(.27) | 82.6%(.24) | +5.8% | 80.6%(.29) | 77.0%(.32) | -3.6% |
| Light | 21.7%(.26) | 36.2%(.28) | +14.5% | 29.9%(.28) | 35.7%(.29) | +5.9% |
| Total untreated topics | 53.3%(.13) | 54.4%(.14) | +1.1% | 54.3%(.18) | 49.4%(.19) | -4.9% |

The paired samples t-test showed no significant difference in level of SMK about the untreated topics in the experimental group, $t(22)=-.41$, $p=.34$. In the comparison group a significant difference was found between pre-test and post-test, $t(40)=2.06$, $p=.02$. This significant difference can be explained by a lower post-test score than pre-tests score.

Pre-test results showed that the experimental group did not significantly differ from the comparison group in their level of SMK on untreated topics, $t(69)=.35$, $p=.73$. These results suggest that the average level of knowledge about the untreated topics between the groups before the intervention was the same. The independent samples t-test showed that no significant differences between the groups were found after the intervention, $t(64)=1.13$, $p=.26$.

*Difference scores on untreated topics*

Figure 5.2 shows the mean SMK scores on untreated topics of both groups on the pre-test and post-test. The experimental group showed a minimal growth of +1.1%, while the comparison group shows a decrease in SMK score of 4.9%. However, difference scores showed no significant difference between the groups, t(62)=1.60, p=.06. The results of this test indicate that the science PD program has no effect on SMK of untreated science topics.

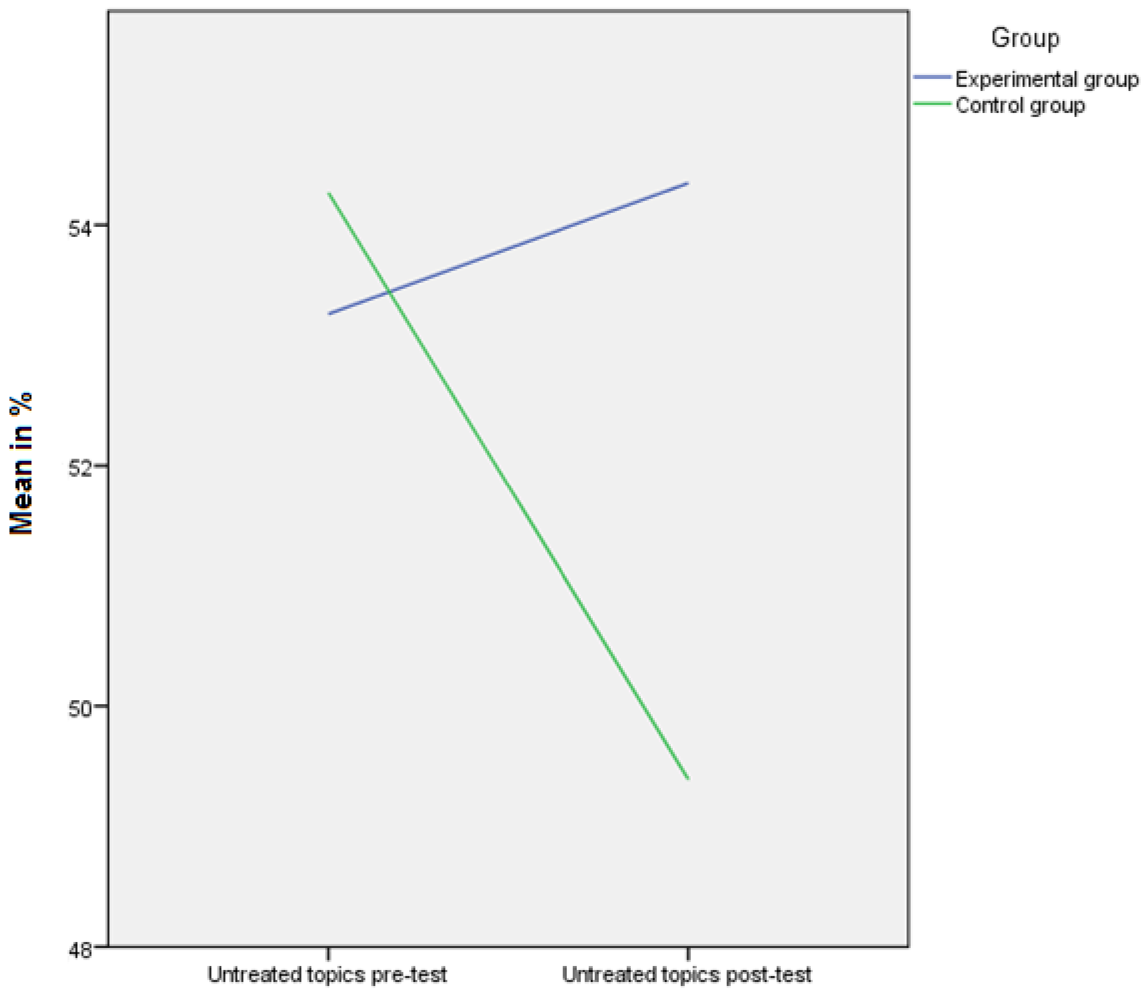


*Figure 5.2.* Mean scores on untreated topics (no significant effect on difference scores).

*5.1.2. Teaching strategies*

Mean scores and difference scores of both groups about the utilization of teaching strategies were represented in Table 5.3. The scale in this questionnaire was 1 to 5. A higher score indicated a more frequent utilization of the strategy. Based on descriptive statistics, it seems that the experimental group made on average more progress than the comparison group.

Table 4.3
*Results teaching strategies*

| | Experiment group | | | Comparison group | | |
|---|---|---|---|---|---|---|
| | *M*(*SD*) Pre-test | *M*(*SD*) Post-test | Difference score (*SD*) | *M*(*SD*) Pre-test | *M*(*SD*) Post-test | Difference score (*SD)* |
| Enhances Context Strategy | 3.96(.15) | 4.13(.34) | +.17(.89) | 4.00 (.46) | 4.00 (.40) | .00(.51) |
| Collaborative Learning Strategy | 4.04(.31) | 4.09(.43) | +.04(.45) | 4.07 (.42) | 4.16 (.45) | +.09(.59) |
| Questioning Strategy | 3.73(.54) | 4.01(.37) | +.28(.66) | 3.76 (.37) | 3.79 (.46) | +.03(.42) |
| Inquiry Strategy | 3.36(.67) | 3.70(.50) | +.33(.85) | 3.47 (.60) | 3.82 (.45) | +.35(.59) |
| Manipulation Strategy | 3.61(.54) | 3.84(.51) | +.23(.86) | 3.64 (.72) | 3.83 (.41) | +.19(.65) |
| Testing Strategy | 3.20(.79) | 3.67(.54) | +.48(.95) | 3.51 (.61) | 3.72 (.45) | +.21(.63) |
| Instructional Technology Strategy | 3.35(.93) | 3.65(.78) | +.30(1.15) | 3.42 (.72) | 3.76 (.49) | +.34(.88) |
| Enhanced Material Strategy | 3.91(.67) | 4.22(.42) | +.31(.82) | 4.08 (.59) | 4.21 (.53) | +.13(.58) |
| Total score teaching strategies | 3.64(.42) | 3.90(.29) | +.26(.51) | 3.75(.35) | 3.90(.26) | +.17(.30) |

The experimental group scored on average the highest on *enhanced context strategies.* Although this the most often-used strategy, the strategy did not result in the largest growth on the post-test. The average of the experimental group on the use of *testing strategies* increased the most. The least growth was made on the *collaborative learning strategy.*

The paired samples t-test showed a significant difference in the experimental group, $t(22)=-2.46$, $p=.01$. Also in the comparison group a significance difference between pre-test and post-test scores was found, $t(37)=-3.63$, $p=.00$.

The independent samples t-test showed that the experimental group and comparison group did not significantly differ from each other on the pre-test concerning the use of teaching strategies in science, $t(68)=-1.12$, $p=.27$. The independent samples t-test of the post-test scores also showed no significance differences between the groups, $t(62)=-.09$, $p=.93$, because mean scores were close to each other.

*Difference score on teaching strategies*

Figure 5.3 presents the mean scores of the questionnaire of both groups. The figure showed that the experimental group made more progress than the comparison group. Difference scores showed that the experimental group made a growth of .26 and the comparison group made a growth of .17. Although the experimental group had a higher difference score than the comparison group, no significant difference was found between the groups, $t(59)=.85$, $p=.20$.

So, the results indicate that the science PD program does not influence the utilization of teaching strategies more than the regular science program. Both programs have a positive influence on pre-service teachers' utilization of the teaching strategies.

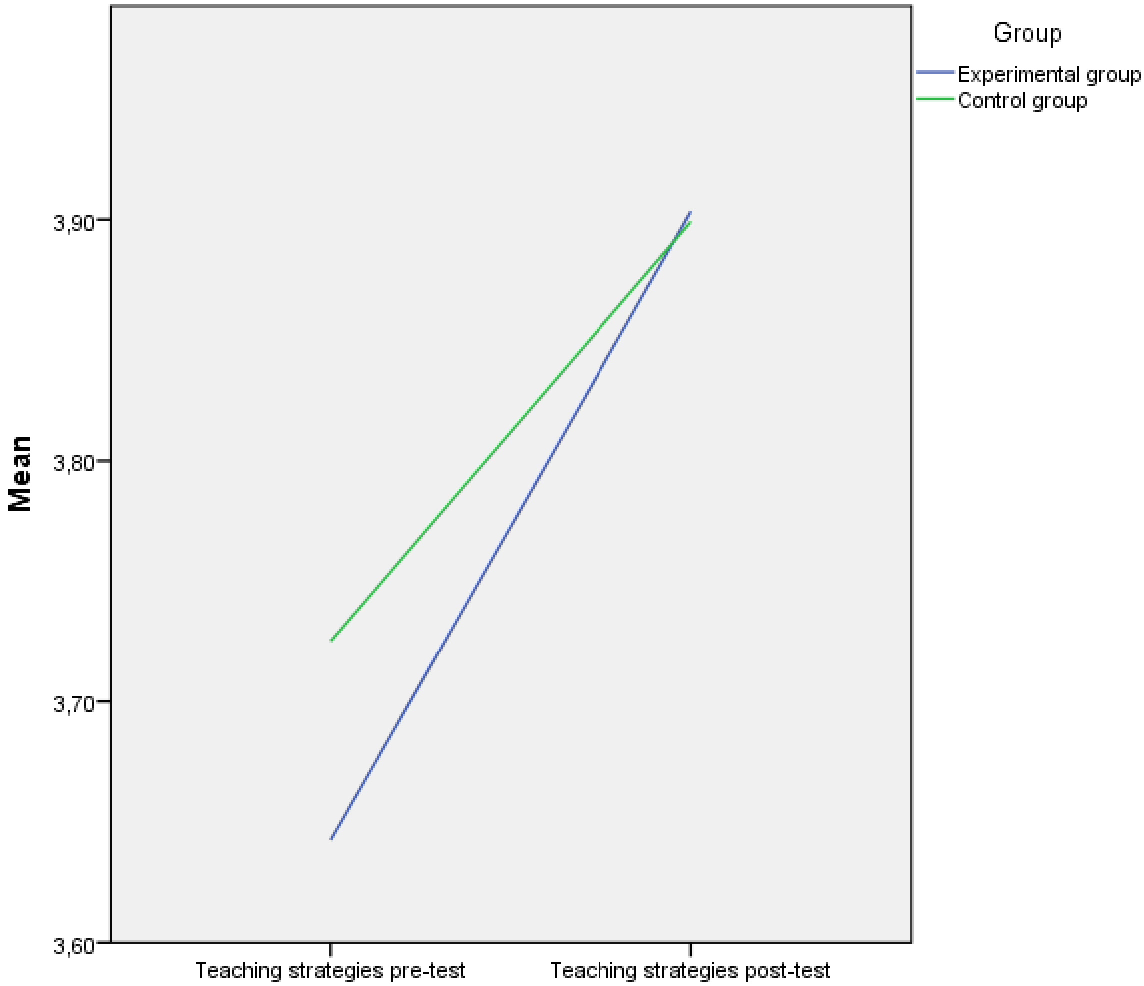


*Figure 5.3.* Mean scores on teaching strategies (no significant effect on difference scores).

*5.1.3. Self-efficacy*

Table 5.4 provides an overview of the mean scores and difference scores of both groups. The scale in this questionnaire was 1 to 5. A higher score indicated a higher self-efficacy. The experimental group scored a lower average self-efficacy score on pre-test, but a higher average score on post-test than the comparison group. Based on descriptive statistics, it seems that the experimental group made more progress than the comparison group.

Table 5.4

*Results self-efficacy in teaching science*

| | Pre-test | | Post-test | | Difference score | |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Experimental group | 3.15 | .47 | 3.53 | .26 | +.39 | .59 |
| Comparison group | 3.40 | .43 | 3.45 | .42 | +.05 | .34 |

The paired samples t-test shows a significant difference in the scores of the experimental group, $t(22)=-3.17$, $p=.00$. This indicates that the science PD-program has a positive influence on pre-service teachers' self-efficacy in teaching science. No significant differences were found in the scores of the comparison group, $t(36)=-.88$, $p=.19$.

The independent samples t-test shows that the comparison group significantly differed from the experimental group, $t(69)=-2.23$, $p=.03$. The mean pre-test score on self-efficacy of the comparison group was higher than the mean pre-test score of the experimental group.

*Difference scores on self-efficacy*

The difference scores between pre-test and post-test showed that the experimental group made a growth of .39 and the comparison group showed a growth of .05 (see Table 5.4). Figure 5.4 provides an overview of the development of the mean scores of both groups on pre-test and post-test. The figure shows that the experimental group made more growth than the comparison group with regard to science teaching self-efficacy.

The difference scores showed a significant difference between the groups, $t(58)=2.82$, $p=.00$. This results confirms that the science PD program has a positive effect on pre-service teachers' self-efficacy in teaching science, because the experimental group showed a higher difference score between pre-test and post-test.

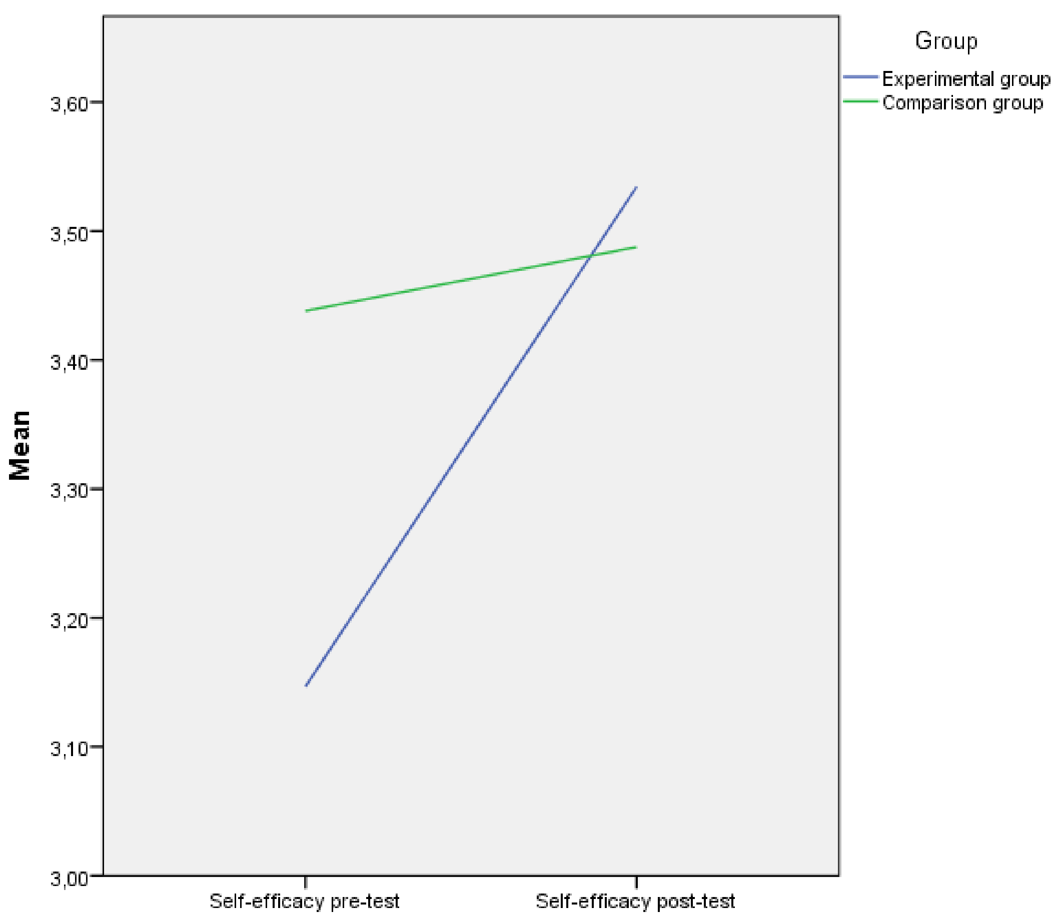


*Figure 5.4.* Mean scores of self-efficacy in teaching science (significant on differences scores).

*5.1.4. Attitude*

Table 5.5 provides an overview of the mean scores and difference scores of both groups on attitude towards science. The scale in this questionnaire was 1 to 5. A higher score indicated a more positive attitude towards science. Based on descriptive statistics, it seems that the experimental group made more growth after the intervention than the comparison group.

Table 5.5

*Results attitude towards science*

| | Pre-test | | Post-test | | Difference score | |
|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Experimental group | 2.91 | .30 | 3.08 | .26 | +.17 | .43 |
| Comparison group | 3.03 | .34 | 3.08 | .30 | +.05 | .17 |

The paired samples t-test showed that a significant difference in the pre-test and post-test results of the experimental group, $t(22)=-1.93$, $p=.03$. This result indicated that the science PD program has a positive effect on pre-service teachers' attitude towards science. In the comparison group, the paired samples t-test showed no significant differences between pre-test and post-test, $t(36)=-.88$, $p=.19$.

To gain insight into the effects of the science PD program on teachers' attitudes, an independent samples t-test was conducted on pre-test scores of the experimental group and comparison group. No significant differences between the groups were found, $t(69)=-1.41$, $p=.16$. Also post-test results showed no statistically significant differences between the groups, $t(64)=.07$, $p=.95$.

*Difference scores on attitude*

Figure 5.5. shows how the scores of pre-service teachers developed after following the type of program. The experimental group makes a small growth, while the comparison group remains almost at the same level in pre-test and post-test score.

The difference scores between pre-test and post-test showed that the experimental group made a growth of .17 and the comparison group showed a growth of .05 (see Table 5.5). However, the results showed that the groups do not significantly differ from each other on the difference scores, $t(61)=1.66$, $p=.05$. So, this results indicate that attitude in the experimental group, after following the science PD program, did not increase more than in the comparison group.

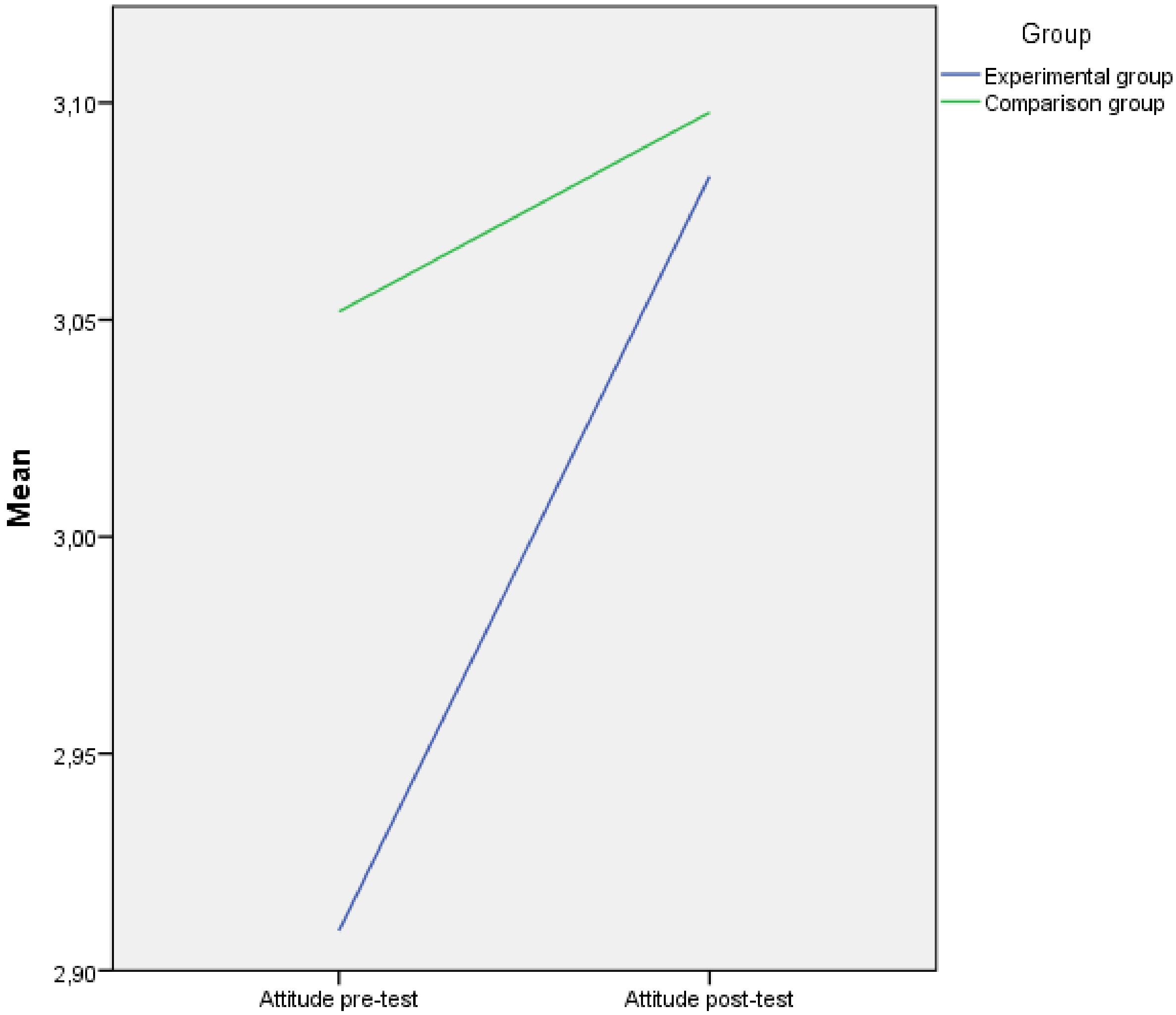

*Figure 5.5.* Mean scores attitude towards science (no significant effect on difference scores).

**5.2. Effective elements**

The previous paragraph presented the results on how the science PD program contributes to teacher challenges in science education. In this paragraph, the second research question will be answered: 'What is, according to the pre-service teachers, the contribution of the four elements to the development of pre-service teacher professionalism in teaching science?'.

In this section, it was described how the experimental group perceived that the effective elements of the science PD program affected their professionalism in science teaching. In the following subparagraphs, the obtained data are described and analysed. The mean scores and standard deviations for each item are presented in a table 5.5. The mean scores were calculated with a minimum of 1 (strongly disagree) and a maximum of 5 (strongly agree from 1 (strongly disagree).

*5.2.1. Student assessment*

*Test development to check whether the students achieved the goals* (item 1) had, on average, a lower mean score than *analysing student work to check whether the students achieved the goals* (item 2). The standard deviation on item 1 is higher than on item 2. Respondents varied in scores. One respondent (4.3%) ‘strongly disagreed’, two respondents (8.7%) did ‘not agree or disagree’ and twenty respondents (87.0%) ‘agreed’. No respondents ‘totally agreed’ with the statement.

Item 2 varied in scores from 3 to 5. The standard deviation on this score was relatively small, which indicates that the scores of the respondents were close around the mean score. Nineteen respondents (82.6%) ‘agreed’ with this statement. It seems that analysing student work was experienced as a valuable element for pre-service teachers professionalism in science teaching.

*5.2.2. Observation and reflection*

On general, it seems that the items related to *observation and reflection* gained the highest mean scores in comparison to the items of other elements. All the items were scores with a mean score of 3.91 or higher. *Reflecting on own science lessons* obtained the highest item score (*M*=3.91, *SD*=.42).

*Observing example lessons* (item 5) showed a higher standard deviation than the other items. One respondent (4.3%) ‘disagreed’, one respondent (4.3%) did ‘not agree or disagree, seventeen respondents (73.9%) ‘agreed’ and four respondents (17.4%) ‘totally agreed’ with the statement. Thus, a small group of the respondents (8.6%) finds that observation made no or little contribution to their professionalism in science teaching. It also appears that opinions about *observing examples of experiments* (item 5b) were divided. One respondent (4.3%) ‘disagreed’ and two respondents (8.7%) did ‘not agreed or disagreed’. So, 13.0% of the pre-service teachers experienced that observing examples of experiments has no or little contribution to their professionalism in teaching science. However, twenty respondents (87.0%) assess the item as valuable.

*5.2.3. Collaborative learning*

*Discussing about the subject-specific tests* (item 6b) showed the lowest mean score of the whole questionnaire (*M*=3.56, *SD*=.72). Seven respondents (30.0%) gave a score of 2 or 3 on this item and sixteen respondents (70.0%) gave a 4-score.

It seems that pre-service teachers experienced *thinking together about science concepts* (item 6), *discussions about the subject-specific tests after giving the lessons* (item 6b), and *collaborating in thinking about the effective science teaching strategies* (item 7) as contributing to their professionalism in science teaching. All the items showed a mean score of 3.93 or higher.

*5.2.4. Teacher (partially) identify their own professional development focus*

The element *teacher (partially) identify their own focus* refers to the science preparation form, which respondents used for the science lessons at their internship. During the science PD program, the pre-service teachers had to give science lessons at primary school. The first preparation form was fully completed by the science teacher. The second preparation form was only partially completed and the pre-service teachers were required to fill in the empty parts on their own. For the last preparation form it was required for the pre-service teachers to complete it on their own.

The data on this item showed that the opinions of the respondents differ. Respondents scores differ from 2 to 5. One respondent (4.3%) disagreed’, four respondents (17.4%) ‘agreed or disagreed’, fifteen respondents (65.2%) ‘agreed’ and the other three respondents (13%) ‘totally agreed’ with the statement. It seems that some respondents perceived it helpful to get more freedom to develop their own lessons for their professionalism, while some students did not find it helpful.

Table 5.6
*Outcomes effective elements*

| | *M* | *SD* |
|---|---|---|
| *Student assessment:* | | |
| 'Test developing to check whether the students achieved the goals contributes to my professionalism in science teaching' | 3.78 | .67 |
| 'Analyzing student work to check whether the students achieved the goals contributes to my professionalism in science teaching' | 4.09 | .42 |
| *Observation and reflection:* | | |
| 'Reflecting on my own science lessons contributed to my professionalism in science teaching' | 4.09 | .42 |
| 'Reflecting example lessons contributed to my professionalism in science teaching' | 4.04 | .56 |
| 'Observing example lessons contributed to my professionalism in science teaching' | 4.04 | .64 |
| 'Observing examples of the completion of the different phases has contributed to my professionalism in science teaching' | 3.91 | .51 |
| 'Observing examples of experiments has contributed to my professionalism in science teaching' | 3.96 | .64 |
| 'Observing of examples of science lessons has contributed to my professionalism in science teaching' | 4.04 | .56 |
| *Collaborative learning:* | | |
| 'Thinking together about the science concepts has contributed to my professionalism in science teaching' | 4.04 | .56 |
| 'Thinking together about the science concept in advance (before giving the science lesson) has contributed to my professionalism in science teaching' | 4.04 | .56 |
| 'Discussion about the subject-specific tests after giving the lesson has contributed to my professionalism in science teaching' | 3.56 | .72 |
| 'Thinking together about the effective science teaching strategies has contributed to my professionalism in science teaching' | 4.09 | .51 |
| *Teacher (partially) identify their own professional development focus:* | | |
| 'Getting more freedom for developing my own science lessons, has contributed to my professionalism in science teaching' | 3.84 | .69 |

## Chapter 6 Conclusion, discussion and limitations

There are many concerns about science education in the Netherlands, especially in primary education (Techniekpact, 2013). Many primary school teachers experience challenges in teaching science (Davis, Petish & Smithey, 2006). The most prominent ones are: 1) little subject matter knowledge about science topics, 2) the utilization of teaching strategies in science education, 3) a low level of self-efficacy in science teaching, and 4) a lack of a positive attitude towards science.

The research group 'Science and Technology in Education' at Saxion University developed a science PD program to reduce the challenges and to better prepare pre-service teachers to provide high-quality science lessons in primary education. The first aim of this study was to investigate the contribution of the science PD program to the four teacher challenges. The second aim was to investigate how the elements of the program contribute to pre-service professionalism in teaching science. In this chapter conclusions will be drawn on the basis of the results of the study. Finally, several limitations of this research will be addressed and recommendations for further research will be presented.

### 6.1. Conclusion and discussion

In the following subparagraphs the two research questions of this study will be answered.

*6.1.1. Teacher challenges*

The first research question of this study was: 'To what extent are pre-service teachers who followed the science PD program better equipped to teach science?'. This will described according to the four teaching challenges.

The *SMK* level of treated topics was enhanced after following the science PD program. Results showed that the science PD program has a positive influence on SMK regarding air, levers, and constructions. A possible explanation for this is that a structural common element in the PD program was *collaborative learning* through professional dialogues about science SMK. Each lesson, the answers of a short SMK test about a specific topic were discussed. Van Veen, Zwart, Meirink and Verloop (2010) argued that when teacher receive the opportunity to exchange and discuss knowledge it can move them towards a deeper understanding of subject matter. No effects were found in the comparison group.

The science PD program has no effect on SMK about untreated science topics. Results indicated that the science PD program did not stimulate pre-service teachers to deepen their understanding of topics that were not included in the program. However, the comparison group showed a contradictory significant change in pre-test and post-test results, because respondents decreased in score. This indicates that SMK could potentially decrease, when limited or no attention is paid on science topics.

The comparison and experimental group both showed a significant growth on the *utilization of effective teaching strategies.* So, the science PD program has a positive influence on the utilization of effective teaching strategies, but not more than in a regular science program. In both programs, the pre-service teachers conducted science lessons in primary schools. This could have contributed to the utilization of the strategies.

Especially in the experimental group, a strong growth was found on the utilization of *testing strategies*. Probably this is because the science PD program paid much attention to *student assessment*. The pre-service teachers had to collect data from their pupils to check whether their pupils achieved the goals of the science lessons, and used formative tests, worksheets and observations to assess the level of understanding of their pupils. According to Struyf (2000), in this way pre-service teachers obtain more insight on how they have to adapt their pedagogy. The science PD program had the least effect on the utilization of *collaborative teaching strategies.* A possible explanation for this finding can be that pre-service teachers are afraid to lose control (Davis, Petish & Smithey, 2006). Another explanation is that it is difficult to use more frequently collaborative teaching strategies in science lessons, because pre-test score indicated that the strategy was already used quite often before participating in the intervention.

The science PD program has a positive effect on *self-efficacy in teaching science*. A possible explanation for the increase in self-efficacy after following the science PD program could be that the experimental group obtained more SMK. According to Rohaan, Taconis, and Yochems (2012) sufficient SMK about science topics is a prerequisite for self-efficacy. Teachers with more science SMK showed a higher personal self-efficacy in teaching science. Another possible explanation for the increased self-efficacy in the experimental group could be that the pre-service teachers understand better how a science lessons is structured and how to deal with the complexity of the science lessons (Boone & Gabel, 1998). The enhanced self-efficacy in the experimental group was an interesting finding, since science courses do not always have a positive influence on pre-service teachers, because participants can gain more insight into the complexity of conducting science lessons. Hence, pre-service teachers might feel less prepared to teach it (Boone & Gabel, 1998).

*Attitude towards science* of pre-service teachers was significantly enhanced in the science PD program and not in the regular science program. However, there was no significant effect found in the difference scores between groups. This is a remarkable finding, because both SMK and self-efficacy did increase in experimental group, which should have a positive effect on difference scores on attitude (Van Aalderen-Smeets, Walma Van Der Molen & Asma, 2012). This might indicate that the science PD program has a positive influence on attitude, but not more than in another science program. Perhaps (more) growth of attitude was difficult to achieve, because attitude probably occurs in small increments over time and many pre-service teacher must overcome previously formed attitudes they have acquired over many previous years of science education (Boone & Gabel, 1999).

*6.1.2. Contribution of the effective elements to teachers' professionalism in teaching science*

The second research question was: 'What is, according to the pre-service teachers, the contribution of the four elements to the development of pre-service teacher professionalism in teaching science?'. Four elements were included in the science PD program: analyzing student work, observation and reflection, collaborative learning and teachers own professional development focus.

*Analyzing student work* was assessed by the pre-service teachers as a valuable contribution to professionalism in teaching science. This is in line with findings from the review of Van Veen, Zwart, Meirink & Verloop (2010), who argued that this is an important and effective activity in PD programs to enhance teacher quality and their teaching, which subsequently influences pupils' performance.

Also *observation and reflection* was perceived by the pre-service teachers as a valuable contribution to professional development in teaching science. The most successful activity of this element was reflection on pre-service teachers' own lessons. Previous research (Kroek, 2016) indicated that observation can lead to more confident in managing a science lesson when pre-service teachers reflect on their lessons. This could explain why pre-service teachers assessed this element as a valuable contribution to their professionalism.

Reflect on examples of science lessons was also perceived as a valuable contribution for pre-service professionalism in teaching science. This result supports the argument made by Vrieling, Stijnen, Besselink, Velthorst and Van Maanen (2015). They argued that it is helpful for students to observe other teachers, because they can analyse qualitative sample lessons or behaviours and they can imitate it in their own practice.

*Collaborative learning* was perceived as a valuable element for pre-service teachers' professional development in teaching science. 'Thinking together about effective strategies' was perceived as the most valuable activity in this element. This result mirrors the results of Kroek (2016), who concluded that pre-service teachers find it very valuable to discuss didactical knowledge. The opinions of pre-service teachers about 'discussing the subject-specific test' differed from positive to negative. This results contradicts the opinion of Verbiest (2003), who claims that sharing and exchanging knowledge and discussing topics is effective. A possible explanation for why some pre-service teachers assessed this activity as not being helpful, is that some respondents already had the content-knowledge (by preparing their science lessons for primary school), so no further explanation was needed for them (Kroek, 2016).

The fourth element, *teachers (partly) identify their own professional development focus,* was assessed by the pre-service teachers as a moderately positive contribution to their professionalism in teaching science. Some of the respondents argued that more professional development focus did not contribute to their professional development. A possible explanation for this, is that the pre-service teachers were uncertain about how to fill in the preparation forms on their own. In a previous study of Kroek (2016), it was concluded that some pre-service teachers felt uncertain about the quality of their lessons when they had to choose their own professional development focus. Perhaps some pre-service teachers in this study experienced also uncertainty about it and therefore a professional development focus did not enhance their professionalism in teaching science.

**6.2. Limitations and recommendations**

Several limitations of this research are worth mentioning. The five most important ones are: 1) the "Hawthorne effect", 2) generalization of the results, 3) quantitative data, 4) snapshot view of the contribution of the program and 5) reliability of the 'effective elements' questionnaire. These limitations will be briefly discussed and recommendations for follow-up research are provided.

The first limitation is the 'Hawthorne effect' (Van Weert, 2009). The experimental group and control group had to fill in questionnaires at the beginning and at the end of the program, what is uncommon in regular teacher training curriculum. Due to the questionnaires, both groups could have suspect that they participated in a research. Therefore, social desirability considerations could lead to adapt their real perceptions about the teacher challenges. The experimental group got the science lessons from a teacher, which was a teacher outside the teacher training college. Therefore, this group might have the suspicion that they were the experimental group in a research. Van Weert (2009) argues that when respondents obtain more attention in a research, respondents can show an increase in observed variables. Probably this was also in case with the experimental group in this research. Because of a new teacher and another science program than the other groups, the respondents wanted learn more or provided social desirability considerations.

The teacher of the experimental group was the researcher of this study, so this can caused the second 'Hawthorne effect' (Van Weert, 2009). When a researcher believes that the investigated intervention is better than the comparison program, respondents can be sent in a certain direction (Van Weert, 2009). In this study, the researcher took part in the experiment as the teacher for the experimental group. It might be possible that the researcher paid attention on the teacher challenges during the meetings, which could have influence the teacher challenges in teaching science. For example, the researcher could give the respondents the idea that they provided high-quality science education, which could influence their self-efficacy. Therefore, in follow-up study the researcher should not take part in the intervention. Additionally, for more insight into the effect of the science PD program, participated science teacher(s) should be blinded about the possible effects of the programs.

On the other hand, the teacher of Saxion was an experienced and educated science teacher on the teacher training college. Thereby, it might be expected that he had more expertise about educating pre-service teachers and that it influenced teacher challenges more positive than the unexperienced teacher. Therefore, the positive results of this study also could be explained by the effect of the science PD program. In order to exclude the suspicions, follow-up study with other and more teachers and respondents would give more insight into the effects of the program.

The second limitation is that the results from this research cannot be generalized, since this research was a case study. The research was carried out at only one university. It is not possible to generalize the results of this study to other contexts. When the same method is used in other contexts and therefore more respondents will be used, stronger outcomes can support a conclusion of the findings of this study.

The third limitation is that the research only used quantitative data. Therefore, it is not exactly known why pre-service teachers positively developed SMK, self-efficacy and teaching strategies in this way, and why the pre-service teachers did not gain a more positive attitude towards science. In future research, qualitative data could be used to gain insights into how the science PD program did and did not contribute to pre-service professional development (Onwuegbuzie & Leech, 2006). Qualitative data also can be used to investigate how pre-service teachers assess the effective elements of the science PD program.

The fourth limitation is that the research was conducted over a period of two months, during which the surveys were conducted. The results provide a snapshot of pre-service teachers' perceptions of the contribution of the science PD program to teacher challenges and the contribution of the effective elements on teachers' professionalism in teaching science. It would be interesting to follow the development of teacher challenges during their next study year and first year(s) in primary school, to explore the long-term effects of the science PD program.

Finally, insufficient research of the instrument about the effective elements was conducted. Even though the instrument is based on scientific principles, additional testing needs to be done to increase validity and reliability. Two scales showed an acceptable Cronbach's Alpha, namely *observation and reflection* and *collaborative learning*. However, the reliability for *student assessment* and *teachers own professional development focus* was low. It is recommended to increase the items, so that reliability of each element can be measured. Then, more insight can be obtained about what makes the element effective or ineffective.

### 6.3. Contributions

In first place, this research has a practical value for teacher training college at Saxion Academy. The science PD program gained attention for science education at primary school and the effects of the program are being investigated. Although some limitations have been found in this study, the study indicates that it might be interesting to further developing the science PD program. In this study, suggestions are given for the science PD program in order to improve pre-service teachers attitude towards science. The results in this study and context showed that the science PD program has a positive influence on two teacher challenges, so the program contains hopeful elements. It is recommended to continue developing the science PD program.

The findings of this study can especially be used by the research group 'Science and Technology in Education' at Saxion Academy to make adjustments in the program and to perform the program on larger scale.

This research also contributes to science, since it provides new insights on how pre-service teachers appreciate the activities which belong to *student assessment, observation and reflection* and *collaborative learning.* The findings from this research were compared to recommendations from literature. In this way, recommendations form literature could be confirmed.

### 6.4. Recommendations for improving the science PD program

Recommendations can be made for the improvement of the science PD program. The most important two are: 1) attention on attitude towards science, and 2) lesson preparations.

The attention on attitude towards science can be improved in the science PD program. Van Aalderen-Smeets and Van Der Molen (2015) stated that three components are important to enhance teachers' attitude towards science: 1) knowledge about (teaching) science and scientific skills, 2) attitude towards (teaching) science, and 3) scientific attitude. Only one of these was included in the program, namely 'knowledge about (teaching) science and scientific skills'. This component alone, so it appears, does not have sufficient impact for teachers' attitudes to enhance. Perhaps if attention is also paid to the other components in the science PD program, teachers' attitudes towards science could enhance more.

The element *teachers (partly) identify their own professional development focus* needs more attention. Pre-service teacher rated this element as only moderately contributing to their professionalism. More attention can be paid on how to fill in the preparation forms. The science teacher can provide more feedback on preparation forms, to guidance pre-service teachers how to develop a science lesson according to the orientation-, experimental- and deepening phases.

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## Appendices

### Appendix 1: Test matrix SMK

Toetsmatrijs – Schriftelijke toets

Algemene informatie

| | |
|---|---|
| Vak | Wetenschap en Techniek |
| Onderwijstype | Pabo (HBO) |
| Leerjaar | 3 |
| Naam toets | Kennistoets natuur en techniek |
| Toetsvorm | Meerkeuzetoets |

De thema's van de vakinhoudelijke toets zijn ontleend aan de bronnenboeken 'Maken en onderzoeken' en 'Natuurlijk beginnen' (Bouwmeester, Doornekamp & Kleingeld, 2006; Oostendorp-Bourgonjon & Oostendorp, 2002). Deze boeken zijn samengesteld voor studenten van de Pedagogische Academie voor het BasisOnderwijs (PABO). De kerndoelen op het gebied van natuur- en techniek in het basisonderwijs vormen de leerstof van de bronnenboeken. Op basis van de bronnenboeken zijn de onderstaande toetsdoelen en specifieke doelen geformuleerd. De bronnenboeken tonen aan dat leerkrachten kennis moeten hebben van onder andere de thema's: drijven, zinken en zweven, luchtdruk, constructies, hefbomen, magnetisme en elektriciteit. Deze thema's worden opgenomen in de vakinhoudelijke toets.
De onderstaande tabel geeft een overzicht van de gekozen toetsdoelen en de daarbij behorende specifieke doelen. Per specifiek doel wordt aangegeven hoeveel items er getoetst worden. Het percentage geeft aan in hoeverre het specifieke doel getoetst wordt per toetsdoel. Ook wordt weergegeven welke type items er getoetst worden: inzicht, kennis en toepassing.

| **Toetsdoel** | **Specifieke doel** | **Aantal items** | **Percentage** | **Item-nummer** | **Item type** |
|---|---|---|---|---|---|
| *De student kan …* | *De student kan …* | | | | |
| | | | | | |
| Verklaren waardoor objecten drijven/zinken/zweven in verschillende vloeistoffen | Op basis van kennis over dichtheid verklaren waardoor objecten in het water gaan drijven | 4 | 33.33% | 1 | Inzicht |
| | | | | 3 | Kennis |
| | | | | 5 | Inzicht |
| | | | | 7 | Inzicht |
| | Op basis van kennis over dichtheid verklaren waardoor objecten in het water gaan zinken | 3 | 25% | 2 | Inzicht |
| | | | | 6 | Toepassing |
| | | | | 9 | Inzicht |
| | Op basis van kennis over dichtheid verklaren waardoor objecten in het water gaan zweven | 2 | 16.67% | 10 | Kennis |
| | | | | 12 | Toepassing |
| | Op basis van kennis verklaren wat de natuurkundige verklaring | 3 | 25% | 4 | Kennis |

| | | | | | |
|---|---|---|---|---|---|
| | is voor drijfkracht | | | 8 | Kennis |
| | | | | 11 | Inzicht |
| | | | | | |
| Verklaren wat voor een effect luchtdruk kan hebben op objecten en/of omstandigheden | Op basis van kennis verklaren hoe lucht is opgebouwd | 1 | 10% | 14 | Kennis |
| | Op basis van kennis verklaren hoe luchtdruk wordt gemeten | 1 | 10% | 18 | Kennis |
| | Op basis van kennis verklaren wat het effect is van een lage luchtdruk op objecten | 2 | 20% | 16 | Inzicht |
| | | | | 20 | Kennis |
| | Op basis van kennis verklaren wat het effect is van een hoge luchtdruk op objecten | 2 | 20% | 13 | Inzicht |
| | | | | 22 | Inzicht |
| | Op basis van kennis verklaren welke rol warmte en kou speelt bij luchtdruk | 4 | 40% | 15 | Inzicht |
| | | | | 17 | Kennis |
| | | | | 19 | Kennis |
| | | | | 21 | Toepassing |
| | | | | | |
| Verklaren welke eigenschappen de stabiliteit van een constructie beïnvloeden | Aangeven welke type constructies er zijn | 1 | 14.29% | 23 | Kennis |
| | Verklaren wat voor een invloed vorm heeft op de stabiliteit van een constructie | 3 | 42.89% | 24 | Kennis |
| | | | | 27 | Kennis |
| | | | | 28 | Inzicht |
| | Verklaren wat voor een invloed materiaal heeft op de stabiliteit van een constructie | 3 | 42.89% | 25 | Inzicht |
| | | | | 26 | Inzicht |
| | | | | 29 | Kennis |
| | | | | | |
| Verklaren wat de werking van een hefboom is | Herkennen welke functies een hefboom kan hebben | 4 | 50% | 31 | Kennis |
| | | | | 32 | Kennis |
| | | | | 34 | Kennis |
| | | | | 36 | Kennis |
| | Verklaren wat voor een invloed de armlengte van een hefboom heeft op gewicht | 3 | 37.5% | 30 | Inzicht |
| | | | | 33 | Inzicht |
| | | | | 35 | Inzicht |
| | Verklaren wat voor een invloed de grootte van een tandwiel heeft op de kracht die het kan dragen | 1 | 12.5% | 37 | Inzicht |
| | | | | | |
| Verklaren wat de functie van een magneet kan zijn | Herkennen wat een magneet is | 2 | 33.33% | 40 | Kennis |
| | | | | 43 | Kennis |
| | Uitleggen welke factoren invloed hebben op de magnetische eigenschappen van een stof | 2 | 33.33% | 38 | Kennis |
| | | | | 39 | Kennis |
| | Verklaren hoe polariteit werkt | 2 | 33.33% | 41 | Kennis |

| | | | | | |
|---|---|---|---|---|---|
| | | | | 42 | Inzicht |
| | | | | | |
| Verklaren wat voor een invloed elektriciteit kan hebben | Aangeven wat de voeding voor elektriciteit kan zijn | 1 | 14.29% | 44 | Inzicht |
| | Onderscheiden wat voor types stroom er zijn | 1 | 14.29% | 46 | Kennis |
| | Onderscheiden welke elektriciteitsschakelingen er zijn | 1 | 14.29% | 47 | Kennis |
| | Verklaren welk effect een elektriciteitsschakeling geeft | 4 | 57.14% | 45 | Inzicht |
| | | | | 48 | Kennis |
| | | | | 49 | Toepassing |
| | | | | 50 | Inzicht |

**Referenties:**

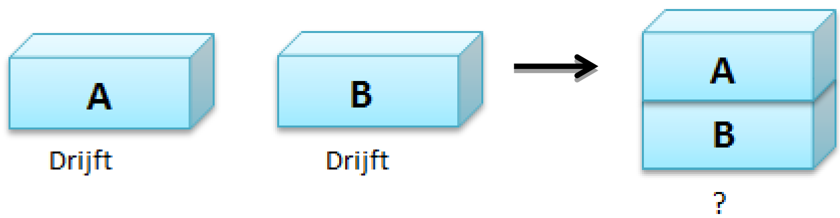

Bouwmeester, T., Doornekamp, G., & Kleingeld, R. (2006). *Maken en onderzoeken.* Houten: Wolters-Noordhoff bv Groningen.

Oostendorp-Bourgonjon, C., & Oostendorp, P. (2002). *Natuurlijk beginnen.* Houten: Wolters-Noordhoff Groningen.

**Appendix 2: Science SMK test**

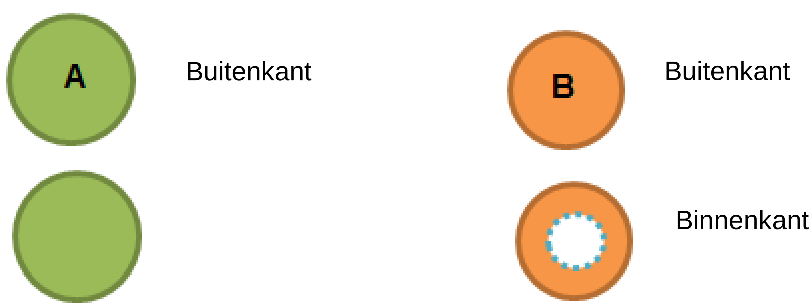
## Water

**Vraag 1:**
Blok A en blok B drijven beide in het water. Wat zal er gebeuren als de blokken aan elkaar worden gelijmd en in het water worden gelegd?




A. Het blok AB zal drijven
B. Het blok AB zal zweven
C. Het blok AB zal zinken

**Vraag 2:**
Bal A en Bal B zijn gemaakt van verschillend materiaal, maar hebben dezelfde massa en hetzelfde volume. Bal A is massief en Bal B is hol in het midden (zie afbeelding). Bal A zinkt in het water. Als Bal B in het water wordt gelegd zal deze………..



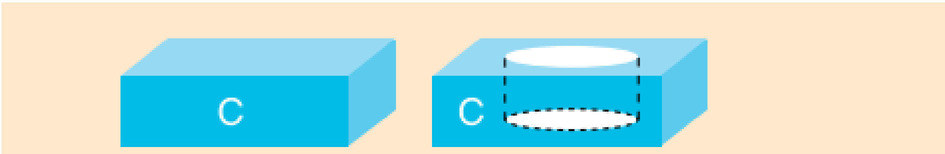

A. Drijven
B. Zweven
C. Zinken

**Vraag 3:**
Hoe noemen we de tegenwerkende kracht die door het water uitgeoefend wordt?

A. Waterkracht
B. Zwaartekracht
C. Luchtdruk
D. Opwaartse kracht

**Vraag 4:**

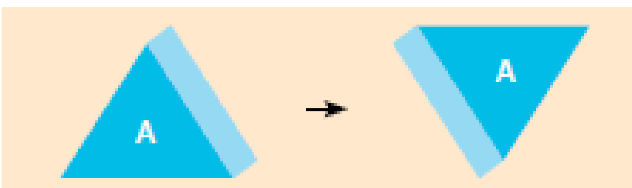
Blok C drijft in het water. Stel dat er een gat in wordt gemaakt. Als blok C dan in het water wordt gelegd zal het.........




A. Drijven
B. Zweven
C. Zinken

**Vraag 5:**

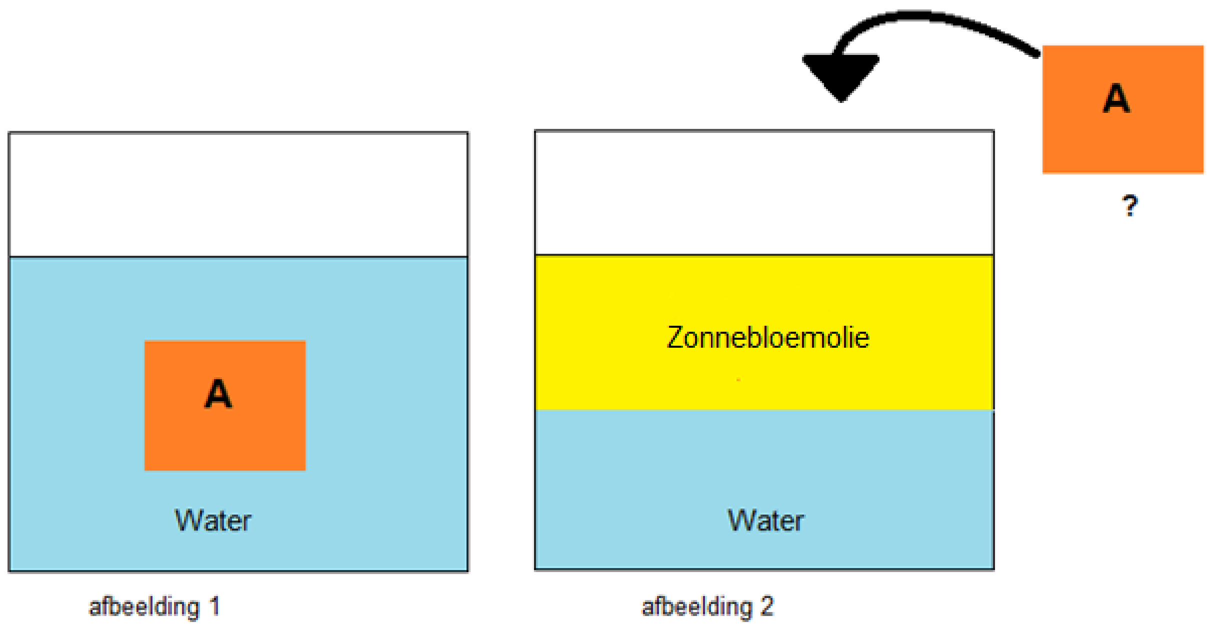
Wanneer blok A op de manier-links in het water wordt gelegd, blijft het drijven. Stel dat we het ondersteboven in het water leggen, zoals in de rechter afbeelding. In dat geval zal blok A......




A. Drijven
B. Zweven
C. Zinken

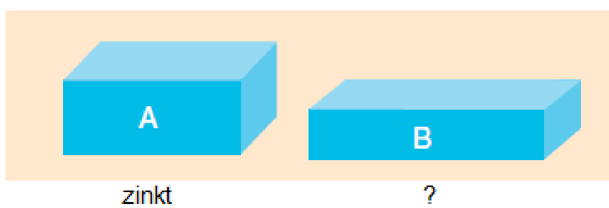
**Vraag 6:**

Blok A zweeft onder het wateroppervlak (zie afbeelding 1). Kokende olie drijft op het water (zie afbeelding 2). Als blok A in kokende olie wordt gelegd, zal het……



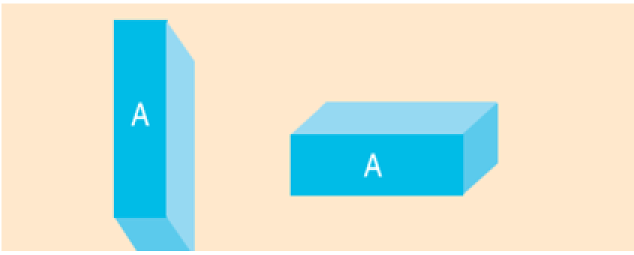

A. Drijven
B. Zweven
C. Zinken

**Vraag 7:**
Blokken A en B zijn gemaakt van hetzelfde materiaal. Blok B is platter dan Blok A. Blok A zinkt in het water. Wanneer blok B in het water wordt gelegd, zal het…….




A. Drijven
B. Zweven
C. Zinken

**Vraag 8:**
Blok A zinkt in het water als we het op de linker manier in het water leggen. Als we blok A op de rechter manier in het water leggen, zal het……




Zinkt ?

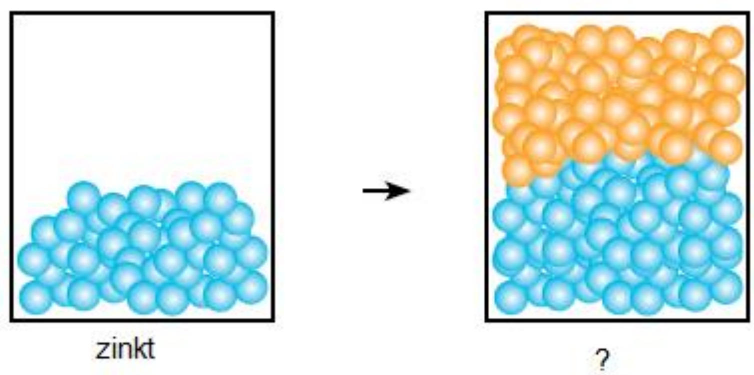
A. Drijven
B. Zweven
C. Zinken

**Vraag 9:**
Bal A en bal B hebben dezelfde massa en hetzelfde volume. Bal A is van zacht materiaal gemaakt. Bal B is van hard materiaal gemaakt. Bal A drijft in het water. Wanneer bal B in het water wordt gelegd, zal deze…


drijft ?

A. Drijven
B. Zweven
C. Zinken

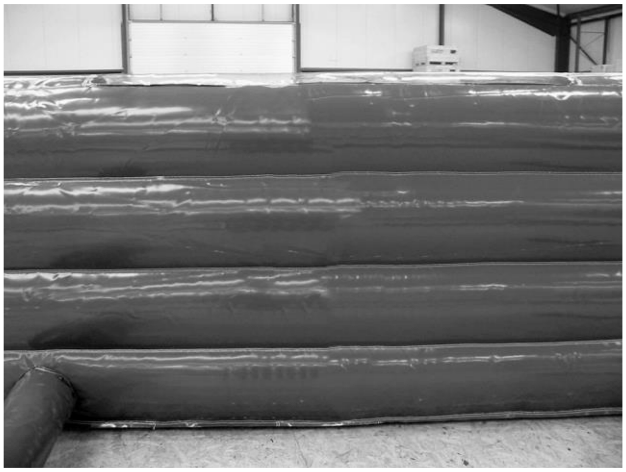
**Vraag 10:**
Een dichtgeplakte bak is half gevuld met stenen en zinkt in het water. We vullen de andere helft met verpakkingsschuim, plakken het weer stevig dicht en leggen het in het water. De bak zal nu…..




A. Drijven
B. Zweven
C. Zinken

## Lucht

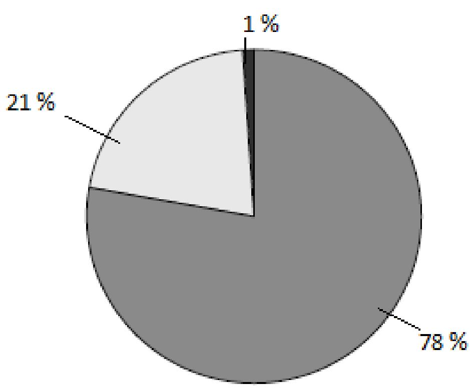
**Vraag 11:**
Bij schaatswedstrijden staan langs de baan stootkussens. De stootkussens kunnen zware klappen van gevallen schaatsers opvangen. De stootkussens langs de baan staan bol.



Welk antwoord is juist over de luchtdruk in het stootkussen?

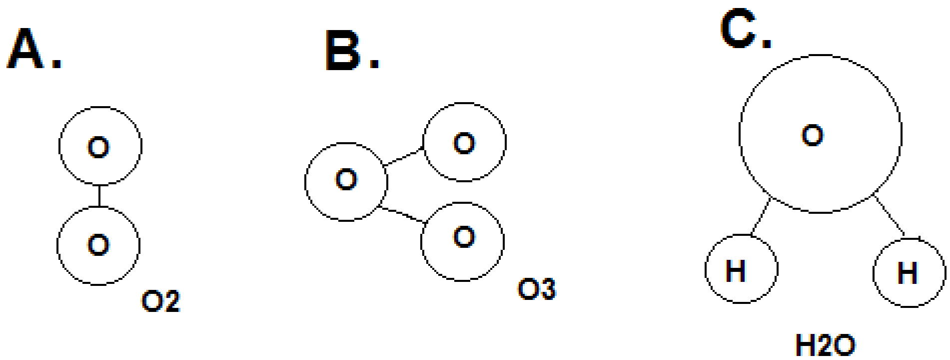
A. De luchtdruk in het stootkussen is **gelijk aan** de luchtdruk buiten het stootkussen
B. De luchtdruk in het stootkussen is **kleiner dan** de luchtdruk buiten het stootkussen
C. De luchtdruk in het stootkussen is **groter dan** de luchtdruk buiten het stootkussen

**Vraag 12:**
In het diagram hieronder is de samenstelling van lucht weergegeven. Geef aan hoe de verdeling is.




A. 1 % = andere gassen, 21 % = zuurstof, 78 % = stikstof
B. 1 % = stikstof, 21 % = zuurstof, 78 % = andere gassen
C. 1 % = stikstof, 21 % = andere gassen, 78 % = zuurstof
D. 1 % = zuurstof, 21 % = stikstof, 78 % = andere gassen

**Vraag 13:**
Op welke afbeelding wordt worden de moleculen van ozon weergegeven?




A.O2
B.O3
C.H2O

**Vraag 14:**
Wat is de belangrijkste oorzaak dat er luchtdrukverschillen op het aardoppervlak ontstaan?

A. Dit komt door de draaiing van de aarde
B. Dit komt door opstijgende warme lucht
C. Dit komt doordat de aarde niet op alle plaatsen even warm is
D. Dit komt door de wind

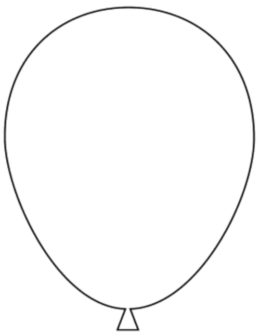
**Vraag 15:**
Stef gaat de Kilimanjaro in Afrika beklimmen.


Wat is waar over de luchtdruk als hij rond een hoogte van 3000 meter zal zijn?

A. De luchtdruk zal daar hoger zijn, dus het ademhalen wordt gemakkelijker
B. De luchtdruk zal daar hoger zijn, dus het ademhalen wordt zwaarder
C. De luchtdruk zal daar lager zijn, dus het ademhalen wordt gemakkelijker
D. De luchtdruk zal daar lager zijn, dus het ademhalen wordt zwaarder

**Vraag 16:**
Juf Anke wil de kinderen van haar groep laten zien dat een ballon binnen een paar uur kan krimpen, zonder lucht te laten ontsnappen.

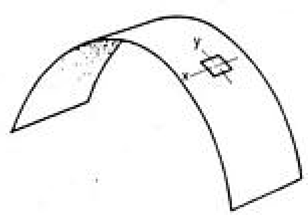
Ze blaast de ballon in de klas op. Wat moet ze doen om de kinderen te laten zien dat de ballon kan krimpen, zonder lucht te laten ontsnappen?



A. De ballon in de koelkast leggen. Na een paar uur zal de ballon gekrompen zijn
B. De ballon in een boodschappentas doen en deze afsluiten. Na een paar uur zal de ballon gekrompen zijn.
C. De ballon boven de verwarming hangen. Na een paar uur zal de ballon gekrompen zijn.
D. De ballon in een donkere ruimte leggen. Na een paar uur zal de ballon gekrompen zijn.

## Constructies

**Vraag 17:**
Wat is waar over een boogvorm?




A. Een boogvorm kan meer druk opvangen dan een rechte vorm
B. Een boogvorm kan minder druk opvangen dan een rechte vorm
C. Een boogvorm kan evenveel druk opvangen als een rechte vorm

**Vraag 18:**
Wat is een voorbeeld van een voorwerpverbinding?

A. Lijm
B. Soldeertin
C. Specie
D. Spijker

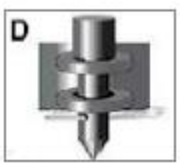
**Vraag 19:**
De keuze van materialen voor constructies hangt af van eigenschappen. Welke van de onderstaande eigenschappen is het *minst* belangrijk?

A. Doorzichtigheid
B. Hardheid
C. Prijs
D. Bewerkbaarheid

**Vraag 20:**
Eva maakt voor haar dochter een houten karretje met een bijpassend aanhangwagentje. Het aanhangwagentje moet makkelijk los- en vast te koppelen zijn. In de doe-het-zelfzaak zoekt Eva het juiste materiaal om deze verbinding te maken.

Welk soort verbinding tussen karretje en aanhangwagentje moet Eva kiezen?

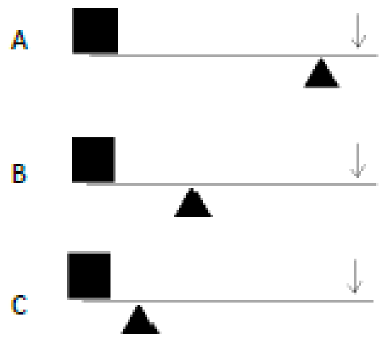



A. Verbinding A
B. Verbinding B
C. Verbinding C
D. Verbinding D

## Hefbomen

**Vraag 21:**
Waar moet je het *hardst* drukken om het blok omhoog te tillen?



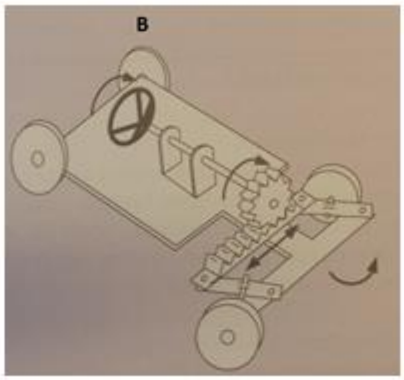

A. Bij tekening A
B. Bij tekening B
C. Bij tekening C
D. Het maakt geen verschil, overal even hard

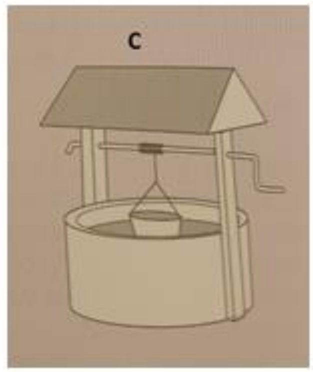
**Vraag 22:**

Het gewicht van de twee dozen is hetzelfde. Welke doos zal *omhoog* gaan?


A. Doos 1
B. Doos 2
C. De dozen zullen op dezelfde hoogte blijven

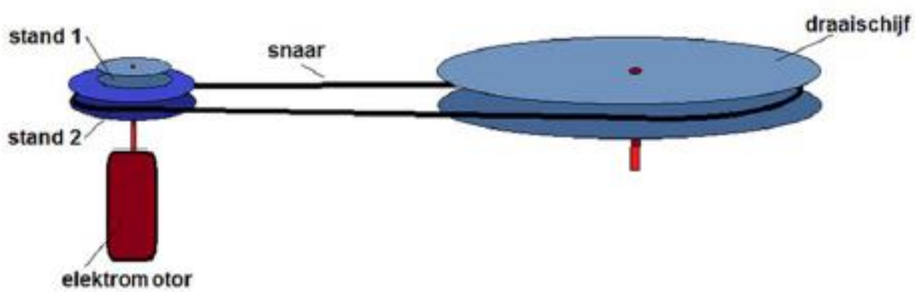
**Vraag 23:**
Op welk plaatje wordt gebruik gemaakt van een windas?






A. Op afbeelding A
B. Op afbeelding B
C. Op afbeelding C
D. Er wordt hier geen windas afgebeeld

**Vraag 24:**



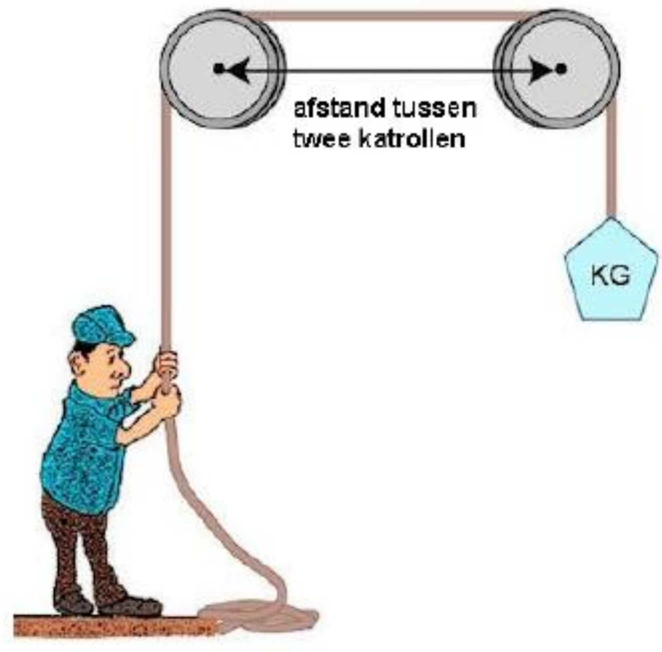

Op de tekening zie je hoe de aandrijving van een platenspeler werkt. Op de elektromotor zijn via een as twee wielen gemonteerd. Deze wielen laten via een snaar de draaischijf draaien. Op de tekening zit de snaar om het onderste wiel (**stand 2**), maar de snaar kan ook om het bovenste wiel (**stand 1**) geplaatst worden. Door te wisselen van stand wordt de draaischijf rondgedraaid met 33 of 45 toeren (rondjes) per minuut.

Welke uitspraak over de werking van deze platenspeler is juist?

De wielen op de elektromotor…

A. draaien langzamer dan de draaischijf: stand 1 is voor 45 toeren per minuut
B. draaien langzamer dan de draaischijf: stand 2 is voor 45 toeren per minuut
C. draaien sneller dan de draaischijf: stand 1 is voor 45 toeren per minuut
D. draaien sneller dan de draaischijf: stand 2 is voor 45 per minuut

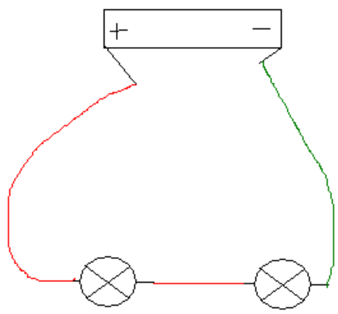
**Vraag 25:**




De afstand tussen de twee katrollen kan groter of kleiner gemaakt worden.
Wat is de invloed van de afstand tussen de twee katrollen op de kracht die nodig is om het gewicht omhoog te tillen?

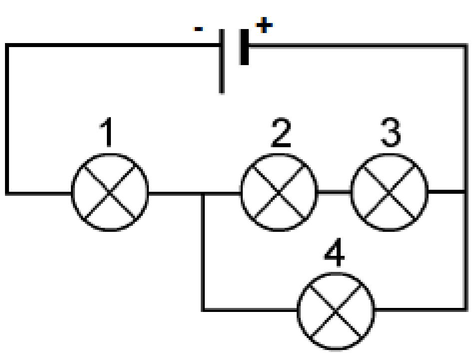
A. De afstand tussen de twee katrollen heeft geen invloed op de kracht die nodig is
B. Hoe groter de afstand tussen de twee katrollen, hoe meer kracht er nodig is
C. Hoe kleiner de afstand tussen de twee katrollen, hoe meer kracht er nodig is

**Vraag 26:**
Wat voor een schakeling wordt op de afbeelding weergegeven?



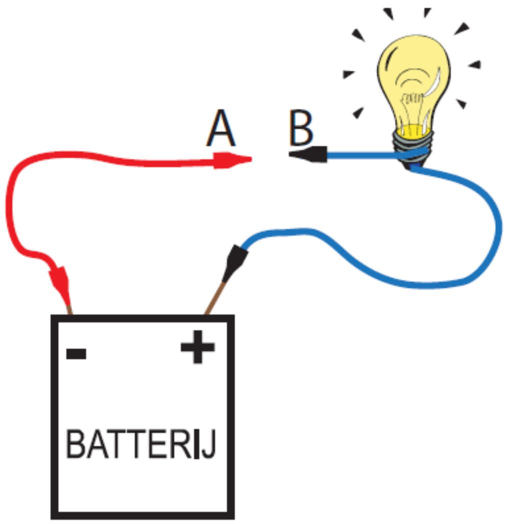

A. Serieschakeling
B. Wisselschakeling
C. Lampschakeling
D. Parallelschakeling

**Vraag 27:**
Zie onderstaande tekening. Alle lampjes branden. Stel dat je lampje 1 losdraait.
Wat zal er gebeuren?




A. Lampje 2, 3 en 4 zullen blijven branden
B. Lampje 2 en 3 zullen uit gaan. Lampje 4 blijft branden
C. Lampje 4 zal uit gaan. Lampje 2 en 3 blijven branden
D. Alle lampjes zullen uit gaan

**Vraag 28:**
Nynke onderzoekt hoe zij het lampje kan laten branden. Zie de onderstaande tekening. Ze heeft een glazen roerstaafje, een zilveren schaaltje en een porseleinen lepeltje. Om de beurt klemt ze deze tussen A en B in.




Met welk ingeklemd voorwerp kan het lampje gaan branden?

A. Met een glazen roerstaafje
B. Met een zilveren schaaltje
C. Met een porseleinen lepel
D. Met al deze drie voorwerpen

## Licht

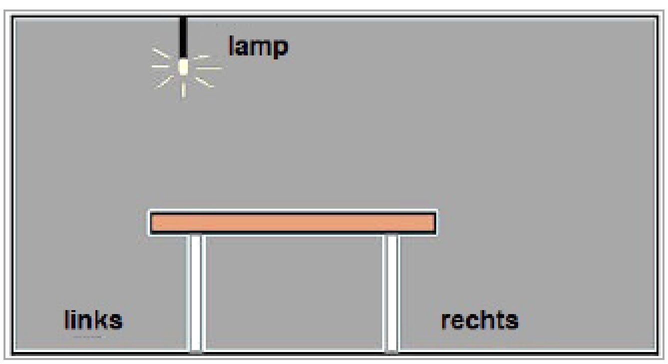
**Vraag 29:**
Welke van de onderstaande omschrijving geeft juist aan wat infrarood is?

A. Een golflengte die we voelen als warmte
B. Een golflengte die de huid bruin maakt
C. Een golflengte met elektromagneten
D. Een elektromagnetische straling

**Vraag 30:**
Welke stelling(en) is/zijn juist?
*Stelling 1:* Golven met een heel korte golflengte kunnen we wel zien
*Stelling 2:* Golven met een hele lange golflengte kunnen we niet zien

A. Stelling 1 is juist, stelling 2 is onjuist
B. Stelling 2 is juist, stelling 1 is onjuist
C. Beide stellingen zijn juist
D. Beide stellingen zijn onjuist

**Vraag 31:**




De houten tafel wordt vanaf het plafond verlicht door een kleine felle led-lamp (puntlichtbron). Verder is er geen lichtbron in de kamer (zie tekening).

Welk type schaduw ontstaat er?

A. Alleen een kernschaduw
B. Een kernschaduw en aan beide zijkanten een halfschaduw
C. Een kernschaduw en alleen aan de linker zijkant een halfschaduw
D. Een kernschaduw en alleen aan de rechter zijkant een halfschaduw

**Appendix 3: Questionnaire utilization teaching strategies**

**Naam:**

Hieronder staan een aantal stellingen die betrekking hebben op leerstrategieën op het gebied van onderwijs in natuur en techniek.
Er wordt onderscheid gemaakt tussen acht verschillende strategieën: *enhanced context strategy, collaborative learning strategy, questioning strategy, inquiry strategy, manipulation strategy, testing strategy, instructional strategy* en *enhanced material strategy.* Onder iedere strategie wordt een voorbeeld gegeven hoe je deze strategie toe zou kunnen passen in je technieklessen.

Ieder voorbeeld heeft 5 antwoordmogelijkheden en het is de bedoeling om aan te kruisen welk antwoord het beste bij jouw ervaring past. Als het lukt, zou het fijn zijn als je hier een voorbeeld van kunt geven.

Vul de vragenlijst zo eerlijk mogelijk in zonder hulp van anderen. Er zijn geen foute of goede antwoorden.

| | **Helemaal mee oneens** | **Oneens** | **Noch eens/ noch oneens** | **Eens** | **Helemaal mee eens** | **Toelichting:** |
|---|---|---|---|---|---|---|
| ***Enhanced Context Strategy*** | | | | | | |
| Ik werk vanuit een betekenisvolle context naar het doel toe | | | | | | |
| ***Collaborative Learning Strategy*** | | | | | | |
| Ik laat leerlingen samenwerken tijdens de les | | | | | | |
| Ik zorg ervoor dat iedere leerling een gelijke bijdrage levert aan het samenwerkingsproces | | | | | | |
| Ik stimuleer de samenwerkingsvaardigheden van leerlingen | | | | | | |
| ***Questioning Strategy*** | | | | | | |
| Ik stel vragen met verschillende doelstellingen | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ik stel vragen van lagere orde | | | | | | |
| Ik stel vragen van hogere orde | | | | | | |
| Ik pas genoeg wachttijd toe na het stellen van een vraag (>3 sec. bij lage orde vraag, >5 bij hoge orde vraag) | | | | | | |
| ***Inquiry Strategy*** | | | | | | |
| Ik stimuleer de onderzoeksvaardigheden van leerlingen | | | | | | |
| Ik volg de onderzoekscyclus tijdens het geven van de les | | | | | | |

| | Helemaal mee oneens | Oneens | Noch eens/ noch oneens | Eens | Helemaal mee eens | Toelichting: |
|---|---|---|---|---|---|---|
| Ik maak een duidelijke connectie met een vorige les | | | | | | |
| ***Manipulation Strategy*** | | | | | | |
| Ik zorg ervoor dat de leerlingen werken  met het materiaal | | | | | | |
| Ik zorg ervoor dat leerlingen zelf hun experiment kunnen opzetten via hand-outs | | | | | | |
| Ik zorg ervoor dat leerlingen variabelen kunnen controleren (ligt aan het onderwerp of dit kan) | | | | | | |
| ***Testing Strategy*** | | | | | | |
| Ik zorg laat zien dat hij aan de hand van leerlingenwerk een remediering kan bedenken (kleuters: observaties). | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ik maak tijdens de les gebruik van het leerlingenwerk om het leren bij te sturen (kleuters: observaties) | | | | | | |
| ***Instructional Technology Strategy*** | | | | | | |
| Ik gebruik technologie om het denken over de vakconcepten te stimuleren | | | | | | |
| ***Enhanced Material Strategy*** | | | | | | |
| Ik zet materiaal in om het denken over de vakconcepten te stimuleren (zoals spelletjes, werkbladen en ander materiaal) | | | | | | |

**Appendix 4: STEBI-NL**

**Naam:**

Hieronder volgen een aantal stellingen die betrekking hebben over percepties op het gebied van onderwijs in natuur en techniek. De eerste 12 vragen gaan over jouw perceptie over de invloed die de leerkracht kan uitoefenen op de leerling resultaten op het gebied van natuur en techniek. De laatste 12 vragen gaan over jouw zelfvertrouwen bij het lesgeven in natuur en techniek. Elke stelling heeft 5 antwoordmogelijkheden en het is de bedoeling om het antwoord aan te kruisen dat het best past bij jouw gevoel en ervaring.

Vul deze vragenlijst zo eerlijk mogelijk in zonder hulp van anderen. Er zijn geen foute of goede antwoorden. Het kan voorkomen dat vragen op elkaar lijken, maar dit is nodig om de nauwkeurigheid van de vragenlijst te waarborgen. Het is daarom van belang dat je alle vragen beantwoord. De gegevens worden anoniem verwerkt.

| | **Stellingen** | **Volledig oneens** | **Oneens** | **Noch eens/ noch oneens** | **Eens** | **Helemaal eens** |
|---|---|---|---|---|---|---|
| 1 | Als een leerling beter presteert dan anders in natuur en techniek, dan kan dat komen doordat de leerkracht zich extra heeft ingespannen voor deze leerling | ○ | ○ | ○ | ○ | ○ |
| 2 | Wanneer de natuur- en techniekresultaten van leerlingen verbeteren, komt dit vaak door een verandering in de manier van lesgeven door de leerkracht | ○ | ○ | ○ | ○ | ○ |
| 3 | Als leerlingen goed presteren op het gebied van natuur- en techniek ligt dat zeer waarschijnlijk aan het aangeboden natuur- en techniekprogramma op de school | ○ | ○ | ○ | ○ | ○ |
| 4 | Onvoldoende achtergrondkennis van leerlingen op het gebied van natuur- en techniek kan overwonnen worden door natuur- en techniekonderwijs op een andere manier aan te bieden | ○ | ○ | ○ | ○ | ○ |
| 5 | Goede natuur- en techniekprestaties van leerlingen zijn over het algemeen te danken aan de kwaliteit van de leerkracht | ○ | ○ | ○ | ○ | ○ |

| | Stellingen | Volledig oneens | Oneens | Noch eens/ noch oneens | Eens | Helemaal eens |
|---|---|---|---|---|---|---|
| 6 | Wanneer een slecht presterend kind vooruitgang boekt bij natuur- en techniek, is het vaak het resultaat van extra aandacht door de leerkracht | ○ | ○ | ○ | ○ | ○ |
| 7 | De leerkracht is over het algemeen verantwoordelijk voor de resultaten van de kinderen voor natuur- en techniek | ○ | ○ | ○ | ○ | ○ |
| 8 | De prestaties van leerlingen voor natuur- en techniek zijn direct afhankelijk van de invulling van de natuur- en technieklessen van hun leerkracht | ○ | ○ | ○ | ○ | ○ |
| 9 | Als ouders aangeven dat hun kind meer interesse toont voor natuur- en techniek, komt dat waarschijnlijk door de kwaliteiten van de leerkracht op dit gebied | ○ | ○ | ○ | ○ | ○ |
| 10 | Goed natuur- en techniekonderwijs heeft weinig effect op de prestaties van leerlingen met een slechte motivatie | ○ | ○ | ○ | ○ | ○ |
| 11 | Leraren met veel kennis en vaardigheden op het gebied van natuur- en techniekonderwijs kunnen de meeste leerlingen helpen om natuur- en techniekonderwerpen te begrijpen | ○ | ○ | ○ | ○ | ○ |
| 12 | Natuur- en techniekonderwijs geef ik net zo goed als andere vakken | ○ | ○ | ○ | ○ | ○ |
| 13 | Ik weet hoe ik leerlingen concepten uit het natuur- en techniekdomein moet aanleren | ○ | ○ | ○ | ○ | ○ |
| 14 | Ik kan leerlingen zodanig begeleiden bij natuur- en techniekonderzoek, dat zij zelf antwoorden kunnen vinden op hun eigen vragen | ○ | ○ | ○ | ○ | ○ |

| Stellingen | | Volledig oneens | Oneens | Noch eens/ noch oneens | Eens | Helemaal eens |
|---|---|---|---|---|---|---|
| 15 | Over het algemeen ben ik tevreden over de manier waarop ik natuur- en techniekonderwijs geef | ○ | ○ | ○ | ○ | ○ |
| 16 | Ik begrijp zelf de natuur- en techniekinhouden goed genoeg om de kinderen deze inhouden op een effectieve manier te leren | ○ | ○ | ○ | ○ | ○ |
| 17 | Ik kan leerlingen uitleggen wat het onderliggende verschijnsel is bij een proefje | ○ | ○ | ○ | ○ | ○ |
| 18 | Ik ben over het algemeen in staat om natuur- en techniekvragen van kinderen te beantwoorden | ○ | ○ | ○ | ○ | ○ |
| 19 | Ik heb de benodigde vakdidactische vaardigheden om les te geven in natuur- en techniek | ○ | ○ | ○ | ○ | ○ |
| 20 | Als mijn directeur of een collega bij een les aanwezig is, dan vind ik het prima als dat een natuur- en techniek les is | ○ | ○ | ○ | ○ | ○ |
| 21 | Als een leerling moeite heeft met een natuur- en techniekconcept, dan weet ik hoe ik de leerling moet helpen om het beter te begrijpen | ○ | ○ | ○ | ○ | ○ |
| 22 | Als ik natuur- en techniek geef vind ik het fijn als leerlingen vragen stellen | ○ | ○ | ○ | ○ | ○ |
| 23 | Ik weet wat ik moet doen om leerlingen voor natuur- en techniek te motiveren | ○ | ○ | ○ | ○ | ○ |

Opmerkingen over je zelfvertrouwen bij het geven van techniek:

## Appendix 5: Questionnaire effective elements

**Naam:**

Deze vragenlijst gaat over het gehele traject. Met behulp van deze vragenlijst proberen we erachter te komen in welke mate de aspecten van het traject invloed hebben op de ontwikkeling van je **professionele ontwikkeling (= kennis, zelfvertrouwen, houding en leerstrategieën!!!!!)** bij het geven van wetenschap- en technieklessen. Er is geen goed of fout antwoord. Het is de bedoeling dat je eerst goed de bijbehorende tekst leest, alvorens de stellingen te beantwoorden.

***Ontwikkeling van toetsen en het analyseren van leerlingenwerk***

Tijdens de bijeenkomsten hebben we het onder andere gehad over hoe je leerlingenwerk kan gebruiken om te zien leerlingen de doelen hebben behaald. Leerlingenwerk kan inzicht geven in hoe leerlingen denken, waarop je jouw instructie kan aanpassen. Daarnaast heb je bij de invulling van je lessen steeds meer zelf moeten nadenken over hoe je toetsen opstelt. Hierbij was het belangrijk dat je door middel van de toetsen erachter komt of de leerlingen de doelen hebben behaald.

| | **Stelling** | **Volledig oneens** | **Oneens** | **Noch eens/ noch oneens** | **Eens** | **Helemaal eens** |
|---|---|---|---|---|---|---|
| 1 | Het ontwikkelen van toetsen om te kijken of leerlingen de doelen hebben behaald, heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap- en technieklessen | ○ | ○ | ○ | ○ | ○ |
| 2 | Het analyseren van leerlingenwerk om te zien of leerlingen de doelen hebben behaald, heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |

*Opmerkingen:*

***Observatie en reflectie***

Aspecten die steeds terugkwamen tijdens de bijeenkomsten waren het reflecteren en het observeren van voorbeelden. Het reflecteren bestond uit:
- Reflecteren op je eigen lessen
- Reflecteren op voorbeelden (zie voor toelichting de voorbeelden hieronder).

De voorbeelden bestonden uit:
- Voorbeelden van de invulling van verschillende fasen (oriëntatiefase, experimentfase, verdiepingsfase)
- Voorbeelden van experimenten die je kon gebruiken in je lessen
- Voorbeelden van lessen (beeldmateriaal)

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | Het reflecteren op mijn eigen lessen heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |
| 4 | Het reflecteren op voorbeelden heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |

| | Stelling | Volledig oneens | Oneens | Noch eens/ noch oneens | Eens | Helemaal eens |
|---|---|---|---|---|---|---|
| 5 | Het observeren van voorbeelden heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |
| 5a | Het observeren van voorbeelden van de invulling van de verschillende fasen heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |
| 5b | Het observeren van voorbeelden van experimenten heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |
| 5c | Het observeren van voorbeeldlessen heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |

*Opmerkingen:*

***Professionele dialoog, samenwerkend leren en elkaar ondersteunen***

Tijdens het traject hebben we regelmatig samen nagedacht over zaken. Zo hebben we steeds nagedacht over de concepten (drijven en zinken, lucht, hefbomen en constructie). Voorafgaand aan het geven van je lessen, zijn de concepten steeds kort besproken en hebben we experimenten gedaan. Na het geven van de les kreeg je steeds een vakinhoudelijk toetsje, welke besproken werd. Hiernaast hebben we de acht effectieve strategieën besproken en nagedacht over hoe deze toe te passen in je lessen (questioning strategy, enhanced context strategy, etc.).

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | Het samen nadenken over de vakconcepten heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |
| 6a | Het van tevoren (vóór de gegeven les) samen nadenken over de vakconcepten heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |
| 6b | Het bespreken van de vakinhoudelijke toetsen heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |
| 7 | Het samen nadenken over de effectieve strategieën bij wetenschap- en techniekonderwijs heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |

*Opmerkingen:*

***Het bepalen van de eigen focus***

Gedurende het traject kreeg je steeds meer vrijheid om de lessen zelf in te vullen.

| | Stelling | Volledig oneens | Oneens | Noch eens/ noch oneens | Eens | Helemaal eens |
|---|---|---|---|---|---|---|
| 8 | Het krijgen van steeds meer vrijheid bij de invulling van mijn wetenschap- en technieklessen heeft bijgedragen aan mijn professionele ontwikkeling bij het geven van wetenschap-en technieklessen | ○ | ○ | ○ | ○ | ○ |

*Opmerkingen:*