Testing Teacher Knowledge for Technology Teaching in Primary Schools

PROEFSCHRIFT

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“On the mountains of truth you can never climb in vain: either you will reach a point higher up today, or you will be training your powers so that you will be able to climb higher tomorrow”

(Friedrich Nietzsche)
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Chapter 1

General introduction

In this introductory chapter, the terms technology and technology education are considered and the relevance and purpose of technology education are explained. Moreover, a short outline of technology education for primary schools in the Netherlands is given. Next, the core constructs used in this thesis are defined and, subsequently, the problem statement, research aim, and research questions are formulated. In the end, an overview of the following chapters in this thesis is presented.
1.1 The technological society

Technology is strongly interwoven in today’s society. It is everywhere around us and some technological artifacts have become so familiar that you hardly recognise them as such. Think about the chair or couch you are sitting on, the pencil you use when writing, and the cloths you are wearing. In order to satisfy their needs and wants, people have developed and improved ways to communicate, travel, build, make products, cure disease, and provide food. Through technology, people have changed the world.

To be able to control the technological future, it is necessary that people understand the nature of technology, appropriately use technological devices and processes, and participate in society’s decisions and technological issues. People should not just have knowledge about, for instance, computers and their applications, but they should also have a certain degree of knowledge about the nature and consequences of technology in a broader perspective. In the words of the International Technology Education Association (ITEA), “the promise of the future lies not in technology alone, but in people’s ability to use, manage, and understand it” (ITEA, 1996, p. 3). Consequently, education needs to adapt to the growing importance of technology. New educational programmes should be aimed at making people more technologically literate. In particular, people should learn to think critically when designing and developing products, systems, and environments to solve practical problems (ITEA, 1996).

In a document of the Global Science Forum of the Organisation for Economic Co-operation and Development (OECD) on the evolution of students’ interest in science and technology, several major issues are reported. Firstly, in the last 15 years the numbers of science and technology students have been increasing in absolute terms, but decreasing in relative terms. With respect to a continuing transition to a more technology-intensive economy, this is a worrying trend. Secondly, women are strongly underrepresented in science and technology studies. Persistent stereotypes seem to weigh heavily on female students’ choices throughout their education. Governments are advised to actively promote equal opportunities and to take steps to eliminate negative stereotypes. Thirdly, study choices are mainly determined by the image of science and technology professions, the content of science and technology education, and the quality of teaching. In the OECD document, it is reasoned that pupils in primary schools still have a natural curiosity for science and technology, but primary school teachers often lack the ability and confidence to develop this curiosity with exciting
Science and technology lessons and hands-on activities. The Global Science Forum therefore concludes that primary school teachers should be better trained to teach science and technology (Wendelaar Bonga, 2006).

1.2 Technology education

Technology is a term that is often used and just as often misused. In everyday language, people sometimes speak of ‘technology’ when they actually mean ‘technique’ or of ‘technological’ when they mean ‘technical’. Similarly, the terms ‘technologists’ and ‘technicians’ are easily confused. Because of these common misunderstandings and the wide use of technology and related terms, it is necessary to consider what is meant by technology and technology education in the scope of this thesis. According to the Oxford Dictionary of English (2nd revised edition) ‘technology’ has a threefold meaning.

1. The application of scientific knowledge for practical purposes, especially in industry;

2. Machinery and equipment developed from scientific knowledge;

3. The branch of knowledge dealing with engineering or applied sciences.

In the first meaning, technology is described as applied science (technology uses science). In the second meaning, technology is described as a collection of instruments (making use of technology), whereas the third meaning refers to technology as a framework of knowledge (technology as a scientific discipline). Although these descriptions help to clarify what is meant by technology in general, they are of little help to explain what is meant by technology in the context of technology education and, in turn, in this thesis. For that purpose, it is more useful to consider a definition formulated by the ITEA and acknowledged by the authoritative National Academy of Engineering (NAE) in the USA. According to the ITEA, technology is “human innovation in action that involves the generation of knowledge and processes to develop systems that solve problems and extend human capabilities” (ITEA, 1996, p. 16). In this way, technology is described rather comprehensively and is basically seen as the process of creating and using knowledge to solve problems.

Attempting to answer questions as ‘what is technology?’ and ‘what is technological knowledge?’ is one of the main tasks of philosophers of tech-
nology. Among other things, they try to find out what general characteristics determine if something can be called technology. These questions are not as easy to answer as they might seem. The philosopher Carl Mitcham identified four ways to conceptualise technology, i.e., as objects (technical artifacts), as knowledge, as activities (processes), and as an aspect of human volition (will) (Mitcham, 1994). Although promising attempts, for instance by Carl Mitcham, have been made, philosophers of technology are still struggling with the question of what technology is and it might take some time before this question can be properly answered, if the question can be answered at all. Hence, for the time being, we need to content ourselves with the definition by ITEA mentioned above.

Science, referring to the natural sciences (physics, chemistry, biology, and earth sciences), is often confused with technology. This is not surprising, because the fields of science and technology are strongly related. In general, science can be described as “the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment” (The Concise Oxford English Dictionary, 12th edition). Technology is clearly distinct from science. While science aims at developing new knowledge about the natural world, technology aims at changing the world according to human needs (De Vries, 2005). Technology often uses science when designing artifacts to solve practical problems or to explain the working of technological artifacts. Nonetheless, technology is more than just applying science. Technology has its own body of knowledge, it creates and uses knowledge that belongs specifically to the context of technology. Moreover, technology has its own rules and agreements, e.g., the fixed size of A4 paper. In short, technology and science represent uniquely different, though mutual supportive, bodies of knowledge. Technology education should therefore be more than just teaching science in a technological setting.

Technology education is interpreted in different ways in various countries. Some countries mainly focus on industrial arts and crafts, e.g., the Scandinavian countries, while others put a stronger emphasis on the design process, e.g., the UK. De Vries (1994) characterised eight different conceptual approaches of technology education: (1) the craft-oriented approach, (2) the industrial production-oriented approach, (3) the high-tech approach, (4) the applied science approach, (5) the general technology concepts approach, (6) the design approach, (7) the key competence approach, and (8) the science-technology-society (STS) approach. However, these
conceptual approaches are hardly ever carried out in their pure forms, but mostly as a mixture in which several elements can be recognised. Common to most of these approaches is the aspect of problem solving. According to McCormick (2004), problem solving is the most important form of procedural knowledge (i.e., ‘know-how’) that is used in technology and should therefore have a strong position in technology education. Other forms of procedural knowledge that are closely related to technology are designing, planning, analysing systems, optimising, modelling, and strategic thinking.

Despite the large variations in approaching technology education, some universal features of good technology education can be identified. First of all, technology education should provide knowledge about basic technological concepts and processes and should develop pupils’ technical skills. In other words, technology education should make pupils ‘technologically literate’, i.e., being able to understand and evaluate technology (ITEA, 1996). This educational goal is preferably achieved by means of problem solving, exploring, designing, making, analysing, and innovating. Besides, technology education should always connect hands and mind (doing and knowing), which implies that technology lessons should involve activities that make pupils design and make (use their hands) as well as think and understand (use their minds) (Raizen, 1997; McCormick, 2004).

As described by Slangen (2005), the need for technology education in primary schools (‘primary technology education’) is based on four reasons. Firstly, today’s children grow up in a world full of technology. It is of great importance that education offers them the opportunity to develop technological literacy, i.e., the ability to use, manage, assess, and understand technology, and provide them with a broad and realistic view of technology in order to ‘survive’ in today’s technological society. Secondly, children are naturally interested in how and why stuff works. It is a task of education to keep this curiosity alive and motivate them to deepen and broaden their knowledge. Thirdly, technology education is highly suitable to create a rich and attractive learning environment. And finally, a negative attitude towards technology as a study or career, which many students between 12 and 18 years old have, is expected to change in a positive direction when starting to teach technology already in primary schools.
1.3 Primary technology education in the Netherlands

In the Netherlands, technology education does not have a long history. In 1973, a subject called ‘general techniques’, with a strongly craft-orientated approach, was introduced in (secondary) vocational schools. In the late 1980s, technology education slowly started to be embedded in the curriculum of (secondary) general schools. Teachers often adopted the craft-orientated approach from vocational education (De Vries, 1994). At that time, technology education was barely taught in primary schools and, if it was taught, it was often integrated with arts and craft and focused on working with tools and materials.

Science education, as a compilation of physics, biology, and chemistry, was introduced in primary education around 1991, when an influential report on primary science education was published (Kamer-Peeters, 1991). Up to this time, a subject called ‘knowledge of nature’, which was primarily based on biology, was taught in the primary school classrooms. However, the subject received little attention and was often seen as an engaging relaxation on Friday afternoons. In educational practice at primary schools today, science education (usually called ‘nature education’) is still mainly concerned with biological topics and is still a minor subject in the curriculum.

In 1996, the government decided to revise the national standards of primary education, which had a major impact on the position of technology education. Technology education became theoretically part of a broad learning domain ‘human and world orientation’ in order to stimulate the integration with other subjects in that domain, e.g., history, geography, and science (Bouwmeester et al., 2001). In daily practice however, many of these subjects, including technology education, were taught in a non-integrative way.

In 2005, the national inspectorate of education investigated the quality of technology education in primary schools. The results showed that 73% of the schools offered technology education no more than incidentally, and only 12% of the examined schools taught technology regularly. The main obstacle was found to be the overloaded curriculum. Other problems mentioned were the absence of good materials and the high costs of purchasing them. About 50% of the schools mentioned insufficient expertise of the teachers as a restraint to offer more technology education. The content of technology activities was aimed at making a product, listening
to a technician or engineer, and using the internet. Technology activities were mostly hands-on and less mind-on. That is, they involved more making (unfortunately often imitating) than designing and analysing. One of the main conclusions of the report was that primary school teachers interpreted technology education in many diverse ways (Inspectorate of Education, 2005).

In 2006, the Dutch government shifted from stimulating the integration of technology education as a single subject into the curriculum, towards stimulating the integration of science and technology as a combined subject. According to the latest document of national standards for primary education (Greven and Letschert, 2006), science and technology education belongs to the learning domain, ‘personal and world orientation’ (notice a small change in name compared to 1996). In this learning domain, pupils orientate on themselves, on how people interact, on how people solve problems, on how people give a meaning to their existence, and on the natural environment and its phenomena. The national standards for science and technology education are described as follows.

1. Pupils learn to distinguish and name most common plants and animals in their own environment and learn how they function in their habitats.

2. Pupils learn about the makeup of plants, animals, and humans and about the structure and function of their parts.

3. Pupils learn to investigate materials and physical phenomena, including light, sound, electricity, force, magnetism, and temperature.

4. Pupils learn to describe the weather and climate in terms of temperature, precipitation, and wind.

5. Pupils learn to find connections between the functioning, design, and use of materials of products in their own environment.

6. Pupils learn to design, realise, and evaluate solutions for technical problems.

7. Pupils learn that the position of the earth in relation to the sun causes our seasons and the day and night cycle.

The 5th and 6th standard clearly relate to technology education, while the other five standards relate to science education (1 and 2: biology, 3: physics, 4: meteorology, 7: astronomy). It is commonly known that there
is often a gap between the standards of the government and the effectuated curriculum in schools. Because these standards are formulated in a highly general way, it is often the teachers, but most often the textbook editors, who actually decide what is taught in the primary school classrooms. Until recently, science textbooks did not pay much attention to technology education, which counteracted the intended integration of science and technology education. Nowadays, if technology education is taught at all, it is often still taught as a separate subject. Since the new standard of 2006, textbooks and educational materials that put more emphasise on technology education gradually appear in schools.

Inquiry-based and problem-based learning are generally accepted to be the most appropriate pedagogical approaches for science and technology education (Boersma et al., 2005). Both approaches are constructivist teaching methods, which are based on the constructivist learning theory. According to this theory, understanding is distributed in the learner’s environment, cognitive conflict (‘puzzlement’) is the stimulus for learning, and knowledge evolves through social interaction and through evaluation of the viability of individual knowledge. These constructivist principles imply certain pedagogical-didactic guidelines. In short, the starting point for learning should be an authentic problem, the learner should feel ownership of the problem and the problem-solving process, the learner’s thinking should be challenged, and reflection should be supported (Savery and Duffy, 2001). For inquiry-based learning, it also implies that the steps of the empirical cycle (i.e., observation, induction, deduction, testing, and evaluation) should be followed. Hence, constructivist teaching methods suggest that learning is more effective when the learner is actively engaged in the construction of knowledge rather than passively receiving it. Science and technology activities are by nature suitable for active learning or learning by doing.

Since the beginning of this century, several projects to promote technology education were initiated. The Dutch government acknowledged that science and technology education received too little attention in the last 10 to 15 years. The ‘Platform Bèta Techniek’ has been commissioned to ensure sufficient availability of people with a scientific or technical background in the nearby future. The general aim of this project is not just to make careers in science and technology more appealing, but also to introduce educational innovations that inspire and challenge young people (Platform Bèta Techniek, 2005). The government has specifically expressed the ambition to give science and technology education a structural place in
the curriculum of primary schools, which is translated into a national programme called ‘Verbreding Techniek Basisonderwijs’ (VTB), which literally means ‘broadening of primary technology education’ (VTB, 2004).

The VTB-programme is not only aimed at primary schools, but on teacher training colleges for primary education as well. The teacher training colleges play a key role in a broad and structural implementation of technology education in primary schools. In addition to educating preservice teachers for technology teaching, they serve as expertise centres for in-service teachers, for instance by offering refresher courses in technology education. An investigation on the position of technology education in teacher training colleges showed that all teacher training colleges in the Netherlands prefer an integrative approach of the implementation of technology education. Their general vision on technology education is mainly about integrating the subject in the curriculum and using it as a pedagogical-didactic tool to facilitate other, more hands-on, learning styles. About 75% of the colleges offer technology education, though only in 25% of the colleges technology education can be depicted as broadly embedded in the curriculum. More than half of the colleges support primary schools by lending out materials, offering refresher courses, and organising workshops or demonstrations (Vermaas et al., 2006).

Although new standards for science and technology education in primary schools have been developed and governmental programmes have been started, science and technology education has not yet an established position in the curriculum of most primary schools and teacher training colleges. Nowadays, teachers express to be confused about the content and learning activities that belong to the domain of science and technology education. Consequently, some important goals of both science and technology education may be disregarded. Clearly, primary school teachers need to be trained in order to improve their knowledge of science and technology and, subsequently, improve the quality of science and technology education.

1.4 Definitions of core constructs

1.4.1 Teacher knowledge

In the late 1980s, the American educationalist Lee Shulman advocated a paradigm shift in educational research by making an argument for the existence of a specialised knowledge base of teaching. He stated that “teaching necessarily begins with a teacher’s understanding of what is to be learned
and how it is to be taught” (Shulman, 1987, p. 7). By shifting the focus of educational effectiveness to the knowledge base of teaching, Shulman wanted to stimulate the professionalisation of teachers as well as research on the knowledge base of teaching. Since that time, the issue was prioritised on the research agenda and the numbers of studies addressing this issue grew exponentially.

Gradually, research on the general knowledge base of teaching changed to research on context-dependent and individual knowledge of teaching, i.e., a teacher’s knowledge and beliefs. Whereas the knowledge base of teaching is “all profession-related insights that are potentially relevant to the teacher’s activities” (p. 443), teacher knowledge can be defined as “the whole of knowledge and insights that underlies teachers’ actions in practice” (Verloop et al., 2001, p. 446). In other words, teacher knowledge guides a teacher’s behaviour in the classroom. It is a teacher’s own personal knowledge base that is acquired through teaching experiences in practice. However, certain elements of teacher knowledge are shared by a larger group of teachers. Consequently, these common elements contribute to the general knowledge base of teaching. Various other terms have been used to describe the concept of teacher knowledge, e.g., ‘personal knowledge’ (Elbaz, 1991), ‘craft knowledge’ (Grimmett and MacKinnon, 1992), and ‘practical knowledge’ (Van Driel et al., 2001).

One of the most cited structural views of the domains of teacher knowledge is presented by Grossman (1990), who designed a model of teacher knowledge with four components: (1) subject matter knowledge (SMK), (2) general pedagogical knowledge, (3) knowledge of context, and (4) pedagogical content knowledge (PCK). In this model, PCK is presented as the central domain, which reciprocally interacts with the other domains. Opposed to this so-called transformative model, in which PCK is a transformation of different knowledge domains into a new domain (‘a compound’), the integrative models do not present PCK as a knowledge domain on its own. In these models teaching is seen as an act of integrating knowledge of the subject, pedagogy, and context (‘a mixture’) (Gess-Newsome and Lederman, 1999). Despite of the strong simplification of reality (the models do certainly not represent cognitive structures), these structural models are useful when investigating teacher knowledge.

The studies presented in this thesis focus on technology-specific teacher knowledge. Based on the above mentioned transformative model by Grossman (1990) and the description of teacher knowledge by Verloop et al. (2001), three components of teacher knowledge domains that are specific
for technology education are investigated: (A) SMK, (B) PCK, and (C) attitude and self-efficacy. In this categorisation, knowledge domains A and B represent the ‘cognitive’ domain and domain C can be depicted as the ‘affective’ domain of teacher knowledge. Although it might be seen as inconsistent to classify attitude and self-efficacy as a knowledge domain, it is thought to be legitimate because in a teacher’s mind cognitions and affects are inextricably bound up with each other (Pajares, 1992; Verloop et al., 2001). In the following sections, the teacher knowledge domains are further explained and defined in the context of this thesis.

1.4.2 Subject matter knowledge

SMK, also called ‘content knowledge’, is knowledge about the subject area that is taught. This knowledge domain contains conceptual and procedural knowledge, on the one hand, and understanding of the nature and structure of the subject, on the other (Grossman, 1990). Conceptual knowledge is knowledge of facts, principles, and theories. Regarding technology education, this includes knowledge about technological concepts, e.g., energy and power, constructions, transportation, ICT, and electronics. Procedural knowledge of technology is mainly concerned with knowledge to solve technological design problems (Garmire and Pearson, 2006), but also includes determining and controlling, utilising, and assessing impacts of technology (ITEA, 2006).

Understanding the nature of the subject has to do with teachers’ perception of technology and includes, for instance, understanding the differences between science and technology. Knowledge of the structure, i.e., knowledge about the hierarchy of ‘big ideas’ (i.e., key concepts and theories) and knowledge about the rules or methods that prescribe how to make and evaluate claims in the field of technology, belong to this aspect of SMK as well. Without knowledge of the structure of the discipline, teachers may misinterpret the nature of the discipline (Grossman, 1990).

1.4.3 Pedagogical content knowledge

Teachers cannot solely rely on their SMK, but need knowledge about how the subject matter can be taught effectively as well. In other words, they should be able to combine subject matter knowledge and pedagogical knowledge in an appropriate manner. Shulman introduced the term ‘pedagogical content knowledge’ and defined this kind of knowledge as “a special amalgam of content and pedagogy that is uniquely the province of
teachers, their own special form of professional understanding” (Shulman, 1987, p. 8). Although PCK is closely related to the Dutch term ‘vakdidaktiek’ and the German ‘Fachdidaktik’, they are not fully identical. While PCK is individual teacher knowledge, Fachdidaktik is a specific research domain where educational science and school subjects, such as science and technology, meet. Hence, teachers’ PCK can be seen as field of research within Fachdidaktik (Van Dijk and Kattmann, 2007).

PCK is conceptualised in many different ways by various researchers. However, most researchers agree on two essential components: (1) understanding of pupils’ specific learning difficulties, and (2) knowledge of representations of the subject matter to overcome these difficulties. Moreover, most researchers assume SMK to be a prerequisite for the development of PCK (Van Driel et al., 1998). In this thesis, the ‘transformative’ view on PCK (see section 1.4.1) is supported, which implies that PCK is seen as a transformation of SMK, pedagogical knowledge, and possibly other knowledge domains, and that PCK can be investigated as distinctive domain of teacher knowledge.

In order to define PCK in the context of this thesis, three knowledge components of PCK in technology education for primary schools were formulated as a result of a literature review (reported in chapter 2): (1) knowledge of pupils’ concept of technology and their pre- and misconceptions related to technology, (2) knowledge of the nature and purpose of technology education, and (3) knowledge of pedagogical approaches and teaching strategies for technology education. As part of the construction of a test to measure PCK (reported in chapter 3), PCK was explored and elaborated in cooperation with a team of experts in the field of primary technology education. Without any notice of the literature-based definition, the experts came up with approximately the same components of PCK, which validated the choice for these three components. For each of the three basic components of PCK several subelements were described. In Table 1.1 the result of this so-called ‘construct analysis’ is shown.

1.4.4 Attitude and self-efficacy

In this thesis, teachers’ attitude towards technology is investigated as one of the affective components of teacher knowledge. An attitude can be generally described as representing “a summary evaluation of a psychological object captured in such attribute dimensions as good-bad, harmful-beneficial, pleasant-unpleasant, and likable-dislikable” (Ajzen, 2001, p. 28). According to the expectancy-value model (Fishbein, 1993), one’s attitude
Table 1.1: Construct analysis of PCK for primary school technology education.

<table>
<thead>
<tr>
<th>Component</th>
<th>Subelement</th>
</tr>
</thead>
</table>
| 1\(^a\)   | a) Know how to link the content to pupils’ prior knowledge and experiences.  
|           | b) Know how to capture and increase pupils’ involvement and curiosity.  
|           | c) Know about pupils’ cognitive development and how to account for this in technology education.  
|           | d) Know which (mis)conceptions pupils often have and how to account for this in technology education.  
|           | e) Know that gender issues, learning styles, interests, cultural differences, and pupils’ competencies play a role in learning.  
|           | f) Know how to influence pupils’ behaviour, motivation, and cognition.  
|           | g) Know how to react strategically on pupils’ cognitive development.  
| 2\(^b\)   | a) Know how to translate the nature and purposes of technology education in learning activities.  
|           | b) Know how to formulate tasks that meet the learning goal(s) and stimulate pupils’ problem solving and inquiry skills.  
|           | c) Know how to evaluate the process and results of a technological learning activity profoundly.  
|           | d) Know about the effects of different role models of teachers on pupils’ attitudes towards technology.  
|           | e) Know about the differences between science and technology and how to integrate these domains.  
| 3\(^c\)   | a) Know which learning materials are available and how to adapt and use these appropriately.  
|           | b) Know how to create and use a rich learning environment in terms of functionality and comfort.  
|           | c) Know which questions are most effective to enhance learning.  
|           | d) Know how to have a dialogue with pupils and to use suitable terminology.  
|           | e) Know how to apply classroom incidents or current events in technology education.  
|           | f) Know which teaching strategies are available and how to use them in an appropriate way.  
|           | g) Know how to deal with the technological design cycle and the approaches of problem- and inquiry-based learning.  
|           | h) Know how to handle pedagogically in a way that stimulates pupils learning process and personal development.  

\(^{a}\) Knowledge of pupils’ concept of technology and their pre- and misconceptions related to technology.  
\(^{b}\) Knowledge of the nature and purpose of technology education.  
\(^{c}\) Knowledge of pedagogical approaches and teaching strategies for technology education.
towards an object is determined by subjective values related to the object and by the strength of associations between the object and its subjective values.

Attitudes are influenced by cognition (beliefs) as well as affect (feelings) (Eagly and Chaiken, 1993). The predominance of either cognition or affect depends on personality traits (‘thinkers’ and ‘feelers’) and the object itself. The theory of planned behaviour (Ajzen, 1991) states that people act in accordance with their intentions and perceptions of control over the behaviour, while intentions are influenced by attitudes towards the behaviour, subjective norms, and perceptions of behavioural control. The extent to which attitudes contribute to behaviour varies. Strong attitudes are better predictors of behavioural intentions and perceptions of behavioural control and, subsequently, of actual behaviour (Ajzen, 2001). In line with this theory, it is reasoned that teachers’ attitude towards technology is reflected in teachers’ behaviour and could be passed on to their pupils.

Another important determinant of intentions and actions is the perceived difficulty of performing certain behaviour, i.e., ‘self-efficacy’. Together with teachers’ attitude, it forms the affective domain of teacher knowledge as investigated in this thesis. Self-efficacy is defined as “beliefs in one’s capabilities to organise and execute the courses of action required to produce given attainments” (Bandura, 1997, p. 3).

Teachers have been shown to spend less time on subject areas of which their perceived self-efficacy is low (Enochs and Riggs, 1990). In addition, high self-efficacy is related to high student achievement (Ashton and Webb, 1986) and desirable teaching behaviour (Bandura, 1997). Teachers’ beliefs about their ability to enact effective teaching methods for specific teaching goals, i.e., their self-efficacy or confidence in teaching, is thought to be an affective affiliate of PCK (Park and Oliver, 2008; Appleton, 2008). Thus, high self-efficacy beliefs in technology teaching are expected to positively affect the quantity and quality of technology education. The terms ‘self-efficacy’ and ‘confidence in teaching’ are used interchangeably in this thesis.

1.5 Problem statement and research questions

The Netherlands needs more technical workers and engineers with regard to the intended transition towards a knowledge-based economy. However, only a small number of students seems interested in a study or career in the field of science and technology (Wendelaar Bonga, 2006). In order to
Problem statement and research questions

improve students’ interest in this field of study, the Ministry of Education started a governmental programme to stimulate science and technology education on all educational levels, including primary schools. Nonetheless, on most primary schools, science and technology education is not yet structurally implemented in the curriculum. Insufficient teacher knowledge of science and technology is probably one of the causes of the lack of structurally implemented science and technology education (Inspectorate of Education, 2005). Therefore, it would be useful for primary school teacher training colleges to know what domain teacher knowledge to train specifically in order to educate pre-service and in-service teachers for science and technology teaching effectively.

The cognitive and affective domains of teacher knowledge are assumed to be important determinants of high quality technology education. In the context of this thesis, the quality of technology education is measured through pupils’ concept of and attitude towards technology. It is assumed that teachers themselves need to have sufficient SMK (Parkinson, 2001; De Vries, 2000) and PCK (Jones and Moreland, 2004; Fox-Turnbull, 2006) of technology, and a positive attitude towards technology and high self-efficacy in teaching technology (Johnston and Ahtee, 2006; Davies, 2000) in order to stimulate their pupils’ development of a realistic and comprehensive concept of technology and a positive attitude towards technology. Subsequently, more pupils with better concepts and more positive attitudes could lead to a larger number of students choosing technical studies and careers.

The general research aim of this thesis is to investigate primary school teachers’ knowledge of technology and technology education. Moreover, the impact of teacher knowledge of technology and technology education on pupils’ concept of and attitude towards technology is investigated. For the reason that teachers’ PCK is considered to be a central and vital domain of teacher knowledge by many researchers (e.g., Grossman, 1990; Jones and Moreland, 2004; Magnusson et al., 1999; Shulman, 1987; Van Driel et al., 1998), one of the main issues in this thesis is teachers’ PCK of technology education. Currently used methods to measure PCK are most often qualitative by nature and, consequently, time and labour intensive (e.g., De Jong et al., 2005; Jones and Moreland, 2004; Mulholland and Wallace, 2005; Van Driel et al., 1998). Because it is aimed to collect data on a large scale and, hence, make use of quantitative methods, a significant part of this thesis concerns the construction and validation of a multiple choice test to measure primary school teachers’ PCK of technology education. The
The research questions addressed in this thesis are as follows.

1. What teacher knowledge of technology do primary school teachers have and how are the different domains of teacher knowledge inter-related?

2. To what extent is teacher knowledge of technology related to pupils’ concept of and attitude towards technology?

3. How to construct and validate a multiple choice test to measure primary school teachers’ PCK of technology education?

4. What latent factor structure underlies primary school teachers’ PCK of technology education?

1.6 Overview of this thesis

The research project presented in this thesis consisted of four parts. The first part concerned a literature review in which the relations between the teacher knowledge domains and the relations between teacher knowledge
and pupils’ concept and attitude were theoretically explored. Because quantitative methods to examine primary school teachers’ PCK of technology education were unavailable, the second part included the construction of a multiple choice test. The third part was formed by the pilot study, in which a set of instruments was tested and the self-constructed PCK test was validated on a small scale. The fourth part concerned the main study, which served to validate the PCK test on a large scale, to analyse the latent factor structure of PCK, and to investigate the relations between the teacher knowledge domains and the effects of teacher knowledge on pupils’ concept and attitude empirically.

In chapter 2, which is entitled “Reviewing the relations between teachers’ knowledge and pupils’ attitude in the field of primary technology education”, research questions 1 and 2 are addressed by means of a review of relevant literature. In chapter 3, “Measuring teachers’ pedagogical content knowledge in primary technology education”, research question 3 is addressed with a focus on the construction of the PCK test. In chapter 4, “Conceptualising pedagogical content knowledge by analysing the latent factor structure of a multiple choice test”, research questions 3 and 4 are addressed. In this chapter, a large scale validation of the PCK test is reported. In chapter 5, “Analysing teacher knowledge of technology education and its effects on pupils’ concept and attitude”, research questions 1 and 2 are addressed in an empirical way. Chapters 2 to 5 are all published or submitted research articles. Finally, in chapter 6, general conclusions of the thesis are drawn and the overall findings are discussed. Figure 1.1 schematically illustrates how the four parts of the research project are related to the time span and the chapters in this thesis.

Bibliography


Chapter 2

Reviewing the relations between teachers’ knowledge and pupils’ attitude in the field of primary technology education*

abstract

This literature review reports on the assumed relations between primary school teachers’ knowledge of technology and pupils’ attitude towards technology. In order to find relevant aspects of technology-specific teacher knowledge, scientific literature in the field of primary technology education was searched. It is found that teacher knowledge is essential for stimulating a positive attitude towards technology in pupils. Particularly, teachers’ enhanced pedagogical content knowledge is found to be related to pupils’ increased learning and interest in technology. Six aspects of technology-specific teacher knowledge that are likely to play a role in affecting pupils’ attitude are identified and schematically presented in a hypothetical diagram. It is concluded that more empirical evidence on the influence of technology-specific teacher knowledge on pupils’ attitude is needed. The hypothetical diagram will serve as a helpful tool to investigate the assumed relations between teacher knowledge and pupils’ attitude empirically.

2.1 Introduction

When people lived as hunters and gatherers, they needed to know about and understand their natural environment in order to survive. In modern times, we need to know about and understand our technological environment. The technological world is developing fast and technology takes a constantly growing place in today’s society. Consequently, education needs to adapt to this increasing importance of technology, and educational programmes should be aimed at developing pupils’ technological literacy. As the International Technology Education Association (ITEA) propagates, all pupils should learn to think critically about how to design, develop, and implement products, systems, and environments to solve practical problems (ITEA, 2006). Technology education should develop an understanding of the nature of technology, the relationship between technology and society, and technological design. Through technology education, pupils will understand the most important areas of the ‘designed world’, i.e., medical, agricultural, energy and power, information and communication, transportation, manufacturing, and construction technologies. In short, technology education ought to make pupils technological literate in a broad sense (ITEA, 2007).

A document of the Organisation for Economic Co-operation and Development (OECD) about the evolution of pupils’ interest in science and technology studies, reports that in the last 15 years the numbers of science and technology students have been decreasing in relative terms. This trend is worrying with respect to the continuing transition to a more technology-intensive economy. In contrast, pupils in primary schools generally show a natural curiosity for science and technology. It is argued that most primary teachers apparently lack the ability and confidence to develop and stimulate this natural curiosity for technology (Wendelaar Bonga, 2006).

Regarding a growing need for engineers and technologists, it is important to know if stimulating 10 to 12-year-old pupils’ attitude towards technology affect their study and career choices later on in life. As far back as in 1927, a prominent study showed that vocational interest is an enduring characteristic of an individual that is easily observed and can be used to predict a person’s choices and behaviour (Boekaerts and Boscolo, 2002). This finding implies that attitude, which usually comprises vocational interest, is a good predictor for study and career choices later in life. It seems likely that the earlier attitude towards technology is positively stimulated, the more persistent and predictive it will be, although strong empirical evidence is still lacking.
In studies on pupils’ attitude towards technology, it is found that pupils’ positive attitude is often related with a correct and comprehensive concept of technology. With emphasis on only few specific aspects of technology, there is considerable risk that pupils develop a limited concept of technology. Hence, it is important that teachers have a correct and comprehensive concept of technology in order to be able to shape their pupils’ attitude (De Vries, 2000).

In their book ‘How people learn’, Bransford et al. (2004) concluded “Outstanding teaching requires teachers to have a deep understanding of the subject matter and its structure, as well as an equally thorough understanding of the kinds of teaching activities that help students understand the subject matter in order to be capable of asking probing questions” (p. 188).

This quote implies that not only a correct and comprehensive concept of technology, but subject-specific teacher knowledge in general is important for successful technology education. Primary school teachers, who are educated to teach a wide variety of subjects, will therefore need a thorough understanding of the subject matter of technology to know which topics to address and how to address them in their technology lessons. Until now, little scientific research on the role of teacher knowledge in the field of primary technology education has been done.

In this literature review the relations between primary school teachers’ knowledge of technology and technology education, on the one hand, and pupils’ attitude towards technology, on the other, are theoretically explored. The central aim is to elucidate how technology-specific teacher knowledge affects pupils’ attitude towards technology. Insights into this relationship will help teacher educators to train primary school teachers in the field of technology education.

First, a hypothetical diagram of six aspects of technology-specific teacher knowledge, their interrelationships, and their relations with pupils’ attitude, is presented. Next, these six aspects of teacher knowledge and their relations are described in more detail. Then, the relation between pupils’ concept and attitude is clarified. In the concluding section, the findings are summarised and critically discussed.

2.2 Technology-specific teacher knowledge

Teacher knowledge is an umbrella term that covers a large variety of cognitions, beliefs, skills, and knowledge domains. Various labels have been used
by researchers underlining the different appearances of teacher knowledge (e.g., ‘wisdom of practice’, ‘professional craft knowledge’, ‘action oriented knowledge’). According to Verloop et al. (Verloop et al., 2001), teacher knowledge comprises the whole of knowledge and insights that underlies teachers’ actions in practice, including tacit knowledge.

It is said that a teacher should be able to combine subject matter knowledge and pedagogical knowledge for effective coaching of pupils’ learning processes. This implies that a teacher should know about particular subject-related difficulties and should know how to handle these difficulties, for example, by explaining the same subject matter in different ways (Verloop et al., 2001). This specific domain of teacher knowledge is called ‘pedagogical content knowledge’ (PCK) and was first examined by the American educationalist Lee Shulman. He defined it as “a special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding” (Shulman, 1987, p. 8).

In order to find relevant aspects of teacher knowledge regarding technology education, recent scientific literature in the field of primary technology education was searched thoroughly. Articles that mentioned specific aspects of teacher knowledge or pupils’ attitude towards technology were included in the review. When literature on primary technology education on certain topics was not available, literature on secondary technology education was included instead. When necessary, literature on primary science education was used as well.

Based on the reviewed literature, six technology-specific knowledge aspects, which can be categorised into three domains, (A) subject matter knowledge (SMK), (B) pedagogical content knowledge (PCK), and (C) Attitude, are defined. In the domain of SMK the aspects (1) general SMK (Parkinson, 2001; Davis et al., 2002), and (2) concept of technology (Jarvis and Rennie, 1996a; Cunningham et al., 2006; De Vries, 2000) are classified. The domain of PCK consists of the aspects (3) knowledge of pupils’ concept of technology, and knowledge of pupils’ pre- and misconceptions related to technology (Davis et al., 2002; Jarvis and Rennie, 1996b), (4) knowledge of pedagogical approaches and teaching strategies for technology education (Boser et al., 1998), and (5) knowledge about the nature and purpose of technology education (Jones and Moreland, 2004). The third domain and sixth aspect is (6) attitude towards technology and confidence in teaching technology (Johnston and Ahtee, 2006). These six aspects of technology-specific teacher knowledge are schematically presented in a hypothetical diagram (Figure 2.1). This diagram structurally outlines hypothetical re-
In the following sections, the teacher knowledge domains (A, B, and C), their assumed interrelationships (a, b, and c) and their hypothetical relations with pupils’ concept of and attitude towards technology (e, f, g, and h) are discussed.

### 2.2.1 Subject matter knowledge

In this subsection, the domain of SMK (A) and the hypothetical relation between SMK and pupils’ concept (d) are discussed (see Figure 2.1). The categorisation of SMK in two aspects, general SMK of technology and concept of technology, is based on Grossman’s model of teacher knowledge. In this model, SMK includes understanding the content of a subject area, as well as knowledge of the substantive and syntactic structures of the discipline. Grossman states that without knowledge of the structures of a discipline, teachers may misrepresent both the content and the nature of the discipline itself (Grossman, 1990).

With respect to understanding the subject matter, Parkinson (2001) recommended that pre-service primary school teachers should clarify and reconstruct their own misconceptions related to technology. He argued that the more active pre-service teachers are in constructing their own knowledge, the more able they will be to enhance their pupils’ learning. Additionally, the more teacher’s SMK is shaped in a scientifically and technologically correct way, the less likely it is that teachers will encourage
pupils’ development of inappropriate conceptions (Parkinson, 2001). In line with this statement, Davis et al. (2002) advocates that all pre-service and in-service primary school teachers should be better informed about the key areas of technology.

In order to define the key areas of technology, the ITEA (2006) listed ten fundamental concepts (‘universals of technology’). The universals are categorised into three groups: (A) Knowledge, (B) Processes, and (C) Contexts. Group A is comprised of the concepts (1) nature and evolution of technology, (2) linkages, and (3) technological concepts and principles. Group B contains (4) designing and developing, (5) determining and controlling, (6) utilising, and (7) assessing impacts and consequences. To group C belong (8) biological and chemical systems, (9) informational systems, and (10) physical systems (ITEA, 2006). From these universals more detailed content elements for the study of technology were developed and thoroughly described in the Standards for Technological Literacy (STL) document (ITEA, 2007).

Besides understanding the subject matter, which could be tagged as ‘conceptual knowledge’, two other knowledge aspects are reported to be important in technology education, i.e., metacognitive strategies and procedural knowledge. Meta-cognitive strategies, which include scaffolded inquiry, reflection, and generalisation, are supposed to be important in the development of technological literacy and specifically important in problem solving activities. Procedural knowledge is related to the design component of technology education, and is necessary to successfully solve a design problem (Garmire and Pearson, 2006).

The second aspect of SMK is teachers’ concept of technology, i.e., their perception of the subject. Interviews from an English study (Jarvis and Rennie, 1996a) on primary school teachers’ perceptions about technology indicated that teachers have a wide range of ideas about technology. These perceptions differ from very narrow views (‘technology is applied science’) to more sophisticated ones (‘technology is designing and making artifacts that fulfil a need’). The researchers found that even teachers in the same school had different perceptions and that a lot of teachers thought of technology exclusively in the school context, usually referring to model-making. A teacher’s narrow perception may inhibit pupils’ understanding of technology and may lead to pupils considering technology as irrelevant to adult (‘real’) life. Another finding was that some of the teachers, who used science to explain technology, appeared to be confused about the general concepts of science and technology. It was concluded that teachers not
only need to explore their concept of technology, but that the differences and similarities between technology and science need to be clarified too (Jarvis and Rennie, 1996a).

In line with the study above, Cunningham et al. (2006) explored primary school teacher’s basic concept of technology in the USA. She found that teachers’ sense of what counts as technology is often non-scientific and grows from common usage in conversation and writing. According to the researcher, this is partly caused by the vague definitions presented by the government to the teachers. Without more specific definitions it is very difficult to determine what is technology and what is not (Cunningham et al., 2006). As mentioned before, if teachers do not have a correct and comprehensive concept of technology themselves, they will not be able to transfer a correct and comprehensive concept to their pupils (De Vries, 2000).

2.2.2 Pedagogical content knowledge

In this subsection, the domain of PCK (B) and its hypothetical relations (a, e, and f) are discussed (see Figure 2.1). In the model of teacher knowledge, Grossman (1990) presented PCK as an unique and central domain that includes four central components: (1) knowledge and beliefs about the goals for teaching a subject at different grade levels, (2) knowledge of pupils’ understanding and (mis)conceptions of particular topics in a subject matter, (3) curricular knowledge, i.e., knowledge about the content of the courses within one field and about the available materials, and (4) knowledge of instructional strategies and representations for teaching particular topics knowledge of context (Grossman, 1990). As usual, not every researcher agrees on this conceptualisation, which results in a proliferation of definitions.

In an attempt to clarify the nature and structure of PCK, Van Driel et al. (1998) compared conceptualisations by different researchers. They concluded that there is no universally accepted conceptualisation, but that all researchers seem to agree on two core elements: (1) understanding of students’ specific learning difficulties, and (2) knowledge of representations of the subject matter to overcome these difficulties. Furthermore, they underline that research on PCK is valuable, because it provides insights into the instruction process, i.e., how teachers transform SMK into meaningful student learning.

Mainly based on the work of Grossman (1990) and Van Driel et al. (1998), three aspects in the domain of PCK were identified. Firstly, an
important aspect is teachers’ knowledge of pupils’ general concept of technology and specific conceptions related to technology. According to various studies on primary technology education, a good awareness of pupils’ pre- and misconceptions, which they acquire and develop through engagement in technology education, has a positive effect on technology teaching (Davis et al., 2002; Jarvis and Rennie, 1996b). In addition, Lewis (1999) asserted that knowledge of the technology concepts pupils possess is important for effective teaching and improved learning.

Secondly, knowledge of different pedagogical approaches and teaching strategies that are effective in technology education seems important, although this aspect is less established in the scientific literature as an influential aspect of PCK regarding pupils’ attitude. However, it seems obvious that teaching will be more effective if the teacher knows what approach or strategy is most appropriate in certain situations.

Teachers use a lot of different pedagogical approaches to teach technology. Some teachers integrate technology with other disciplines, while others focus on finding creative solutions for a technical problem. Boser et al. (1998) classified the approaches typically used in secondary (middle school) technology education in four categories: (1) the industrial arts approach, focussing on understanding of industrial technology and including activities such as using tools, machines and materials, (2) the integrated approach, incorporating other disciplines such as science and social studies, (3) the modular approach, which consists of individualised, action-based units of instruction, and (4) the problem solving approach, in which critical thinking is emphasised. The researchers measured pupils’ attitude towards technology with a questionnaire to provide insights into effective teaching approaches of technology education. Although attitudes were slightly affected in a positive as well as a negative direction, no clear directions of change in attitude that resulted from any of the four pedagogical approaches were found (Boser et al., 1998).

Similarly, several other studies hypothesised the teaching method or pedagogical approach would affect pupils’ learning and attitude. Stables (1997) recommended the ‘hands-on’ exploration in the context of problem solving, in which pupils are thinkers as well as doers, as the best way of teaching technology in primary schools. In a quantitative study about gender-based preferences for instructional approaches in secondary (middle and high school) technology education, it was found that both boys and girls were more interested in ‘doing’ activities (Weber and Custer, 2005). In a qualitative study the ‘hands-on’ approach was again advocated for
primary school pupils, but the researchers added that pupils’ understanding of technology can be best achieved when the presented problems are authentic (Twyford and Järvinen, 2000). In a study that compared traditional and innovative technology programmes, i.e., less handicraft-based and promoting creativity, problem-solving, and collaborative skills, in secondary schools, innovative programmes were found to have larger effects on pupils’ attitudes than more traditional programmes (Volk et al., 2003).

In a review study, teaching methods were found to be one of the factors that enhance effective learning and teaching in technology education. Most researchers seemed to agree that effective teaching of technology requires a wide range of teaching methods, e.g., inquiry learning, collaborative learning, and cross-curricular learning. However, it was concluded that more scientific research evidence is required to draw solid conclusions about which teaching methods are most favourable (Wilson and Harris, 2003). In a follow-up review, this conclusion was repeated (Wilson and Harris, 2004).

Thirdly, teachers’ knowledge of the nature and purpose of technology education is assumed to play an essential role in technology education. This aspect influences, among other things, what the teacher highlights as important (Jones and Moreland, 2004) and, in turn, what the pupils are being taught.

On the whole, PCK is a vital domain of teacher knowledge. The New Zealand researchers Jones and Moreland (2004) found that enhanced PCK is associated with enhanced learning of pupils in primary technology education, and specifically with increased motivation and interest in technology. In related studies on the implementation of technology education in New Zealand, the important influence of PCK on technology teaching was affirmed (Jones and Compton, 1998; Jones et al., 2004; Moreland and Jones, 2000). The results of several other studies in primary technology education (Alamäki, 1999; Fox-Turnbull, 2006; Stein et al., 2002) and primary science (Davis, 2004; Smith, 1999) are in line with this finding.

Magnusson et al. (1999) presented two important ideas about PCK. First, within each aspect of PCK teachers possess topic-specific knowledge, for example, knowledge about misconceptions that pupils often have about electricity. Hence, effective teachers need to develop knowledge regarding all aspects within all topics they teach. Second, the aspects function as a whole. Consequently, a lack of coherence between the aspects is problematic and teacher’s knowledge of one particular element may not be predictive of his or her teaching practice. For that reason, it is impor-
tant to know how strong the aspects are tuned to each other and how this degree of tuning affects teaching (Magnusson et al., 1999).

Furthermore, Van Driel et al. (1998) illustrated that most researchers assumed SMK to be an essential prerequisite for the development of PCK. In other words, “strong and useful pedagogical content knowledge cannot be built on a shaky content foundation” (Smith, 1999, p. 181).

2.2.3 Attitude towards technology

In this subsection, the domain of teachers’ attitude (C) and its hypothetical relations (b, c, and g) are discussed (see Figure 2.1). Teacher’s attitude towards technology and confidence in teaching technology are other important aspects with respect to pupils’ attitude towards technology. These aspects do neither fit easily into the domain of SMK, nor to the domain of PCK, because they are affective rather than cognitive aspects. However, attitude and confidence are considered to be part of the general construct of teacher knowledge (Verloop et al., 2001).

Primary school teachers have very limited or narrow perceptions of design and technology and such views may affect adversely their ability and confidence to teach the key learning area of design and technology in the classroom. In a study that aimed to broaden pre-service teachers’ perceptions of technology and technology education, many pre-service teachers believed that they had achieved the confidence and capability to teach design and technology in primary school after engagement in a technology unit of study (McRobbie et al., 2000). This finding implies that enhanced knowledge is related to enhanced confidence.

Relations between attitude, confidence, SMK, and PCK were investigated in a study on pre-service teachers teaching physics in primary schools. The researchers assumed it to be important that pre-service teachers have confidence in their own SMK and PCK in order to support the development of understandings, skills and attitudes in their pupils. Although the results did not clearly affirm these relations, the researchers still believed that attitudes and confidence are related in teaching physics, but that confidence not necessarily results from or in good SMK and PCK. The researchers recommended that teacher education should first focus on forming positive attitudes and then on increasing SMK and PCK (Johnston and Ahtee, 2006).

In a study on the role of confidence in teaching creativity in technology education, it was concluded that secondary technology teachers hamper creativity in their pupils if they themselves lack confidence about their
understanding of creativity in technology education. Teachers with low confidence were frustrated about keeping their knowledge and skills updated and failed to encourage pupils which in turn lead to a negative attitude towards technology education (Davies, 2000). Generalising these findings, it is expected that a teacher who has a negative attitude towards technology or has little confidence in teaching technology, reflects this in the classroom and, in turn, affects pupils’ attitude towards technology.

2.3 Pupils’ concept and attitude

In the hypothetical diagram (see Figure 2.1), teachers’ PCK and attitude are assumed to be directly related to pupils’ attitude towards technology (relations f and g). Furthermore, SMK is seen as a direct prerequisite of PCK (relation a). Besides, SMK and PCK affect pupils’ attitude towards technology in an indirect way, through pupils’ concept of technology (relation d and e). In this section, the relation between pupils’ concept of technology and their attitude towards technology is further clarified (relation h).

In 1986 an international project called ‘Pupils’ Attitude Towards Technology (PATT)’, with the purpose to develop an instrument to measure pupils’ attitudes, was started. In this context ‘attitude’ was used as a collective term for someone’s affinity, behaviour, and conceptualisation in relation to technology. The PATT instrument is a questionnaire, which consists of 6 scales that measure the Affective and Behavioural components (AB-scales: interest, role pattern, consequences, difficulty, school and career) and 4 scales that measure the Cognitive component (C-scales: society, science, skills and pillars) of attitude towards technology.

In a PATT study among 10 to 12-year-old pupils in the Netherlands, the affective and behavioural part of their attitude towards technology was measured with a PATT questionnaire (Dutch version for primary schools) and their concept of technology with use of drawing tasks and interviews. It was found that the 10 to 12-year-old pupils had a positive attitude towards technology and that boys had a more positive attitude than girls. However, it seemed that pupils were not aware of the daily influence of technology in their lives and that their general concept of technology was rather poor (De Klerk Wolters, 1989).

From a path analysis with three variables, Gender, Affect (score on AB-scales), and Concept (score on C-scales), it was found that Concept influences Affect and not the other way around. This result indicates that a correct and comprehensive concept corresponds with a positive attitude.
towards technology. Pupils’ concept was operationalised beforehand as consisting of four aspects: (1) society: technology is controlled by humans, (2) science: technology and science are mutually influenced, (3) skills: technology is related to designing, making and using, and (4) pillars: matter, energy and information are the pillars of technology. Besides, teachers had to fill in a questionnaire to measure their attitudes towards technology. Remarkably, no influence of teachers’ attitude on pupils’ attitude was found (De Klerk Wolters, 1989).

In order to identify which perceptions pupils have of technology, Cunningham et al. (2005) assessed both primary and secondary school pupils using picture questionnaires. Most pupils appeared to have a limited and often incorrect view of what technology is. Pupils associated technology mostly with power and electricity. It was concluded that education should help pupils to develop a concept of technology that is more robust and accurate and, in turn, develop a more positive attitude (Cunningham et al., 2005).

Jarvis and Rennie (1996a) share the opinion that it is important to be informed about primary pupils’ concept of the term ‘technology’ and how this concept develops. They reasoned that if primary school pupils associate the appropriate broad and positive technology experiences with technology, they are more likely to value and choose technology as a study or career later in life. Therefore, they conducted a study to chart pupils’ development of the concept of technology. The results indicated that many pupils have a narrow concept of technology, i.e., associating technology only with computers and modern appliances. Nonetheless, the pupils showed a wide variety of ideas, with the more complex and coherent ideas among the older ones. As a concluding remark, the researchers recommended that if all teachers point out which classroom activities are related to technology, more pupils will be able to make sense of the word ‘technology’ in different contexts (Jarvis and Rennie, 1996a).

From the PATT studies it can be concluded that pupils who have a narrow view of technology, have less positive attitudes towards technology. Unfortunately, but not fully accidentally, these pupils tend to be mostly girls. Girls usually have more interest in the social and human aspects of technology, but these aspects are rarely associated with technology. Because of their narrow concept, they are hampered in their development of a positive attitude. Therefore, it is of great importance that at primary schools technology education is taught in a way that provides a comprehensive concept, including the human and social aspects (De Vries, 2000).
2.4 Conclusion and discussion

The aim of this review was to explore how technology-specific teacher knowledge relates to pupils’ attitude towards technology. In a hypothetical diagram, all the assumed relations between domains of teacher knowledge and pupils’ concept and attitude were structurally outlined (see Figure 2.1). Regarding the domain of SMK (A) and its relations (a, b, and d), both general SMK and the concept of technology are reported to be important knowledge aspects for teaching technology (Parkinson, 2001; Davis et al., 2002; Garmire and Pearson, 2006; Jarvis and Rennie, 1996a; Cunningham et al., 2006). It is generally assumed that SMK is a prerequisite for the development of PCK (Van Driel et al., 1998). Furthermore, it is found that SMK is related to confidence in teaching technology (McRobbie et al., 2000) and that teachers’ concept of technology is related to their pupils’ concept of technology (De Vries, 2000).

With respect to PCK (domain B) and its relations (c, e, and f), knowledge of pupils’ conceptions (Davis et al., 2002; Jarvis and Rennie, 1996b; Lewis, 1999) and knowledge of the nature and purpose of technology (Jones and Moreland, 2004) are found to positively affect teaching and learning. Although it is not evident which pedagogical approach is most favourable for teaching technology, it seems obvious that it is important to know which approaches and strategies are available and which are best to use in certain situations. It is empirically shown that PCK is associated with enhanced learning of pupils in primary technology education and, specifically, with increased motivation and interest in technology (Jones and Moreland, 2004). The relation between PCK and teachers’ attitude is still unclear. Concerning teachers’ attitude (domain C) and its relation with pupils’ attitude (g), it is expected that teachers’ attitude and confidence affects pupils’ attitude towards technology, although empirical evidence is lacking. From the PATT studies in can be concluded that pupils’ concept of technology is strongly related to their attitude towards technology (De Klerk Wolters, 1989; De Vries, 2000). This implies that it is important that teachers help their pupils developing a correct and comprehensive concept of technology.

The use of different instruments and diverse conceptualisations of the knowledge aspects in the reviewed studies made it complicated to compare the findings of these studies. In particular, PCK is a rather ambiguous concept, without a clear conceptualisation. Besides, it is not claimed that the six aspects of teacher knowledge represent the entire domain of technology-specific teacher knowledge. Several other aspects, and many subordinate
aspects, could be added to the hypothetical diagram.

A critical comment on the method of reviewing might be that only literature in the field of technology education was searched, mainly because the focus was put on technology-specific aspects of teacher knowledge. Literature on science education was occasionally included, because the knowledge domains of these two subject are partly overlapping. Nonetheless, studies from other subject areas may have useful results on teacher knowledge too, and might give some ideas for other knowledge aspects that are important regarding pupils’ attitude towards technology.

In summary, teacher knowledge affects teaching and, in turn, affects pupils’ concept of and attitude towards technology. However, empirical evidence on the assumed relations between teacher knowledge and pupils’ attitude is still poor. More research and, in particular, empirical evidence on teacher knowledge in technology education is clearly needed. It should be further explored how the aspects of teacher knowledge play a role in stimulating pupils’ attitude towards technology. The hypothetical diagram presented in this review will serve as a helpful tool when investigating these relations empirically.

Bibliography


Chapter 3

Measuring teachers’ pedagogical content knowledge in primary technology education*

abstract

Pedagogical content knowledge is found to be a crucial part of the knowledge base for teaching. Studies in the field of primary technology education showed that this domain of teacher knowledge is related to pupils’ increased learning, motivation, and interest. The common methods to investigate teachers’ pedagogical content knowledge are often complicated, and time and labour consuming. Hence, a challenge in measuring teachers’ pedagogical content knowledge is to construct an instrument that is time and labour-efficient, and makes it possible to investigate large sample sizes. This chapter illustrates how a multiple choice test to measure teachers’ pedagogical content knowledge in primary technology education was designed and validated. The procedure of test construction and the first results are presented. It is concluded that the systematic procedure that was followed is effective for the construction of a valid test. In addition, statistical analyses showed that test-retest reliability is moderate. Data collection with larger samples is needed in order to find more statistical support for the psychometric properties of the test.

3.1 Introduction

Technology is strongly interwoven in today’s society. It has become vital to human welfare and economic prosperity and will be even more vital in the future. Consequently, education needs to adapt to the growing importance of technology, new educational programmes should be aimed at making pupils more technological literate (ITEA, 2006).

It is assumed that teacher knowledge affects teaching and, in turn, affects pupils’ concept of and attitude towards technology (Chapter 2). Besides, it is found that pupils with a more correct and comprehensive view of technology, have a more positive attitude towards technology (De Vries, 2000). Consequently, it is of great importance that teachers have sufficient knowledge of technology and technology education to develop pupils’ technological literacy. Furthermore, a positive attitude towards technology is expected to result in a larger number of students choosing technical studies and careers. Larger numbers of these students are necessary because, in the last 15 years, the numbers of science and technology students in the Organisation for Economic Co-operation and Development (OECD) countries have been relatively decreasing. Clearly, this trend is worrying with regard to the continuing transition to a more technology-intensive economy (Wendelaar Bonga, 2006).

Teacher knowledge is an umbrella term that covers a large variety of cognitions, beliefs, and knowledge domains. Various labels have been used by researchers indicating the different aspects of teacher knowledge (e.g., ‘wisdom of practice’, ‘professional craft knowledge’, ‘action oriented knowledge’). According to Verloop et al. (2001), teacher knowledge comprises the whole of knowledge and insights that underlie teachers’ actions in practice, including tacit knowledge.

Teacher knowledge is a popular theme for investigation in the field of science education. Research in this domain has produced valuable results and insights into science teaching. In this chapter, we focus on pedagogical content knowledge (PCK), which is considered to be a distinctive domain of teacher knowledge, in the field of primary technology education. In this specific field, PCK is still rather unexplored. Because science and technology are strongly interrelated subjects, results in both fields are expected to be interchangeable to a large extent.

The New Zealand researchers Jones and Moreland (2004), who investigated PCK in primary technology education, found that enhanced PCK is positively related to pupils’ learning, motivation, and interest in technology. PCK is one of the most crucial domains of teacher knowledge (e.g.,
The central aim of this study was to explore the possibility to measure teachers’ \textit{PCK} of primary technology education with a multiple choice test. This chapter shows how a multiple choice test was designed and validated. First, the construct of \textit{PCK} is conceptualised and current methods of examining \textit{PCK} are briefly presented. Subsequently, two prior initiatives to measure \textit{PCK} with a multiple choice test are discussed. Next, the procedure of test construction and the first results are described in more detail. Finally, a reflection on the results is given and implications are discussed in the concluding section.

### 3.2 Pedagogical content knowledge

The American educationalist Lee Shulman introduced the term ‘pedagogical content knowledge’ when he investigated the knowledge base of teachers. He defined it as “a special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding” (Shulman, 1987, p. 8). He stated that effective teachers need \textit{PCK} rather than just knowledge of a particular subject matter.

In order to clarify the concept of teacher knowledge, Grossman (1990) designed a model of teacher knowledge by summarising the most important investigations in this field. In this model, \textit{PCK} is presented as an unique, central domain that is influenced by other teacher knowledge domains, and includes four central aspects: (1) knowledge and beliefs about the goals for teaching a subject at different grade levels, (2) knowledge of pupils’ understanding and (mis)conceptions of particular topics in a subject matter, (3) curricular knowledge, that is, knowledge about the content of the courses and of the available materials within one field, and (4) knowledge of instructional strategies and representations for teaching particular topics (Grossman, 1990).

In the last two decades, the concept of \textit{PCK} has become popular to investigate. As Mulholland and Wallace (2005) noticed, it is interesting to see that \textit{PCK} is interpreted in many different ways to suit the research context. For example, some researchers include knowledge of curriculum (e.g., Grossman, 1990), while others exclude this knowledge aspect (e.g., Cochran et al., 1993).

Van Driel et al. (1998) compared conceptualisations of \textit{PCK} used by different researchers. They showed that there is no universally accepted
conceptualisation, but that all researchers agree on two essential aspects: (1) understanding of pupils’ specific learning difficulties and (2) knowledge of representations of the subject matter to overcome these difficulties. Most researchers in science education that study PCK seemed to build upon Shulman’s definition of PCK. Furthermore, Van Driel et al. (1998) illustrated that researchers assumed subject matter knowledge to be a prerequisite for the development of PCK.

Some researchers argue that it is impossible to clearly demarcate PCK from other knowledge domains, for example, subject matter knowledge. Van Driel et al. (1998) commented that PCK can be seen as a separate knowledge domain when defined as practical teacher knowledge of pupils’ learning difficulties and of instructional strategies with regard to particular topics. They underlined that research on PCK is valuable, because it can provide insights into the instruction process, especially how teachers transform subject matter knowledge into meaningful learning.

Through a theoretical review on teacher knowledge in primary technology education, three aspects of PCK that are essential for effective technology education were derived from the reviewed literature: (1) knowledge of pupils’ concept of technology and knowledge of their pre- and misconceptions related to technology, (2) knowledge of pedagogical approaches and teaching strategies for technology education, and (3) knowledge about the nature and purpose of technology education (Chapter 2).

In addition to identifying aspects of PCK, Magnusson et al. (1999) presented two important issues regarding the nature of PCK. First, they said that within each aspect of PCK teachers need to have specific knowledge for each topic. In other words, effective teachers need to develop knowledge regarding every aspect of PCK and regarding all topics they teach. Second, they indicated that the aspects of PCK function as a whole. Consequently, a lack of coherence between the different aspects is problematic and a teacher’s knowledge of one particular aspect may not be predictive for a teacher’s teaching practice.

This so-called ‘heterogeneous’ nature of PCK, that is, containing dissimilar aspects at different levels, induces difficulties in comparing PCK among subjects and topics. For example, the PCK required to coach a design task in the context of technology education is different from the PCK required to coach a task in the context of science education. Tasks in technology education tend to have an open-ended character, while tasks in science education are aimed at discovering established, scientific laws. In the words of Banks et al. (2004, p. 144): “Compared with other subjects, such as
Measuring PCK

Most problematic aspects of measuring teacher cognition in general, also apply to the measurement of PCK. Firstly, PCK is difficult to measure directly, because teachers’ PCK is often tacit knowledge. Moreover, teachers are not always able to verbalise their thoughts and beliefs or they may refrain from expressing unpopular ideas. Secondly, PCK is defined to be constituted by what a teacher knows, what a teacher does, and the reasons for a teacher’s actions. Consequently, PCK is not entirely expressed through behaviour. Therefore, observations alone will not reveal why teachers act as they do. Moreover, teachers may only use a small portion of their PCK in the observed situations. Thirdly, making judgments about teachers’ PCK is problematic, because it is still highly debatable what the standards for good (high-quality) PCK are (Baxter and Lederman, 1999). In addition, most common PCK methodologies are time and labour-intensive, complicated, and difficult to replicate. Because groups sizes rarely exceed 10 and the results are very content, context, and teacher specific, generalisation is risky.

Baxter and Lederman (1999) reviewed methodologies and techniques that have been used to measure teachers’ PCK in the context of science teaching. Most researchers (e.g., De Jong et al., 2005; Jones and Moreland, 2004; Mulholland and Wallace, 2005; Van Driel et al., 1998) who investigated PCK used multi method evaluations, that is, a variety of techniques which typically includes structured, semi-structured or stimulated
recall interviews, observations, and concept mapping. Data from these different sources are triangulated, which results usually in a general profile of a teacher’s PCK.

A relatively new technique within the group of multi method evaluations is the use of CoRes (Content Representations) and PaP-eRs (Pedagogical and Professional-experience Repertoires). These techniques capture teachers’ PCK with use of engaging portrayals, that is, individual profiles based on data from interviews and observations. It is an alternative way to evaluate PCK in action without a fixed format. Because this method is rather time and labour intensive, sample sizes are forced to be small. CoRes and PaP-eRs are designed, and most useful, as professional development tools in teacher education (Loughran et al., 2001).

Hewson and Hewson (1989) designed an interview protocol, the ‘interview-about-instances’, to identify teachers’ conceptions of teaching science. Their explanation of this construct shows a lot of similarities with PCK. The interview focuses on knowledge regarding the nature and purpose of the subject matter and regarding pedagogical approaches and teaching strategies. The interview protocol was shown to be a powerful intervention technique, which make teachers think hard about what is involved in science teaching without changing their original conceptions or biasing their responses. Nonetheless, the researchers expressed concern about the analysis technique, because the interviews are rich in detail and the technique is time-consuming. Moreover, the data the interview provides need to be complemented with observations and other data resources to form an adequate profile of a teacher’s conception of teaching science.

Altogether, the methodologies and techniques currently used to measure PCK require teachers to be strongly involved in the research project, and are often labour-intensive and time-consuming. Furthermore, quality indicators of multi method evaluations of PCK are hardly available, which makes comparison between the methods difficult. Hence, the challenge in examining PCK remains to construct an instrument that requires less teacher involvement, measures PCK in a time and labour-efficient way, and makes it possible to investigate large sample sizes. In our view, the best way to achieve this is by constructing a multiple choice test.

3.4 Measuring PCK with a multiple choice test

In this section two promising initiatives to develop a multiple choice test to measure teacher’s PCK are described. Carlson (1990) discussed three
issues related to the development of multiple choice test items to measure PCK for a primary school teacher licensure test, i.e., a test that has been developed and/or approved by a governmental agency to assess prospective primary school teachers’ basic qualifications for licensure in that state or country.

The first issue concerns the level and aim of the test. He stated that it has to be clear what the aim of the test is in order to determine its level. For example, an entrance exam requires a different level of item types than a licensure or certification test. Although this may sound straightforward, it is important to keep in mind when constructing a test. The second issue concerns the integration of pedagogical and content knowledge in test items in such a way that PCK is measured, rather than testing pedagogical and content knowledge separately. PCK test items should require the application of pedagogical knowledge to specific content areas, which means that the questioned person should have enough content knowledge of topic in order to recognise the correct application of the pedagogical principle. These applications need to be distinctively correct, that is, their correctness needs to be as empirically well-supported as possible. The third issue concerns the credibility of items. Although Carlson used two criteria for correctness, that is, empirical support and professional consensus, it was found difficult to write items with correct and convincing answers. As a solution, he developed best-answer in stead of correct-answer items.

A second initiative to construct multiple choice test items in order to measure PCK was taken by Kromrey and Renfrow (1991). Their aim was to increase the practical value of teacher tests by constructing so-called ‘Content-specific Pedagogical knowledge’ (C-P) items. In line with Carlson, Kromrey and Renfrow stated that the ability to answer a C-P item should require knowledge of subject content combined with general pedagogical knowledge and knowledge of specific pedagogical techniques. They described C-P items as “those items for which the examinee’s determination of the correct response depends upon knowledge of the treatment of content in educational situations” (p. 5).

Kromrey and Renfrow (1991) found that constructing C-P items requires more planning, writing, and editing than constructing items on content knowledge. Their assumed explanation was that C-P items demand a meta-cognitive expertise of the teaching process. They advocated field testing as an important way to provide critical and valuable feedback for the revision of items and more research to analyse the statistical properties of C-P items. The work of both Carlson and Kromrey and Renfrow was
not continued and statistical analyses were absent, but their work served as a helpful starting point for the construction of our PCK test.

3.5 Procedure of test construction

To construct our multiple choice test, we needed to find a construction method that fits the current position of PCK in primary technology education. In our view, the prescribed conditions of the ‘rational method’ of test construction (Oosterveld and Vorst, 1996) matched best. This method is classified as ‘intuitive’ and focuses on optimising content validity. Rather than empirical data, judgments of experts are of particular importance for the specification and construction of items. This method is found to be especially useful if the central concept is conceptualised insufficiently and if empirical data are scarce. Both of these features apply to PCK in primary technology education, which made the choice for this method of test construction a valid choice.

The procedure of test construction can be chronologically divided in seven phases: (1) specification of the theoretical framework, (2) construct analysis, (3) specification of item characteristics, (4) production of items, (5) judgement of items, (6) construction of the instrument, and (7) validation of the instrument. According to the rational method, specifying the theoretical framework means creating a shared view of the construct, usually in the form of a working definition. The construct is analysed by describing typical phenomena or situations, which are often used as item scenarios or contexts. It is of particular importance that the experts agree on the working definition. The items are judged by the experts and their judgements form the foundation of the test construction. The test is validated by comparing the results with the experts’ judgements (Oosterveld and Vorst, 1996).

Our expert team consisted of seven members and had four successive meetings, which lasted approximately four hours each and were led by the test constructor, the author of this thesis. A website was set up and used to share information, exchange documents, discuss issues, and make announcements. The first meeting concerned an introduction to the project, a specification of the theoretical framework, and a first analysis of the construct. Beforehand, the experts were asked to think of possible examples of PCK from their own experience and practice, which were discussed in the group. Besides, the national curriculum of technology education in Dutch primary schools was clarified and discussed. The experts agreed on using
the domain description written by Cito (the national institute for educational measurement) as suggested by the test constructor. In Table 3.1 an overview of the key learning areas of the Dutch curriculum for technology education is given. For reference, the key learning areas of the American, English, New Zealand, and Belgian curriculum are also shown.

In the second meeting the construct analysis was continued and complemented with specification of the desired item characteristics and a working definition of PCK was formulated. The experts defined PCK as “the knowledge a teacher needs in order to make the transition from his/her own content knowledge to the knowledge and learning of pupils”. They agreed on three main aspects of PCK in primary technology education: (1) knowledge of pupils’ prior knowledge, experience, and (mis)conceptions related to technology, (2) knowledge about the nature and goals of technology education, and (3) knowledge of pedagogical approaches and teaching strategies for technology education. Within each of these aspects several sub-aspects were formulated, for example, understanding the difference between science and technology education and knowing how to integrate these subjects, which belongs to the second aspect.

The central aim of the third meeting was producing and writing PCK items. Prior to the third meeting the experts were asked to write at least ten PCK items each, following standard rules, collectively defined item specifications, and using an item template. In particular, it was found difficult to formulate plausible distracters. To help structuring the formulation of answers, the four response alternatives were characterised a priori as to require ‘high PCK’, ‘low PCK’, exclusively pedagogical knowledge, and exclusively content knowledge (‘no PCK’). A lot of discussion arose about the correctness of the best answer (‘high PCK’), which was supposed to be chosen by teachers with a lot of PCK. In general, the experts struggled with creating answers that reflected a proper blend of content knowledge and pedagogical knowledge. In the fourth, and last, meeting all the produced items were judged by other experts within the team and, if necessary, rewritten for a final time. With use of a list of judgement criteria, pairs of experts judged the items produced by other experts. From the 52 judged items, 40 items were accepted for admittance to a first version of the PCK test (see Figure 3.1 for an item example).

After the last meeting, the test constructor compiled the first complete instrument, called the Teaching of Technology Test (TTT). Because 40 items in one test would make the test too long for administration, it was divided in two equal parts (version A and B). In both versions, it was made
Table 3.1: Overview of the national curricula for primary school technology education of the United States, England, New Zealand, Flanders, and the Netherlands (key learning areas).

<table>
<thead>
<tr>
<th>USA&lt;sup&gt;a&lt;/sup&gt;</th>
<th>England (UK)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>New Zealand&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Flanders (Belgium)&lt;sup&gt;d&lt;/sup&gt;</th>
<th>The Netherlands&lt;sup&gt;e&lt;/sup&gt;</th>
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<tbody>
<tr>
<td>The nature of technology</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Technology and society</td>
<td>Evaluating processes and products</td>
<td>Technology and society</td>
<td>Choices (societal)</td>
<td>Boundary conditions (economic, societal)</td>
</tr>
<tr>
<td>Design</td>
<td>Developing, planning and communicating ideas</td>
<td>The technological process</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abilities for a technological world</td>
<td>Working with tools, equipment, materials and components to make quality products</td>
<td>Technological capability</td>
<td>Resources (human and material)</td>
<td>Resources (human and material)</td>
</tr>
<tr>
<td>The designed world</td>
<td>Knowledge and understanding of materials and components</td>
<td>Technological knowledge and understanding</td>
<td>Technological systems</td>
<td>Scientific and technological systems</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Materials and material characteristics</td>
</tr>
</tbody>
</table>

<sup>a</sup> ITEA. (2006). Technological literacy for all: A rationale and structure for the study of technology.
<sup>e</sup> Cito. (2002). Techniek voor de basisschool: Een domeinbeschrijving als resultaat van een cultuurpedagogische discussie [Technology for primary schools: A domain description as a result of a cultural-pedagogical discussion].
Two pupils together make a car out of cardboard (see pictures above), which can move due to a rotatable axle to which wheels made from bottle tops have been attached. The car can move forwards by winding up an elastic band attached to the axle and then letting go. The pupils test their car on a smooth table. However they are disappointed to discover that although the wheels rotate, the car scarcely moves forward. The pupils suspect that their car is too heavy but do not know a solution for this problem.

Which one of the following approaches can best be used to help these pupils?

a. You join in with pupils’ line of thought and from this perspective you try to help them discover the relationship between friction, drive and weight.
b. You draw the pupil’s attention to the elastic band and the weight of the car and make sure that they continue searching for a solution.
c. You let the pupils compare their car with those of the other pupils so that they can reach a solution.
d. You explain to the pupils that two smooth surfaces easily move over each other due to the lack of friction. You advise them to attach elastic bands to the wheels to give these more grip.

**Figure 3.1:** Item example. The answers reflect a) ‘high PCK’, b) ‘low PCK’, c) pedagogical knowledge, and d) content knowledge.

sure that the entire construct of PCK was covered (i.e., containing different kinds of PCK aspects), the items involved a wide variety of technology class situations (i.e., preparation, instruction and communication, and assessment), and technological topics (e.g., electricity and construction) of the items varied.

### 3.6 Results

#### 3.6.1 First study

The two versions of the TTT (A and B) were sent to approximately 120 primary schools, which were involved in a governmental project on primary technology education in the Province of Limburg, the Netherlands. The distribution of the tests was done by e-mail. In total, 34 teachers filled out and returned the test. All subjects were primary school teachers in (Dutch) grade 6, 7 and/or 8 (pupils’ age 9-12 years). Version A was completed by 21 teachers (14 male and 7 female) and version B by 13 teachers (7 male and 6 female). Their mean age was 43 years ($sd = 11$) and their mean
teaching experience 20 years ($sd = 12$). A refresher course on technology education was recently completed by 47.1% of the teachers in the sample.

The analysis of the data mainly served as a statistical exploration in order to make a first, well-considered selection of items. Three basic selection criteria were applied, that is, validity, reliability, and discriminating power. For all the analyses described below, the statistical software package SPSS was used. After a descriptive analysis of the items, three items (1 of version A, and 2 of version B) were excluded from further analysis based on the absence of variance in responses, that is, all subjects chose the same alternative.

To detect meaningful underlying dimensions and support the reliability of the response alternatives, Multidimensional Scaling (MDS) analysis was performed, using a dichotomous score (0 or 1) for each of the alternatives. MDS analysis was appropriate because of a meaningful rank ordering of the response alternatives. As mentioned in the procedure section above, the alternatives were characterised as representing ‘high PCK’, ‘low PCK’, pedagogical knowledge, or content knowledge. A three-dimensional MDS analysis of the response alternatives fitted the data in an useful and interpretable way. The fit value Kruskal’s stress was acceptable (0.18 for version A and 0.16 for version B). The 3D scatter plots revealed a distribution of the categories roughly as expected, that is, a cluster of ‘high PCK’ alternatives opposite to a cluster of ‘no PCK’ alternatives (pedagogical and content knowledge) and the ‘low PCK’ alternatives spread in between. The mathematical software programme MATLAB was used to make 3D plots that could be rotated in any direction, which improved the interpretability of the output. Based on these rotatable 3D plots, the outliers in the group of ‘high PCK’ alternatives were traced and the corresponding items were excluded.

The next steps in the item selection procedure were undertaken alternately to create an iterative approach towards a first, rudimentary scale definition. Cronbach’s alpha was calculated to determine internal consistency of the scale. Convergent validity was assessed by using the indicator ‘having completed a refresher course on technology education’. It was assumed that completing a refresher course on technology education is positively correlated with a teacher’s PCK score. In order to make sure that the test would be a mixture of easy as well as difficult items, the discriminating power of the test items were analysed by comparing mean item scores between groups with high ($> 5$) and low ($< 5$) technology teaching experience.
With respect to the reliability, validity, and discriminating power as described above, a final selection of items was made. After this selection version A included 9 items ($\alpha = 0.60$) and version B included 10 items ($\alpha = 0.49$). Merging the 2 versions is expected to increase the internal consistency (alpha), according to the Spearman-Brown formula for test lengthening (Lord and Novick, 1968). For each subject a PCK score was computed simply by counting all the ‘high PCK’ alternatives that were chosen by the subject (divided by the number of items and multiplied by 10). For version A the mean PCK score was 4.89, for version B this mean score was 5.91. On each version the male teachers scored higher than the female teachers, but these differences were not statistically significant. The PCK score of version A correlated significantly with completion of a refresher course (version A: $r_s = 0.448, p < 0.05$; version B: $r_s = 0.503, n.s.$) in the expected direction.

### 3.6.2 Second study

In a follow-up study, the merged TTT (19 items) was administered by means of an online questionnaire system (CORF) to a larger group ($n = 101$) of primary school teachers, who (93%) taught pupils’ in the age of 8 to 12 years (Dutch grades 5 to 8) in the Provinces of Limburg and Noord-Brabant, the Netherlands. The sample consisted of 57 male and 44 female teachers, with a mean age of 44 years. Of these teachers 70.3% had more than 10 years of teaching experience. A refresher course on technology education was completed by 23.8% of the teachers in the sample. In this study, the mean PCK score on the TTT was 4.61, on a scale from 1 to 10. Again, no statistically significant difference was found between male and female teachers.

Regarding the convergent validity of the test, a positive and significant correlation between the TTT score and completion of a refresher course on technology education was found ($r_s = 0.166, p < 0.05$). Furthermore, an interview protocol designed by Hewson and Hewson (1989) called ‘interview-about-instances’ was translated and rewritten to the context of primary technology education. Interviews were held with 10 primary school teachers. Categorical and overall summaries were written for each respondent. Based on these summaries two raters independently gave a PCK score on a continuous scale from 1 (low) to 5 (high) to each of the 10 teachers (inter-rater reliability: $r = 0.56$). Unexpectedly, the mean scores (of rater 1 and rater 2) did not correlate with the TTT scores. This might be due to the fact that the interviews were not specifically designed to ex-
amine teachers’ PCK, but rather to reveal teachers’ perceptions of teaching technology. This made the assignment of PCK scores considerably difficult and arbitrary.

Internal consistency of the test was found to be rather low (Cronbach’s alpha is 0.36 for all 19 items, and 0.46 for 15 items with positive item-total correlations). A factor analysis with oblique rotation showed that the test had multiple dimensions (6 dimensions with Eigenvalue > 1), but these dimensions could not be interpreted in a meaningful way. Multidimensionality was also confirmed by low item-total correlations and high variance in item scores.

In case of multidimensionality or heterogeneousness of a test, Cronbach’s alpha is underestimating reliability and, therefore, not suitable as a reliability coefficient (Cortina, 1993; Lucke, 2005). As an alternative, test-retest reliability was calculated by comparing the scores of 10 teachers who filled out the TTT during the first study (May 2007) and again during the second study (March 2008). The test and retest scores correlated significantly ($r = 0.641, p < 0.05$), which means that the test is moderately reliable over time.

3.7 General discussion

The aim of this study was to explore the possibility to construct and validate a multiple choice test that measures primary teachers’ PCK in technology education.

The rational method of test construction was strictly followed and completed with statistical analyses, which made the entire construction procedure solid and systematic. Experts in the field of primary technology education agreed on the items measuring PCK in technology, which means that content validity of the test can be depicted as being high. Nonetheless, several issues arose during test construction which were hard to solve. Regarding the production of items, it was found difficult to formulate the best answer and plausible distracters. As Carlson (1990) and Kromrey and Renfrow (1991) experienced earlier, our experts struggled with writing best answer alternatives that reflected integration of content knowledge and pedagogical knowledge as well. However, we conclude that the procedure followed to construct our multiple choice test to measure teachers’ PCK of primary technology education is proved to be effective.

The statistical results concerning internal consistency and multi-dimensionality are in line with the heterogeneous nature of PCK, which is reported
by various researchers (e.g., Cochran et al., 1993; Loughran et al., 2001; Magnusson et al., 1999; Van Driel et al., 1998). PCK is a construct that is comprised of different aspects at different levels, which are tightly connected and cooperate as a whole. It is undesirable to artificially isolate these aspects in a single test or test item, because this creates an unrealistic representation of PCK. We conclude that it is possible to statistically validate a PCK test when focusing on test-retest reliability. Compared to Carlson (1990) and Kromrey and Renfrow (1991), we made an important step forward regarding the measurement of PCK with use of a multiple choice test.

This study indicates that measuring PCK with a multiple choice test is complicated, though not impossible. Similarly, neither examining PCK with interviews nor with observations is found to be easy. More data collection in larger samples is needed in order to find more statistical support for the psychometric properties of the TTT. A larger sample will make it possible to use more advanced statistical techniques, for example structural equation modelling. Further exploration of convergent validity by comparing the TTT scores with measures that are expected to correlate positively, for example scores on self-efficacy instruments (Park and Oliver, 2008), will be done in a follow-up study.

The exploration of a new measurement instrument for PCK has scientific as well as practical implications. First, this method of PCK measurement sheds a new light on the construct of PCK and contributes to the conceptualisation of the construct. Moreover, it allows researchers to easily examine large sample sizes. However, to measure PCK more profoundly, it is still strongly recommended to complement these kinds of measurement instruments with interviews, observations, or other qualitative methods that examine teachers’ PCK.

In educational practice the (improved) TTT could be used as an assessment tool in primary teacher education and in relation to professional development of primary school teachers. Insights into teachers’ PCK are expected to improve the efficiency and quality of technology education.

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Chapter 4

Conceptualising pedagogical content knowledge by analysing the latent factor structure of a multiple choice test*

abstract

In this study, primary school teachers’ pedagogical content knowledge (PCK) of technology education was measured with a multiple choice test. The aims of this study were to validate the test and to contribute to the conceptualisation of PCK through analysis of the latent factor structure. As far as known, it is the first time that PCK is approached this way. Many different components of PCK have been proposed in an attempt to define the concept, but these components have never been statistically confirmed. The results of this study give useful insights into primary school teachers’ PCK in technology education. It turned out that three theoretically predefined knowledge components of PCK could be identified as latent factors. Furthermore, PCK could be characterised as a heterogeneous construct. That is, PCK consists of many intrinsic elements, which are difficult to unravel. Despite the complexity of the construct, measurement of PCK with a multiple choice test has clear-cut advantages compared to qualitative methods.

4.1 Introduction

This study is focussed on pedagogical content knowledge (PCK), which is considered to be a crucial and distinctive domain of teacher knowledge (Shulman, 1987; Grossman, 1990). The integrative domain of science and technology education in primary schools (K-6) in the Netherlands served as the context, whereas the measurement of primary school teachers’ PCK was concentrated on technology education exclusively. Regarding technology education in primary schools, PCK is still rather unexplored. An important finding in one of the few studies was that teachers’ enhanced PCK in technology education was positively related to pupils’ learning, motivation, and interest in technology (Jones and Moreland, 2004).

Since the beginning of this century, primary school science and technology education in the Netherlands is encouraged by policy makers to increase the number of science and technology students. The main goal of science and technology education for primary schools is described as ‘to make pupils familiar with a rational approach of the natural world and its artifacts’. The pedagogical approaches that are recommended to use are inquiry-based and problem-based learning. This view on science and technology education is grounded on the theory of social constructivism, which involves a focus on learning, having pupils experience (hands-on) and explain (mind-on) themselves, cooperative learning, and different roles of the teacher (e.g., experts, coach, advisor). Moreover, a powerful learning environment with authentic and realistic problems or tasks that connect to pupils’ prior experiences, knowledge, and interests is an important condition for science and technology education (Boersma et al., 2005).

In the document of national standards for primary education in the Netherlands (Greven and Letschert, 2006), seven standards for science and technology education are formulated, of which the two written below are specifically concerned with technology education.

1. Pupils learn to find connections between the functioning, design, and use of materials of products in their own environment.

2. Pupils learn to design, realise, and evaluate solutions for technical problems.

Because these standards are formulated in a rather general way and a governmentally approved framework of key learning areas is nonexistent, it is often the teachers, but most often the textbook editors, who decide what is actually taught in the classrooms. However, science textbooks
do usually not pay much attention to technology, though textbooks and educational materials that put more emphasis on technology education slowly appear due to the introduction of new standards in 2006.

PCK makes teachers capable of transforming the subject matter into meaningful and effective learning activities (Shulman, 1987; Van Driel et al., 1998). In order to find out how PCK develops and how it affects science and technology teaching and learning, research on teachers’ PCK in science and technology education is needed. Solid research on PCK requires PCK to be conceptualised in a valid way. In turn, valid conceptualisation is prerequisite to valid measurement of PCK. This study contributes to the conceptualisation of PCK in technology education through measurement of primary school teachers’ PCK with a multiple choice test and analysis of the latent factor structure. Our quantitative approach differs from other, more common, approaches that can be characterised as in-depth and small scale approaches, and addresses the concept from a different angle.

In the previous chapter, we reported on the procedure of test construction and the results of a first (exploratory) validation of our multiple choice test to measure technology PCK (Chapter 3). In the present chapter, we report on a large scale validation of this test and on the analysis of the latent factor structure underlying primary school teachers’ PCK of technology education. As far as known, it is the first time that PCK is approached this way. Many different components of PCK have been proposed in an attempt to define the concept (e.g., Shulman, 1987; Grossman, 1990; Van Driel et al., 1998; Carlsen, 1999), but these components have never been statistically confirmed. In the next section a short overview of research on the conceptualisation and measurement of PCK in science education is given. Then, the method and results of this study are presented. In the final section, conclusions are formulated and the findings are critically discussed.

4.2 Pedagogical content knowledge

In the last two decades, PCK has become popular to investigate. As Mulholland and Wallace (2005) noticed, PCK is interpreted in many different ways, often to suit the research context. For example, some researchers include knowledge of the curriculum (e.g., Grossman, 1990), while others exclude this knowledge component (e.g., Cochran et al., 1993). According to Van Driel et al. (1998) and Park and Oliver (2008) most researchers do agree on two essential components of PCK: (1) understanding of pupils’
CONCEPTUALISING PCK

specific learning difficulties, and (2) knowledge of representations of the subject matter to overcome these difficulties. Furthermore, it is known that most researchers assume subject matter knowledge to be a prerequisite for the development of PCK (Van Driel et al., 1998).

With regard to the conceptualisation of PCK in science education, Magnusson et al. (1999) presented two important issues. First, they stated that within each PCK component teachers need to have specific knowledge for each topic. In other words, effective teachers need to develop knowledge regarding every component of PCK and regarding all topics they teach. Second, they indicated that the components of PCK function as a whole. Consequently, a lack of coherence between the different components is problematic and a teacher’s knowledge of one particular component may not be predictive for a teacher’s teaching practice. Appleton (2008) theorised that the PCK development of primary school teachers may differ from secondary school teachers, because primary school teachers usually do not specialise in a specific domain. Therefore, they might not develop specific PCK for all the different subjects and topics they teach.

Another important characteristic of PCK in science education is the strong relationship with teachers’ self-efficacy or self-confidence in teaching science. In a multiple case study, Park and Oliver (2008) revisited the concept of PCK and proposed teachers’ self-efficacy, i.e., teachers’ beliefs about their ability to enact effective teaching methods for specific teaching goals, to be an affective affiliate of PCK. This finding is in agreement with Appleton (2008), who assumed confidence in teaching science to be an important condition for the development of science PCK of primary school teachers. In other words, low levels of PCK are often related with low self-confidence (i.e., low self-efficacy).

Based on a review of scientific literature on PCK (Chapter 2), three components of PCK were selected as the main knowledge components of PCK for technology education in primary schools.

1. Knowledge of pupils’ concept of technology and knowledge of their pre- and misconceptions related to technology.

2. Knowledge of the nature and purpose of technology education.


Besides, in the context of the previous (Chapter 3) and present study, PCK was defined as “the knowledge a teacher needs in order to transform his
Recently, Abell (2008) confirmed that PCK is still a useful construct twenty years after its introduction by Shulman. Besides, she expressed two important challenges for PCK researchers: (1) the relation of PCK to pupils’ learning and (2) moving from descriptive to explanatory research, in other words, shifting from small-scale to large-scale studies. This second challenge includes finding alternative ways to measure PCK.

Most researchers who investigated teachers’ PCK (e.g., De Jong et al., 2005; Jones and Moreland, 2004; Mulholland and Wallace, 2005; Van Driel et al., 1998) used multi method evaluations, a variety of techniques which typically includes structured, semi-structured or stimulated recall interviews, observations, and reflective journals. Data from these sources were triangulated, usually resulting in a general profile of a teacher’s PCK. This method requires teachers to be strongly involved in the research project, and is labour and time consuming. Because groups sizes rarely exceed 10 and the results are very content, context, and teacher specific, generalisation of the results is risky. Furthermore, psychometric quality indicators of multi method evaluations are hardly available, which makes comparison difficult. A multiple choice test requires less teacher involvement, measures PCK in a time and labour efficient way, and makes it therefore possible to investigate large sample sizes. In addition, psychometric quality indicators of the measurement can be evaluated by strict and objective procedures.

In the past, two promising initiatives to develop a multiple choice test to measure teacher’s PCK were taken by Carlson (1990) and Kromrey and Renfrow (1991). In both studies, it was said that PCK test items should require the application of pedagogical knowledge to specific content areas, which means that the questioned teacher should have enough content knowledge of the topic in order to recognise the correct application of pedagogical strategies. Carlson as well as Kromrey and Renfrow reported difficulties with writing good PCK items that are a balanced blend of content and pedagogical knowledge and have correct and convincing answer alternatives. Unfortunately, statistical analyses were absent and neither study was continued.

PCK is constituted by what a teacher knows, what a teacher does, and the reasons for his actions (Baxter and Lederman, 1999). A multiple choice test is not suited to measure all these appearances of PCK, but is limited to ‘what a teacher knows’, the cognitive aspect of PCK. The reasoning (‘the reasons for his actions’) and behavioural (‘what a teacher does’) aspects
remain uninvestigated when using this method. On the other hand, PCK is not entirely expressed through behaviour and teachers may only use a small portion of their PCK in observed situations. Similarly, interviews will not reveal all reasons for teaching behaviour. However, it may be expected that measurement of (cognitive) PCK with a multiple choice test is a good predictor for behavioural PCK.

4.3 Methodology

4.3.1 Instruments

For the measurement of primary school teachers’ PCK of technology education, an adapted version of the Teaching of Technology Test (TTT) was used (Chapter 3). The TTT is a multiple choice test containing 18 items with four answer alternatives each. The four alternatives were characterised a priori as to require ‘high PCK’, ‘low PCK’, exclusively pedagogical knowledge, or exclusively content knowledge (‘no PCK’). The experts, who produced and judged the items, had a shared view on technology education, which was in line with the view presented in section 4.1, and agreed on the three basic knowledge components of PCK in primary technology education (see section 4.2). Within each of these components subelements of PCK were formulated (e.g., ‘know which (mis)conceptions pupils often have and how to account for this in education’ and ‘know how to translate the nature and purposes of technology education in learning activities’). At least one subelement was represented in each item and it was made sure that the test covered the entire construct of PCK, that is, contained a wide variety of PCK elements. Besides, the items involved different phases of technology class situations (i.e., preparation, instruction and communication, and assessment) and varied on technological topics (i.e., electricity, constructions, mechanic transmissions, and applied physics).

With the intention to determine the convergent validity of the TTT, teachers’ content knowledge of technology was measured with the Cito technology test (Weerden et al., 2003). This test measures factual, or descriptive, knowledge and is originally designed to use with primary school pupils in the end of the sixth (last) grade, but turned out to be useful with primary school teachers as well. The Cito technology test is a multiple choice test that contains 48 items with 3 to 4 answer alternatives. Reliability (Cronbach’s alpha) was found to be 0.79 for the present sample (n = 361).

With the same intention, the Personal Science Teaching Efficacy Belief
(PSTE) scale of the Science Teaching Efficacy Belief Instrument (STEBI) was used to measure self-efficacy in technology teaching. We adapted the STEBI from Bleicher (2004), which is a modification from the original by Enochs and Riggs (1990), translated it into Dutch and slightly revised it to fit the context of technology education. The scale contains 13 items with a 5-point Likert scale. Reliability (Cronbach’s alpha) was found to be 0.91 for the present sample ($n = 354$).

The instruments were completed in the online questionnaire system CORF (www.corfstart.nl). The software packages SPSS 16.0 and Mplus 5.1 were used to analyse the data statistically.

4.3.2 Participants

Participants were recruited through a letter send by mail and, as a reminder, by email to the directive board of all primary schools in the Netherlands (nearly 7000 schools). Teachers from the upper grades (3-6) were asked to participate voluntarily. In order to stimulate participation, 10 annual season tickets for a science center of choice were randomly assigned. Finally, 637 teachers participated, resulting in a response rate of approximately 9% (with the assumption that maximally 1 teacher per school would participate). Only the data of teachers who completed the TTT were included in the sample for the present study.

The sample consisted of 397 primary school teachers (39.2% male and 60.8% female) in the Netherlands. Their mean age was 42.5 years ($sd = 11.9$), their mean years of teaching experience 17.7 years ($sd = 12.1$), and their mean years of technology teaching experience 4.4 years ($sd = 6.8$). Most teachers (88.7%) in the sample taught in the upper grades (3-6) of primary education. The denomination of the schools, in which the teachers worked, was 41.7% Roman catholic, 21.6% protestant, 25.1% public (non-religious), and 11.6% other (e.g., reformed or Muslim). With regard to these variables, the sample is representative for the population of primary school teachers in the Netherlands.

4.3.3 Procedure

The procedure of data analysis started with removing empty and duplicate cases from the data file. Next, item responses on the TTT were checked by means of descriptive statistics. To distinguish between the three different answer categories (high, low, and no PCK), the answer alternatives that represent content knowledge and pedagogical knowledge were combined
(i.e., recoded into a new variable). Subsequently, the TTT scores were tested for being normally distributed and difficulty values of the test items were calculated. Reliability of the TTT was analysed in terms of internal consistency (Cronbach’s alpha) and stability over time (test-retest reliability). To calculate test-retest reliability data of 31 teachers who completed the TTT in October/November 2008 and March 2009 was used. Next, exploratory factor analysis (EFA) was performed to obtain clues for the latent factor models to be tested.

Based on scientific literature on PCK, five latent factor models were defined (see Table 4.1). Model 1 assumed a single underlying factor. That is, different components of PCK were not distinguished and all items were expected to load on one and the same factor. In model 2 two underlying factors were hypothesised. A distinction was supposed between knowledge component 1 and a combined component (2+3). It was theorised that regarding component 2 and 3 as one factor would result in a component that was rather similar to the second component of science PCK reported by Van Driel et al. (1998) (see section 4.2). Component 1 was supposed to be a distinctive component and corresponded with the first component reported by the same authors. This model was tested with correlated (a) and uncorrelated (b) factors, which means that the model is applied less and more stringent, respectively. Model 3 tested the assumption of two correlated main factors (knowledge component 1 and component 2+3) and two correlated subfactors that distinguished between component 2 and 3. In this model, it was supposed that components 2 and 3 were distinctive, but at a lower level than component 1. All items were supposed to load on one of the four factors.

Model 4 assumed three underlying factors that distinguished between the three predefined knowledge components of technology PCK (see section 4.2). Both a correlated (a) and uncorrelated (b) factor structure was tested. In model 5 additional factors that represented the topic components were included. This model assumed three correlated knowledge factors (similar to model 4a) and five correlated topic factors that distinguished between the different topics of the items. This assumption was based on the study of Magnusson et al. (1999), who stated that within each PCK component teachers need to have specific knowledge for each topic. The items were supposed to load on one of the 3 knowledge factors and on one of the five topic factors. For each model various, standard model fit indices (Schermelleh-Engel et al., 2003) were computed, namely Chi-square, Comparative Fit Index (CFI), Tucker Lewis Index (TLI), Root
Table 4.1: Latent factor structures tested with confirmatory factor analysis.

<table>
<thead>
<tr>
<th>Model</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>Model with one factor. Not distinguishing between different components of PCK. All items load on one and the same factor.</td>
</tr>
<tr>
<td>Model 2a</td>
<td>Model with two correlated factors. Distinguishing between knowledge component 1 and 2+3. Items load on one of the factors.</td>
</tr>
<tr>
<td>Model 2b</td>
<td>Model with two uncorrelated factors. Distinguishing between knowledge component 1 and 2+3. Items load on one of the factors.</td>
</tr>
<tr>
<td>Model 3</td>
<td>Model with two correlated main factors, distinguishing between knowledge component 1 and 2+3, and two correlated subfactors, distinguishing between knowledge components 2 and 3. Items load on the main factor or one of the subfactors.</td>
</tr>
<tr>
<td>Model 4a</td>
<td>Model with three correlated factors. Distinguishing between knowledge components 1, 2, and 3. Items load on one of the factors.</td>
</tr>
<tr>
<td>Model 4b</td>
<td>Model with three uncorrelated factors. Distinguishing between knowledge components 1, 2, and 3. Items load on one of the factors.</td>
</tr>
<tr>
<td>Model 5</td>
<td>Model with three correlated factors, distinguishing between knowledge components 1, 2, and 3, and five correlated factors, distinguishing between topics of technology. Items load on one of the 3 knowledge factors and one of the five topic factors.</td>
</tr>
</tbody>
</table>

Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR).

4.4 Results

Regarding the distribution of TTT scores, skewness was found to be slightly negative (−0.11, left skewed), but still within the norms of a normal (Gaussian) distribution. The mean test score was 5.76 (sd = 1.19) on a scale from 1 to 10. The difficulty values (i.e., proportion of correct items) were evenly distributed among the items, with a lowest value of 0.16 and a highest of 0.71 (10 items with difficulty value < 0.50 and 8 items with difficulty value > 0.50). Overall reliability of the test, calculated with Cronbach’s alpha, was 0.34. However, in case of a heterogeneous construct, such as PCK, Cronbach’s alpha is a strict lower bound to reliability and is a poor measure for consistency of the scale (Lucke, 2005). Alternatively, test-retest reliability was calculated by correlating the test scores of both administrations (October/November 2008 and March 2009). Pearson’s correlation coefficient and was found to be 0.622 (p < 0.01, n = 31).

A principal factor analysis with varimax rotation revealed three factors. These factors could be interpreted theoretically as the predefined
knowledge components of PCK. Factor 1 was labelled as *knowledge of pupils’ general concept and misconceptions related to technology*, factor 2 as *knowledge of the nature and purpose of technology education*, and factor 3 as *knowledge of pedagogical approaches and teaching strategies for technology education*. It was noted that factor 2 contained most of the easy items, which could be explained by the kind of knowledge this component contains. In other words, knowledge about the nature and purpose of technology education could be regarded as an ‘easier’ kind of knowledge than the other two components. The EFA gave no clues for any topic (content) related factor structure.

To find out which factor structure underlies primary school teachers’ PCK of technology education, the models in Table 4.1 were tested by use of confirmatory factor analysis (CFA). The fit for each model is presented in Table 4.2. The data did not support the models with one (model 1) or two factors (model 2a and 2b). Model 3, with two main and two subfactors, fitted better than the previous ones, but the fit was still poor. Model 5, which included five topic related factors, did not have any convergence, neither with less topic factors. The model with three correlated factors (4a) fitted the data best. With a non-significant p-value of the Chi-square test, a CFI and TLI that were larger than 0.95, and a RMSEA and SRMR smaller than 0.05, the fit of this model was close. The factors could be denominated as independent, since the correlations between the factors were statistically non-significant (*F1* × *F2*: 0.102; *F1* × *F3*: −0.006; *F2* × *F3*: 0.294), though factor 2 and 3 clearly showed some correspondence.

Factor loadings of the items were investigated in order to (re)interpret the content of each factor (see Table 4.3). On the first factor items 4 and 15 loaded most strongly. Items 11 and 16 loaded most strongly on the second factor and item 7 on the third factor. Item 10 is associated with factor 1 and 2 at the same time. Three items (2, 6, and 14) showed non-

---

**Table 4.2:** Model fit statistics of CFA models.

<table>
<thead>
<tr>
<th>Model</th>
<th>χ²/df/p-value</th>
<th>CFI/TLI</th>
<th>RMSEA</th>
<th>SRMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>182.4/133/0.0029</td>
<td>0.533/0.462</td>
<td>0.031</td>
<td>0.048</td>
</tr>
<tr>
<td>2a</td>
<td>154.5/132/0.0876</td>
<td>0.787/0.753</td>
<td>0.021</td>
<td>0.045</td>
</tr>
<tr>
<td>2b</td>
<td>154.9/134/0.1047</td>
<td>0.803/0.775</td>
<td>0.020</td>
<td>0.045</td>
</tr>
<tr>
<td>3</td>
<td>149.0/132/0.1485</td>
<td>0.840/0.814</td>
<td>0.018</td>
<td>0.044</td>
</tr>
<tr>
<td>4a</td>
<td>134.4/131/0.4022</td>
<td>0.968/0.963</td>
<td>0.008</td>
<td>0.041</td>
</tr>
<tr>
<td>4b</td>
<td>138.9/134/0.3683</td>
<td>0.954/0.947</td>
<td>0.010</td>
<td>0.042</td>
</tr>
<tr>
<td>5</td>
<td>no convergence</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4.3: Factor loadings (standardised) and percentages explained variance.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Item</th>
<th>Factor loading</th>
<th>Expl. var. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0.182</td>
<td>3.3</td>
</tr>
<tr>
<td>2</td>
<td>0.086</td>
<td>n.s.</td>
<td>0.7</td>
</tr>
<tr>
<td>3</td>
<td>0.221</td>
<td></td>
<td>4.9</td>
</tr>
<tr>
<td>4</td>
<td>0.466</td>
<td></td>
<td>21.7</td>
</tr>
<tr>
<td>10</td>
<td>0.318</td>
<td></td>
<td>16.5</td>
</tr>
<tr>
<td>13</td>
<td>0.210</td>
<td></td>
<td>4.4</td>
</tr>
<tr>
<td>15</td>
<td>0.408</td>
<td></td>
<td>16.7</td>
</tr>
<tr>
<td>19</td>
<td>0.282</td>
<td></td>
<td>8.0</td>
</tr>
<tr>
<td>2</td>
<td>0.222</td>
<td></td>
<td>16.5</td>
</tr>
<tr>
<td>11</td>
<td>0.519</td>
<td></td>
<td>26.9</td>
</tr>
<tr>
<td>16</td>
<td>0.340</td>
<td></td>
<td>11.5</td>
</tr>
<tr>
<td>17</td>
<td>0.214</td>
<td></td>
<td>4.6</td>
</tr>
<tr>
<td>18</td>
<td>0.185</td>
<td></td>
<td>3.4</td>
</tr>
<tr>
<td>3</td>
<td>0.273</td>
<td></td>
<td>7.5</td>
</tr>
<tr>
<td>6</td>
<td>0.077</td>
<td>n.s.</td>
<td>0.6</td>
</tr>
<tr>
<td>7</td>
<td>0.467</td>
<td></td>
<td>21.8</td>
</tr>
<tr>
<td>8</td>
<td>0.244</td>
<td></td>
<td>6.0</td>
</tr>
<tr>
<td>12</td>
<td>0.258</td>
<td></td>
<td>6.6</td>
</tr>
<tr>
<td>14</td>
<td>0.042</td>
<td>n.s.</td>
<td>0.2</td>
</tr>
</tbody>
</table>

significant factor loadings. Omitting item 14, which is the item with lowest factor loading, from the CFA caused a slight improvement of model fit. In addition to the factor loadings, the percentages of variance explained in each of the items are shown in Table 4.3. The percentages range between 0.2% (item 14) and 26.9% (item 11). The largest amount of variance was explained for item 11. The least amount was explained for item 14.

Reliability of the three factors was investigated by calculating internal consistency (Cronbach’s alpha) and stability (test-retest reliability). For factor 1 an alpha of 0.39 was found (0.41 without item 2). For factor 2 alpha was 0.34 and for factor 3 alpha was 0.23 (0.27 without items 6 and 14). Because of the heterogeneous nature of pck, internal consistency was not expected to be high. Alternatively, test-retest reliability was calculated by correlating the test scores on the three subscales (factors) separately. For factor 1 the Pearson correlation coefficient was 0.325 ($p < 0.01$), for factor 2 0.516 ($p < 0.01$), and for factor 3 0.373 ($p < 0.01$). To recall, test-retest reliability for the overall test was 0.622 ($p < 0.01, n = 31$).

In order to examine convergent validity of the TTT, correlations with test scores on the Cito technology test and STEBI (PSTE scale) were calculated. The correlation coefficient between the TTT score and the Cito
score was significant and positive, but small ($r = 0.153, p < 0.01$). The same applies for the correlation between the TTT score and the STEBI score ($r = 0.208, p < 0.01$). These correlations coefficients were expected to be small, because both the Cito and the STEBI measure different constructs (respectively, content knowledge and self-efficacy) compared to the TTT (PCK). Besides, low internal consistency of the TTT causes an attenuation effect that weakens the correlation. The correlations coefficients after correction for attenuation are respectively 0.401 (medium) and 0.239 (small).

### 4.5 Conclusions and discussion

The focus of the reported study was twofold. Firstly, it was aimed at validating the Teaching of Technology Test (TTT) on a large scale. Secondly, we investigated the concept of technology PCK of primary school teachers by analysing the latent factor structure with use of CFA models.

The CFA model with three factors (model 4a) showed the best fit with the data, which indicates that the knowledge components of technology PCK can be distinguished in three factors, as was expected from the literature. However, the factors have relatively low factor loadings and explain relatively small amounts of variance. That is, the factor structure is not prominently present and seems to be obscured by intervening elements. A possible explanation is that the items are aggregated, that is, consist of several intrinsic elements that interrelate to some extent, but not strongly. These intrinsic elements could be the predefined subelements of PCK, which were formulated in preparation of writing the items, but could also be other elements that are inherent to PCK (e.g., topic and/or phase of teaching activity). Alternatively, the items could contain extrinsic ‘noise’ (i.e., disturbing elements), such as interpretation difficulties related to complexity or text length of the items.

Items with a high factor loading and which have a large amount of explained variance are good representatives of the scale. Regarding factor 1, items 4 (see Figure 4.1) and 15 had relatively high factor loadings. Both items clearly handle with the way pupils experience the technological world around them and how education can change misconceptions into correct conceptions. Items 11 (see Figure 4.2) and 16, which loaded high on factor 2, focus on two core characteristics of technology education, namely hands-on experiences and authentic problems. Factor 3 contains items that are related to pedagogical strategies. Item 7 (see Figure 4.3), which had the highest factor loading, deals with the important pedagogical strategy
Two pupils together make a car out of cardboard (see pictures above), which can move due to a rotatable axle to which wheels made from bottle tops have been attached. The car can move forwards by winding up an elastic band attached to the axle and then letting go. The pupils test their car on a smooth table. However, they are disappointed to discover that although the wheels rotate, the car scarcely moves forward. The pupils suspect that their car is too heavy but do not know a solution for this problem.

Which one of the following approaches can best be used to help these pupils?

a. You join in with pupils’ line of thought and from this perspective you try to help them discover the relationship between friction, drive and weight.

b. You draw the pupil’s attention to the elastic band and the weight of the car and make sure that they continue searching for a solution.

c. You let the pupils compare their car with those of the other pupils so that they can reach a solution.

d. You explain to the pupils that two smooth surfaces easily move over each other due to the lack of friction. You advise them to attach elastic bands to the wheels to give these more grip.

**Figure 4.1:** Item 4 of the Teaching of Technology Test.

of asking learning questions that make pupils think critically. Item 10 (see Figure 4.4) loaded on both factor 1 and 2. This implies that these knowledge components were both needed to choose the best alternative (high PCK). Item 10 is about pupils’ conception of fuses in electrical circuits and about how to avoid misconceptions concerning this topic (factor 1). At the same time, the item concerns the notion that technology education are hands-on activities by nature (factor 2).

The items with a non-significant factor loading (items 2, 6, and 14) have a low predictive value for the scale. When taking a closer look at these items, it appears that they didn’t succeed in being a good blend of the application of content and pedagogical knowledge in order to choose the best answer. Here, the balance turned over to the side of pedagogical knowledge. As Kromrey and Renfrow (1991) and Carlson (1990) noted, scoring high on PCK means that teachers have enough content knowledge to recognise the correct application of pedagogical strategies. The content knowledge part seems to be under-represented in these items.

With regard to the conceptualisation of primary school teachers’ PCK in technology education, we conclude that the presupposed factor structure of three knowledge components is confirmed. The first factor, labelled knowledge of pupils’ general concept and misconceptions related to technology,
As the teacher of grade 6 (11/12-year-olds) you want to teach the pupils how to allow for the forces that affect constructions and materials when they build something. The pupils are shown photos of chairs made from corrugated cardboard. They can see that corrugated cardboard constructions can be very strong. You want to explain the following terms: squeezing together (compression), tension, bending, twisting (torsion) and displacement. You show the pupils the diagram pictured above as a visual aid.

Which of the following methods is the most appropriate for explaining the terms?

a. The pupils design, make and test their own corrugated cardboard chair. Using the diagram an accurate analysis is made of what happens to the material and the construction when a load is placed on the chair and which forces play a role in this. Pupils are then given the task of making the chair even stronger still.

b. The pupils build a corrugated cardboard chair using an instruction sheet. They carefully analyse what happens to the material and the construction when a load is placed on the chair and which forces play a role in this. Then with the help of the diagram the pupils describe in their own words what happens if the construction or the material is not good.

c. You show the pupils a flimsy corrugated cardboard chair. You demonstrate that the chair sags and is not stable if you sit on it. Then you let the pupils make a strong corrugated cardboard chair. The diagram serves to support this task.

d. All of the pupils are given the diagram and several pieces of corrugated cardboard. You show the pupils how different ways of loading affect the corrugated cardboard. Using the diagram you explain exactly what happens. Then with the help of the diagram the pupils are given the task of assessing the various demonstration chairs for strength.

**Figure 4.2:** Item 11 of the Teaching of Technology Test.

can be best indicated as knowing how to adjust activities to pupils’ experiences of the technological world around them and their (mis)conceptions of technological topics. The second factor, *knowledge of the nature and purpose of technology education*, is about knowing the core characteristics of technology education, i.e., hands-on experiences and authentic problem solving. The third factor, *knowledge of pedagogical approaches and teaching strategies for technology education*, has mainly to do with the art of asking questions that encourage pupils to think critically about the technological problem encountered.

However, the factor structure turned out to be obscured by many other intrinsic elements of PCK. We therefore conclude that PCK is a heterogeneous construct by nature. This implies that PCK consists of multiple intrinsic elements which can hardly be unraveled. When Shulman introduced PCK as “a special amalgam of content and pedagogy” (Shulman, 1987, p. 8), he chose his words carefully. In chemical terms, an amalgam
Two pupils have built a big wheel from K’nex (see the pictures above). The motor is attached to a gear that drives another gear (of equal size) on the axis of the big wheel. As a teacher you want to pose a question to encourage the pupils to formulate their own questions about cause-effect.

Which of the following questions can best be posed for this purpose?

a. "Can you change something on the big wheel so that it turns faster?"

b. "If you swap this small gear with a bigger gear what will happen to the turning speed?"

c. "Have you already changed something about the big wheel?"

d. "How often does the big wheel turn in one minute if you make the gears twice as large?"

**Figure 4.3:** Item 7 of the Teaching of Technology Test.

is a metallic alloy formed by a chemical reaction of mercury and another metal element (e.g., silver, copper, or zinc). An amalgam has other (preferably better) characteristics than the two elements of which it is composed. Besides, it is impossible to distinguish the elements of an amalgam with the eye or even with a microscope. Thus, the amalgam of PCK is more than a mixture of content knowledge and pedagogical knowledge, in which the elements would be easily recognised, and the elements of PCK are difficult to resolve in their ‘pure’ forms. Moreover, PCK is not only an amalgam of the elements content and pedagogy, but also an amalgam of its numerous subelements. PCK truly is a special amalgam.

The model with factors concerning the technological topics of the items (model 5) did not fit the data at all. That is, no topic factors could be distinguished. Therefore, we conclude that the technological topic of a PCK item, such as electricity or constructions, was not confirmed to be an intrinsic component of technology PCK for primary school teachers. This finding is in agreement with the ideas of Appleton (2008), who suggested that the PCK development of primary school teachers may differ from secondary school teachers, because primary school teachers usually do not specialise in a specific domain and, therefore, do not develop specific PCK for all different subjects and topics they teach.
There is a power cut at the school because the fuses have blown.

Which of the following technology activities can you best use in this situation to explain how fuses work?

a. The pupils make an electrical circuit with a variable voltage source, lamp and wires. They investigate how a fuse works by placing a real fuse in the electrical circuit and letting this blow.

b. The pupils make an electrical circuit with a variable voltage source, lamp and wires. How a fuse works is investigated by placing steel wool in the circuit and pointing out the sparks to the pupils.

c. You invite the electrician from the energy company who fixed the fuses to talk to the class about what was wrong and how he solved the problem.

d. You use a circuit diagram to explain how the fuse box in the school building works.

Figure 4.4: Item 10 of the Teaching of Technology Test.

With regard to the validation of the TTT, we conclude that the instrument is valid in terms of convergent and content validity. As expected from literature on PCK in science education (Van Driel et al., 1998; Park and Oliver, 2008), the test scores correlated significantly with the scores on tests that measure content knowledge (Cito) and self-efficacy (STEBI). Regarding content validity, the experts who wrote and judged the items all agreed on the selection of items that form the test (for more information on the construction of the test see chapter 3). Concerning the reliability of the test, Cronbach’s alpha was found to be low, both for the three subscales as for the overall scale. However, the low alpha’s could be explained by the heterogeneous nature of the measured construct, PCK (Lucke, 2005). Besides, calculation of test-retest reliability showed that the test is satisfactory consistent over time.

Nonetheless, steps could be taken to further improve the validity and reliability of the TTT. According to the Spearman-Brown prophecy formula, Cronbach’s alpha will increase with lengthening of the test. When alpha is set at 0.60, the test needs to be lengthened 2.9 times. This implies that the test will contain at least 52 instead of 18 items. These extra items need to be similar to the original ones to avoid adding more heterogeneity to the scale (and thereby lowering the alpha). Although introducing parallel items will improve homogeneity of the scale, this is undesirable. By adding more parallel items the TTT will lose (part of) its validity, because heterogeneity is an inherent aspect of PCK. In this way, certain aspects of PCK would be over-represented and the measurement of PCK would not provide a complete and balanced picture of a teacher’s PCK. Hence, it should be attempted to find an optimal balance between homogeneity and validity.

In order to improve the predictive validity of the test, the TTT scores, which focus on the cognitive part of PCK, could be related to results from
qualitative methods, which mainly measure the reasoning and behavioural part of PCK. It is expected that the TTT scores can predict teaching behaviour and reasoning regarding PCK correctly. That is, a high score on the TTT is expected to relate positively with teaching behaviour and reasoning that shows high amounts of PCK. Moreover, content validity of the TTT could be further improved by having the respondents think aloud while answering the test items.

Nonetheless, compared to other approaches of measuring PCK, such as the multi method evaluations, the TTT has clear-cut advantages. First of all, collecting data with the TTT is far more time and labour efficient. The same accounts for the analysis of data. Time and labour efficiency opens doors for data collection with large samples, which, in turn, makes generalisation of the results legitimate. Second, psychometric quality indicators of the measurement are relatively easy to obtain and are more objective than non-statistical indicators of quality. Besides, qualitative methods to measure PCK have to deal with the same heterogeneous nature of PCK, but this problem is obscured by the absence of psychometric indices. As Abell (2008) concluded, it is time to shift from descriptive, small-scale studies to explanatory, large-scale studies to give a new impetus to research on PCK in science education. Measurement of PCK with a multiple choice test enables this kind of research.

On the whole, we consider further research on PCK in science and technology education valuable. Approaching the construct of PCK from different perspectives, e.g., investigating PCK with use of innovative methodologies, will provide a more comprehensive picture of this important domain of teacher knowledge. More scientific knowledge on the concept of PCK could support specific professionalisation of teachers and, consequently, contribute to the quality of science and technology education.

Note

The Teaching of Technology Test is available on request for scientific purposes only. Please contact the author by e-mail: e.rohaan@fontys.nl.

Bibliography

CONCEPTUALISING PCK


Chapter 5

Analysing teacher knowledge of technology education and its effects on pupils’ concept and attitude*

abstract

Teacher knowledge of technology education in primary schools and the effects of teacher knowledge on pupils’ concept and attitude regarding technology were empirically investigated by means of path analysis. Although teacher knowledge is generally assumed to play an important role in affecting pupils’ concept and attitude regarding technology, empirical evidence is scarce. Three domains of teacher knowledge, (A) subject matter knowledge (SMK), (B) pedagogical content knowledge (PCK), and (C) attitude and self-efficacy, were measured with tests and questionnaires. Besides, quantitative data on pupils’ concept and attitude were collected. It was found that SMK is an important factor for PCK and self-efficacy. Subsequently, self-efficacy showed to have a strong influence on teachers’ attitude towards technology. Besides, teachers’ PCK was found to be the most important teacher knowledge domain in affecting pupils’ concept of technology. Teachers’ attitude could not be confirmed to have any statistically significant influence on pupils’ attitude. It is recommended that teacher training should focus on the development of teachers’ SMK as well as PCK.

5.1 Introduction

Primary school (K-6) technology education in the Netherlands is part of an integrative domain called science and technology education, which was introduced around the year 2000, but is structurally implemented in only a small number of curricula. For the entire learning domain, seven standards are formulated, two of which are specifically concerned with technology education: (1) pupils learn to find connections between the functioning, design, and use of materials of products in their own environment, and (2) pupils learn to design, realise, and evaluate solutions for technical problems (Greven and Letschert, 2006). Because these standards are formulated in a rather general way, a governmentally approved framework of key learning areas is not available, and textbooks and learning materials are still under construction, it is often the teachers themselves who decide what and how technology is taught in the classrooms. However, most primary school teachers in the Netherlands have not received any training in teaching technology and their affinity with technology is often low.

When high quality technology education is aimed for, high quality technology teachers are required. But what do primary school teachers need to know in order to be high quality technology teachers? And what are the cognitions and beliefs that underlie teachers’ behaviour during technology activities? To answer these questions, we need to study the concept of teacher knowledge, which can be defined as “the whole of knowledge and insights that underlie teachers’ actions in practice” (Verloop et al., 2001, p. 446). Teacher knowledge guides a teacher’s behaviour in the classroom. It is personal knowledge that is acquired through experiences in his or her own teaching practice. Besides, it is partly tacit knowledge, which implies that teachers are unable to articulate some of their acquired teacher knowledge. Furthermore, teacher knowledge is integrated knowledge, consisting of scientific as well as non-scientific elements. Beliefs are closely interwoven and play an important role in constructing and organising teacher knowledge (Van Driel et al., 2001). Various other terms have been used to describe the concept of teacher knowledge, e.g., ‘craft knowledge’ (Grimmett and MacKinnon, 1992) and ‘practical knowledge’ (Van Driel et al., 2001).

Grossman (1990) designed a model of teacher knowledge with four knowledge domains: subject matter knowledge (SMK), general pedagogical knowledge, knowledge of context, and pedagogical content knowledge (PCK). In this model, PCK is presented as the central domain, which reciprocally interacts with the other domains. Opposed to this so-called
transformative model, in which PCK is a transformation of different knowledge domains into a new and unique domain, the integrative models do not present PCK as a knowledge domain on its own. In the integrative models teaching is seen as an act of integrating knowledge of the subject, pedagogy, and context (Gess-Newsome and Lederman, 1999). Despite of the strong simplification of reality, both of these structural models are useful when studying teacher knowledge. In this study, the transformative models of teacher knowledge are supported.

The presented study focussed on technology-specific teacher knowledge. That is, only knowledge domains that are specific for technology education were included. Three domains of teacher knowledge were defined for the purpose of this study: (A) SMK, (B) PCK, and (C) attitude and self-efficacy (the affective domain). SMK is knowledge about the content that is to be taught. This knowledge domain contains conceptual and procedural knowledge, on the one hand, and understanding of the nature of the subject, on the other (Grossman, 1990). Conceptual knowledge is knowledge of facts, principles, and theories. This includes knowledge about technological concepts, e.g., energy and power, constructions, transportation, ICT, and electronics. Procedural knowledge of technology is mainly concerned with knowledge to solve technological design problems (Garmire and Pearson, 2006), but also includes determining and controlling, utilising, and assessing impacts of technology (ITEA, 2006). Understanding of the nature of the subject has to do with teachers’ concept or perception of technology and includes understanding the differences between science and technology, e.g., the objective of both disciplines (i.e., while science aims at developing new knowledge about the natural world, technology aims at changing the world according to human needs (De Vries, 2005)).

PCK is conceptualised in many different ways by various researchers (Van Driel et al., 1998). For the present study, three basic knowledge components of PCK in technology education for primary schools were formulated: (1) knowledge of pupils’ concept of technology and knowledge of their pre- and misconceptions related to technology, (2) knowledge of the nature and purpose of technology education, and (3) knowledge of pedagogical approaches and teaching strategies for technology education (Chapter 2). Most researchers assume SMK to be a prerequisite for the development of PCK (Van Driel et al., 1998). Besides, the components of PCK function as a whole and an effective teacher needs to have knowledge of every PCK component (Magnusson et al., 1999). PCK development of primary school teachers may differ from secondary school teachers, be-
cause they usually do not specialise in a specific subject area. Therefore, they may not develop specific PCK for all different subjects and topics they teach, but instead develop PCK on a more general level (Appleton, 2008).

Attitude towards technology and self-efficacy in teaching technology form the affective domain of teacher knowledge in this study. It is generally agreed upon that one’s attitude “represents a summary evaluation of a psychological object captured in such attribute dimensions as good-bad, harmful-beneficial, pleasant-unpleasant, and likable-dislikable” (Ajzen, 2001, p. 28). Attitudes are influenced by cognition as well as by affect. Hence, teachers’ attitude towards technology is affected by their concept of technology and their feelings about technology. Teachers’ beliefs about their ability to enact effective teaching methods for specific teaching goals (i.e., self-efficacy or confidence in teaching), was proposed to be an affective affiliate of PCK (Park and Oliver, 2008). Confidence in teaching science was assumed to be an important condition for the development of science PCK of primary school teachers (Appleton, 2008). Besides, teachers usually spend less time on subject areas in which their perceived self-efficacy was low (Mulholland and Wallace, 2001). In a study that aimed to broaden pre-service teachers’ perceptions of technology by engagement in a technology unit of study, many teachers reported they had achieved enough confidence and capability to teach technology in primary schools (McRobbie et al., 2000). This implies that enhanced knowledge of the subject is related to enhanced confidence in teaching the subject. However, in another study it was concluded that confidence in teaching not necessarily results from SMK and PCK (Johnston and Ahtee, 2006).

Many pupils have a limited concept of technology, i.e., associating technology only with electricity, computers, and modern appliances (Jarvis and Rennie, 1996; Cunningham et al., 2005). Education should help pupils to develop a concept of technology that is more solid and accurate. Moreover, if primary school pupils would associate positive technology experiences with technology in general, they are more likely to value and choose technology as a study or career later in life (Jarvis and Rennie, 1996). From PATT (Pupils’ Attitude Towards Technology) studies it can be concluded that a comprehensive concept of technology corresponds with a positive attitude towards technology. Therefore, it is of great importance that technology education is taught in a way that provides pupils with a comprehensive concept of technology (De Vries, 2000).

As concluded in a previous literature review (Chapter 2), teacher knowledge affects teaching and, in turn, is assumed to affect pupils’ concept of
and attitude towards technology. However, empirical evidence on the relations between teacher knowledge and pupils’ concept and attitude is scarce. In this study, it is empirically investigated to what extent different domains of technology-specific teacher knowledge play a role in improving pupils’ concept of and affecting pupils’ attitude towards technology. The two main research questions of this study are formulated as follows.

1. What teacher knowledge (i.e., SMK, PCK, attitude and self-efficacy) of technology do primary school teachers have and how are these different knowledge domains related?

2. What effect has teacher knowledge of technology on pupils’ concept of and attitude towards technology?

Based on a literature review (Chapter 2), it is expected that teachers’ SMK positively affects their pupils’ concept and that teachers’ attitude positively affects their pupils’ attitude. Besides, teachers’ PCK is supposed to affect both pupils’ concept and attitude. In Figure 5.1 all hypothesised relations are schematically presented. Path analysis was used to test these hypotheses.

In the next section, the methodology, which includes the instruments, participants, and procedure, of this study is described. Thereafter, the results of two sub studies, (1) teacher knowledge domains and (2) teacher knowledge effects on pupils’ concept and attitude, which respectively refer to the two research questions, are reported. In the concluding section,
answers to the research questions are formulated and the study is critically discussed.

5.2 Methodology

5.2.1 Instruments

To measure teachers’ PCK of technology education, the Teaching of Technology Test (TTT) (Chapter 3) was used. This multiple choice test contains 18 items with four answer alternatives each. The four alternatives can be characterised as representing ‘high PCK’, ‘low PCK’, pedagogical knowledge, and content knowledge (‘no PCK’). The test consists of three sub scales which represent the three predefined knowledge components of PCK: (1) knowledge of pupils’ general concept and misconceptions related to technology, (2) knowledge of the nature and purpose of technology education, and (3) knowledge of pedagogical approaches and teaching strategies for technology education. The items involve different phases of technology class situations, i.e., preparation, instruction and communication, and assessment, and vary on technological topics (i.e., electricity, constructions, mechanic transmissions, and applied physics). Because of the heterogeneous nature of PCK, test-retest reliability was chosen as an alternative measure for consistency of the test. Pearson’s correlation coefficient was found to be 0.622 \((n = 31)\), which means that the test is moderately reliable over time. (For a study on the construction and validation of the TTT see chapter 3.)

Teachers’ SMK of technology was measured with the Cito technology test (Weerden et al., 2003). This test measures conceptual knowledge of technology and is originally designed to use with primary school pupils in the end of the sixth grade (12-year-olds), but turned out to be useful as well with the present sample of primary school teachers. The Cito technology test is a multiple choice test that contains 48 items with 3 to 4 answer alternatives. Reliability in terms of Cronbach’s alpha was found to be 0.79 in the sample of the present study \((n = 361)\).

The Personal Science Teaching Efficacy Belief (PSTE) scale of the Science Teaching Efficacy Belief Instrument (STEBI), was used to measure self-efficacy in technology teaching. We adapted the STEBI from Bleicher (2004), which is a modification from the original by Enochs and Riggs (1990), translated it into Dutch and slightly revised it to fit to the context of technology education in primary schools. The PSTE scale contains 13 items with a 5-point Likert scale. Reliability in terms of Cronbach’s alpha...
was found to be 0.91 in the present sample ($n = 354$).

With the vtb attitude instrument (Walma van der Molen et al., 2007) teachers’ attitude towards technology was measured. The instrument consists of a science and technology scale, of which only the technology scale was used in this study. The technology scale has 18 items distributed over five sub scales (i.e., gender issues, societal relevance, interest, future intentions, and difficulty) and makes use of a 4-point Likert scale. Reliability in terms of Cronbach’s alpha was found to be 0.85 in the present sample ($n = 356$).

In order to chart pupils’ concept of and attitude towards technology, the Technology Questionnaire (tq) (Rennie and Jarvis, 1995) was administered. This questionnaire has two main scales, one to determine pupils’ concept of technology (scale A) and one to assess their attitude towards technology (scale B). Each scale contains 10 items divided into two sub scales. For scale A these sub scales are diversity (narrow/broad concept of technology) and design (design is small/big part of technology). For scale B these are societal relevance (technology is little/highly relevant for society) and interest (low/high interest in technology). Concept and attitude are measured on a 5-point Likert scale. In the present sample reliability (Cronbach’s alpha) was found to be 0.43 for scale A and 0.77 for scale B ($n = 1584$). The low alpha of scale A indicated that the pupils in this sample answered the questions in an unsystematic way, probably because their concept of technology is still too premature. The alpha’s of both sub scales (diversity and design) were low, 0.49 and 0.48 respectively. Unfortunately, no other data on pupils’ concept of technology were collected.

In Table 5.1 an overview of the instruments is provided. All instruments were administered through the online questionnaire system CORF (www.corfstart.nl). For statistical analysis of the data the software packages SPSS 16.0 and Mplus 5.1 were used.

5.2.2 Participants

Participants were recruited through a letter send by mail and, as a reminder, by email to the directive board of all primary schools in the Netherlands (nearly 7000 schools). Teachers from the upper grades (3-6) and their pupils were asked to participate voluntarily. In order to stimulate participation, 10 annual season tickets for a science center of choice were given away at random.

The teachers sample consisted of 354 primary school teachers (61.6% female and 38.4% male) in the Netherlands. Their mean age was 42.5 years
Table 5.1: Overview of instruments used in this study.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Instrument</th>
<th>Reliability</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCK</td>
<td>TTT</td>
<td>0.622a</td>
<td><em>This thesis (chapter 3 and 4)</em></td>
</tr>
<tr>
<td>SMK</td>
<td>Cito</td>
<td>0.79b</td>
<td>Weerden et al. (2003)</td>
</tr>
<tr>
<td>Self efficacy</td>
<td>STEBI (PSTE)</td>
<td>0.91b</td>
<td>Bleicher (2004)</td>
</tr>
<tr>
<td>Attitude</td>
<td>VTB</td>
<td>0.85b</td>
<td>Walma van der Molen et al. (2007)</td>
</tr>
<tr>
<td>Pupils’ concept</td>
<td>TQ (A)</td>
<td>0.43b</td>
<td>Rennie and Jarvis (1995)</td>
</tr>
<tr>
<td>Pupils’ attitude</td>
<td>TQ (B)</td>
<td>0.77b</td>
<td>Rennie and Jarvis (1995)</td>
</tr>
</tbody>
</table>

*a* Pearson correlation coefficient (consistency over time).

*b* Cronbach’s alpha (internal consistency).

(sd = 12.0), their mean years of teaching experience 17.6 years (sd = 12.1), and their mean years of technology teaching experience 4.3 years (sd = 6.7). For these variables, the sample is representative for the population of primary school teachers in the Netherlands. Most teachers (91.4%) taught in the upper grades (3-6) of primary education. A refresher course in technology education was completed by 26.3% of the teachers in the sample.

Part of the teachers sample participated together with their pupils (79 teachers with 1584 pupils). Their mean age was 41.9 years (sd = 12.6), their teaching experience 17.8 years (sd = 12.4), and their technology teaching experience 4.6 years (sd = 6.5). In this sample 57% were female teachers and 43% male teachers. They all taught in the upper grades (3-6) of primary education.

5.2.3 Procedure

The data analysis was performed in several stages. First, empty and duplicate cases were removed from the data file. A descriptive analysis was done in order to check the sample characteristics. Before calculating the test scores, negative formulated items were recoded. After recoding, test scores (means and standard deviations) were calculated and checked on being normally distributed.

Reliability (internal consistency) of the instruments, and their sub scales, was analysed by calculating Cronbach’s alpha. Additionally, for the TTT test-retest reliability (stability over time) was calculated by correlating the test scores of two consecutive administrations in one group of teachers (n = 31). Subsequently, Pearson product-moment correlations
between test scores were computed in order to explore the relations between the measured variables. This was done for all test scores in the teachers as well as the teachers with pupils sample.

In order to uncover the causal relations between (1) the different teacher knowledge domains and between (2) teacher knowledge and pupils’ concept and attitude, two path models were defined. With regard to the teacher knowledge domains, the path model tested was as follows. Self-efficacy was hypothesised to be affected by SMK and PCK. PCK would be affected by SMK, and attitude was assumed to be affected by SMK and self-efficacy. With reference to the hypothetical diagram (Figure 5.1), this path model concerned the relations a (SMK with PCK), b (SMK with attitude and self-efficacy), and c (PCK with self-efficacy). Moreover, between self-efficacy and attitude, the two components of the affective domain, a relation from self-efficacy to attitude was hypothesised. Hence, the relation between PCK and attitude was supposed to be mediated by self-efficacy.

With regard to the effects of teacher knowledge on pupils’ concept and attitude, a second path model was tested. In this model the above mentioned path model of teacher knowledge domains was included. Furthermore, it was expected that pupils’ concept would be influenced by teacher’s SMK and PCK, and pupils’ attitude would be influenced by teacher’s attitude and PCK. With reference to the hypothetical diagram (Figure 5.1), this path model concerned the relations d (teacher’s SMK with pupils’ concept), e (teacher’s PCK with pupils’ concept), f (teacher’s PCK with pupils’ attitude), and g (teacher’s attitude with pupils’ attitude). The path model was tested on the level of a teacher’s class. That is, the pupils’ test scores that were used in the path analysis were all mean group scores.

5.3 Results

5.3.1 Teacher knowledge domains

Table 5.2 presents the mean test scores, standard deviations, and Pearson product-moment correlations for the variables used in the path model of teacher knowledge domains. Teachers’ PCK of technology education ranged from 2.8 to 8.6 on a scale from 1 to 10. The mean score was 5.8 ($sd = 1.1$), which implies that, on average, primary school teachers had developed a basic level of PCK in technology education. Furthermore, they averaged rather high on SMK with a mean score of 8.0 ($sd = 1.0$) and a score range from 3.1 to 9.8. It has to be noticed, that the SMK test was originally constructed for 6-graders (age 11-12) and could be indicated as easy for
Table 5.2: Mean test scores, standard deviations, and correlations of variables in the path model of teacher knowledge domains ($n = 354$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>PCK</th>
<th>SMK</th>
<th>SEF</th>
<th>ATT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCK</td>
<td>5.8</td>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMK</td>
<td>8.0</td>
<td>1.0</td>
<td>0.184**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEF</td>
<td>45.4</td>
<td>8.5</td>
<td>0.153**</td>
<td>0.372**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATT</td>
<td>52.6</td>
<td>7.1</td>
<td>0.122*</td>
<td>0.365**</td>
<td>0.594**</td>
<td></td>
</tr>
</tbody>
</table>

PCK = pedagogical content knowledge; SMK = subject matter knowledge; SEF = self-efficacy; ATT = attitude.

* $p < 0.05$, ** $p < 0.01$.

primary school teachers.

On the self-efficacy in technology teaching scale, scores ranged from 17.0 to 64.0 and the mean score was 45.4 ($sd = 8.5$). A mean score per item of 3.5 on the 5-point Likert scale suggested that, on average, teachers were moderately confident in teaching technology. Teachers’ attitude towards technology had a mean score of 52.6 ($sd = 7.1$) with a score range from 23.0 to 71.0. A mean score per item of 2.9 on the 4-point Likert scale indicated that, on average, teachers had a more positive than negative attitude.

All correlations between the variables of teacher knowledge were statistically significant. The magnitudes varied from small (0.122) to large (0.594). Small size correlations were found between PCK and SMK, PCK and self-efficacy, and PCK and attitude. These correlations sizes were probably affected by the low alpha (0.34) of the PCK test (i.e., attenuation effect). This low alpha is inherent to the heterogeneous nature of the construct (Chapter 3 and 4). Medium size correlations were found between SMK and self-efficacy, and SMK and attitude. A large correlation was found between self-efficacy and attitude.

Figure 5.2 illustrates the path model of teacher knowledge domains with all standardised path coefficients. According to commonly used fit indices (Schermelleh-Engel et al., 2003), a non-significant p-value of the Chi-square test (0.8191), a CFI and TLI that were larger than 0.95 (resp., 1.000 and 1.025), and a RMSEA and SRMR smaller than 0.05 (resp., 0.000 and 0.003), the fit of this model was very close. All paths in the model showed significant effects, except for the path from PCK to self-efficacy. However, when assuming all measurements to be perfectly reliable in terms of internal consistency, i.e., correcting for attenuation effects, this path had a standardised estimate of 0.355. Moreover, with attenuation correction,
the path coefficient of the path from SMK to PCK became a large direct effect of 0.624. All paths were positively related, as hypothesised.

The significant path coefficients varied from small (0.166) to large (0.532). The total effect of SMK on self-efficacy was found to be a medium effect of 0.372 (0.356 + (0.184 * 0.088)) and the total effect of SMK on attitude was found to be a medium effect of 0.355 (0.166 + (0.356 * 0.532)). Table 5.3 provides all path coefficients, p-values, and explained variances of this path model. The variance of attitude was explained for 37.6% by self-efficacy and SMK. The variance of self-efficacy was explained for 14.6% by SMK and PCK. For PCK, only 3.4% of the variance was explained by SMK in this model.

### 5.3.2 Teacher knowledge effects on pupils' concept and attitude

In Table 5.4 the mean test scores, standard deviations, and Pearson product-moment correlations for the variables used in the path model of teacher knowledge effects on pupils' concept and attitude are presented. In this sample ($n = 79$), the teachers had similar mean scores regarding PCK, SMK, self efficacy, and attitude compared to the teachers sample ($n = 354$). The pupils in this sample scored 33.6 ($sd = 2.3$) on average on the concept of technology scale. The scores ranged from 26.0 to 37.7 on a scale from 10 to 50. The mean score per item was 3.4 on a 5-point Likert scale, which
Table 5.3: Standardised path coefficients, p-values, and explained variances ($R^2$) from path model of teacher knowledge domains.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Estimate</th>
<th>p</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>On ATT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of SEF</td>
<td>0.532</td>
<td>0.000</td>
<td>0.376</td>
</tr>
<tr>
<td>of SMK</td>
<td>0.166</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>On SEF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of SMK</td>
<td>0.356</td>
<td>0.000</td>
<td>0.146</td>
</tr>
<tr>
<td>of PCK</td>
<td>0.088</td>
<td>0.078 n.s.</td>
<td></td>
</tr>
<tr>
<td>On PCK</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of SMK</td>
<td>0.184</td>
<td>0.000</td>
<td>0.034</td>
</tr>
</tbody>
</table>

Table 5.4: Mean test scores, standard deviations, and correlations of les in the path model of teacher knowledge effects on pupils’ concept and attitude ($n = 79$).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
<th>PCK</th>
<th>SMK</th>
<th>SEF</th>
<th>ATT</th>
<th>pCON</th>
<th>pATT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCK</td>
<td>5.7</td>
<td>1.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SMK</td>
<td>8.0</td>
<td>0.9</td>
<td>0.309**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SEF</td>
<td>45.3</td>
<td>9.4</td>
<td>0.332**</td>
<td>0.472**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ATT</td>
<td>52.2</td>
<td>7.8</td>
<td>0.285*</td>
<td>0.469**</td>
<td>0.613**</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>pCON</td>
<td>33.6</td>
<td>2.3</td>
<td>0.152</td>
<td>0.129</td>
<td>0.249*</td>
<td>0.193</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>pATT</td>
<td>34.0</td>
<td>2.8</td>
<td>0.039</td>
<td>-0.021</td>
<td>-0.024</td>
<td>0.087</td>
<td>0.081</td>
<td>-</td>
</tr>
</tbody>
</table>

PCK = pedagogical content knowledge; SMK = subject matter knowledge; SEF = self-efficacy; ATT = attitude; pCON = pupils’ concept; pATT = pupils’ attitude.

* $p < 0.05$, ** $p < 0.01$.

means that the pupils had a moderately broad concept of technology. On the attitude towards technology scale, the scores ranged from 27.1 to 41.0. The mean score was 34.0 ($sd = 2.8$) and the mean score per item 3.4 on a 5-point Likert scale. This indicated that the pupils had a slightly more positive than negative attitude towards technology.

The correlations between teacher knowledge variables were all significant and stronger than in the main sample. Again, the largest correlation was found between self-efficacy and attitude (0.613). However, neither of the correlations between the teacher and pupil variables were statistically significant, except for the correlation between teacher’s self-efficacy and pupils’ concept (0.249).

Figure 5.3 illustrates the path model of teacher knowledge effects on
Figure 5.3: Path model of teacher knowledge effects on pupils’ concept and attitude with standardised path coefficients.

pupils’ concept and attitude with all standardised path coefficients. The fit of the model was close, which was supported by a non-significant p-value of the Chi-square test (0.4416), a CFI and TLI that were larger than 0.95 (resp., 1.000 and 1.009), and a RMSEA and SRMR smaller than 0.05 (resp., 0.000 and 0.044). It is noteworthy that the path between PCK and self-efficacy was a significant path in this model, with a coefficient of 0.206. Furthermore, all direct paths between teachers and pupils had non-significant path coefficients. Nonetheless, when exploring the effects with correction for attenuation, it was found that the path between PCK and pupils’ concept had a medium effect size (0.389), whereas the paths between SMK and pupils’ concept, between teachers’ PCK and pupils’ attitude, and between teachers’ attitude and pupils’ attitude remained non-significant.

The total effect of teachers’ SMK on pupils’ concept was found to be 0.133 (0.095+(0.308*0.123)) and the total effect of teachers’ SMK on pupils’ attitude no more than 0.021 ((0.308*0.018)+(0.408*0.503*0.073)). The total effect of teachers’ self-efficacy on pupils’ attitude is 0.037 (0.503 * 0.073) and of teachers’ attitude on pupils’ attitude only 0.026 (0.018 + (0.206*0.503*0.073)). Besides, the outcomes of the path analysis indicated that the correlation between pupils’ concept and pupils’ attitude was non-significant (0.071).
Table 5.5: Standardised path coefficients, p-values, and explained variances ($R^2$) from path model of teacher knowledge effects on pupils’ concept and attitude.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Estimate</th>
<th>$p$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>On ATT of SMK</td>
<td>0.232</td>
<td>0.016</td>
<td>0.417</td>
</tr>
<tr>
<td>On ATT of SEF</td>
<td>0.503</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>On SEF of SMK</td>
<td>0.408</td>
<td>0.000</td>
<td>0.261</td>
</tr>
<tr>
<td>On SEF of PCK</td>
<td>0.206</td>
<td>0.040</td>
<td></td>
</tr>
<tr>
<td>On PCK of SMK</td>
<td>0.308</td>
<td>0.002</td>
<td>0.095</td>
</tr>
<tr>
<td>On PCK of PCK</td>
<td>0.095</td>
<td>0.414</td>
<td>n.s.</td>
</tr>
<tr>
<td>On pCON of SMK</td>
<td>0.123</td>
<td>0.288</td>
<td>n.s.</td>
</tr>
<tr>
<td>On pCON of PCK</td>
<td>0.018</td>
<td>0.875</td>
<td>n.s.</td>
</tr>
<tr>
<td>On pATT of ATT</td>
<td>0.073</td>
<td>0.533</td>
<td>n.s.</td>
</tr>
<tr>
<td>On pATT of PCK</td>
<td>0.073</td>
<td>0.533</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

In Table 5.5 the path coefficients, p-values, and explained variances of this path model are shown. The variance of attitude was explained for 41.7% by self-efficacy and SMK. The variance of self-efficacy was explained for 26.1% by SMK and PCK and the variance of PCK was explained for 9.5% by SMK. With regard to the pupil variables, concept was explained for 3.1% by teachers’ SMK and PCK, and attitude only for 0.6% by teachers’ attitude and PCK. It should be noticed that all effects in the path model were tested on a group level, that is, the pupils’ test scores used in the analysis were all mean group scores. Hence, all effects refer to the relation between teachers and their classes.

### 5.4 Conclusions and discussion

The purpose of this study was to investigate teacher knowledge of technology education in primary schools and to analyse its impact on pupils’ concept of and attitude towards technology. Based on analysis of the various test scores, we conclude that primary school teachers have basic levels of SMK and PCK of technology education. This finding is promising, because science and technology education is a new learning domain in Dutch primary schools and teachers did not have much time yet to develop their
SMK and PCK. Both their confidence (i.e., self-efficacy) in teaching technology and attitude towards technology are moderately positive. From the path analysis of teacher knowledge domains, we conclude that SMK is an important influencing factor for PCK as well as self-efficacy. In turn, self-efficacy has a strong effect on teachers’ attitude towards technology.

With regard to the effects of teacher knowledge on pupils’ concept and attitude, the results of the path analysis pointed out that all effects of teacher on pupil variables were small. Due to the complexity of the research context, a natural learning environment, weak relations between teachers and pupils variables are not surprising. Nonetheless, in the tested model teachers’ PCK was found to be the most influential teacher knowledge domain in affecting pupils’ concept. The assumed positive influence of teachers’ attitude on pupils’ attitude could not be statistically confirmed.

Furthermore, it was found that pupils’ concept is not significantly correlated with pupils’ attitude in the tested path model. However, when analysing the correlation between pupils’ concept and attitude on an individual level, in contrast to the group level used in the path model, a small but significant relation was found \( (r = 0.187, p < 0.01) \). We also found that pupils’ attitude towards technology is less influenceable than pupils’ concept of technology. Pupils’ attitude did not change significantly over time (from grade 3 to 6), while pupils’ concept did, i.e., they had a broader concept in the higher grades. Hence, teachers might better focus on improving pupils’ concept of technology than their attitude.

In search of other factors that might have an effect on pupils’ concept and attitude regarding technology, it was found that the frequency of technology activities, scored on a 5-point scale from ‘never’ to ‘more than once a week’, was significantly and positively, though weakly, related to pupils’ concept \( (r_s = 0.097, p < 0.01) \) as well as their attitude \( (r_s = 0.106, p < 0.01) \). Moreover, the frequency of technology activities was significantly and positively correlated with teachers’ attitude \( (r_s = 0.298, p < 0.01) \) and self-efficacy \( (r_s = 0.336, p < 0.01) \). These findings suggest that increasing teachers’ confidence in technology teaching, for instance by increasing their SMK, will increase the frequency of technology activities, which subsequently improves pupils’ concept and attitude. As a consequence, more experience in teaching technology will stimulate the development of teachers’ PCK.

It could be argued that other factors within the school context, e.g., learning materials and textbooks, or more informal learning experiences, e.g., excursions and guest lectures, have a stronger influence on pupils’ con-
cept and attitude than teacher knowledge, especially when teacher knowledge is not yet fully developed. Apart from factors within the school context, other influential factors might be identity, parents, peers, and media. In short, it is worth investigating to what extent which factors affect the development of pupils’ concept and attitude regarding technology.

A larger sample size of teachers with pupils would probably have help to find more significant effects of teacher knowledge on pupils’ concept and attitude. Besides, low alpha values of two instruments, the TTT and TQ (A), affected the magnitudes of the effects. Above all, technology education is still a relatively underdeveloped learning domain in primary schools in the Netherlands. Good quality teacher guides, textbooks, and materials are still lacking and most in-service teachers did not receive any training in technology education. In addition, the affinity with technology of most primary school teachers is rather low. Consequently, technology is only taught about once a month, and mostly on Friday afternoons. Hence, first of all, more technology education is needed to improve both teachers’ PCK and pupils’ concept.

In our view, to improve the quality of technology education in primary schools, teacher education should focus on the development of SMK as well as PCK. In other words, pre-service teachers should be able to acquire relevant SMK and should be guided in learning how to use their SMK to foster pupils’ learning in technology. More knowledge and more experience with teaching technology will help teachers to recognise the added value of high quality technology education.

**Bibliography**


Chapter 6

General conclusions and discussion

In this final chapter, the main results and conclusions of the studies reported in this thesis are briefly described. Next, several critical remarks concerning the research aim, methodology, and findings are made. In the end, ideas for further research are suggested and theoretical as well as practical implications derived from this thesis are discussed.
6.1 Summary of problem statement and research questions

The general aim of the studies reported in this thesis was to investigate primary school teachers’ knowledge of technology and technology education, on the one hand, and the relations between teacher knowledge of technology and pupils’ concept of and attitude towards technology, on the other. Regarding the investigation of teacher knowledge, the conceptualisation and measurement of teachers’ pedagogical content knowledge (PCK) were of major concern.

The research aim had scientific as well as practical relevance. The research project was scientifically relevant in terms of a contribution to the conceptualisation of PCK through the construction and validation of an instrument to measure primary school teachers’ PCK of technology. Mainly the studies reported in chapters 3 and 4 were concerned with this issue. At the same time, the research was of practical relevance, because it was concerned with improving the quality of technology education for primary schools through the focus on teacher knowledge. With that, the research project indirectly addressed a societal and economical problem, namely, the relatively small number of science and technology students in the Netherlands.

Regarding the pursued development towards a more knowledge-based and technology-intensive economy (cf. the agreement of the Lisbon European Council meeting in 2000), it is worrying that only a relatively small number of students seems interested in a study and career in science and technology (Wendelaar Bonga, 2006). Although, the numbers slightly improved in the Netherlands over the last two years, it is still a relatively small number of students that is interested in a career in science and technology as compared to other European countries (Van den Broek and Hamer, 2008). One of the ways to tackle this problem, is to pay more attention to science and technology in primary schools. At this age, most pupils still have a natural curiosity for science and technology.

Unfortunately, primary school teachers often seem to lack the ability and confidence to develop and stimulate their pupils’ curiosity for science and technology. Because positive experiences at an early age can have a long-lasting impact, teachers should be better trained to teach science and technology (Wendelaar Bonga, 2006). In other words, primary school teachers need sufficient knowledge of science and technology to be able to teach the subject in a way that provides pupils with a comprehensive
concept of science and technology and stimulates pupils’ positive attitude towards science and technology. Consequently, teacher training colleges for primary education need to know what teacher knowledge to train specifically in order to educate pre-service and in-service teachers for science and technology teaching effectively. Therefore, it is important to know how teacher knowledge domains interrelate and what impact those domains have on pupils’ concept and attitude.

The research questions addressed in this thesis were as follows.

1. What teacher knowledge of technology do primary school teachers have and how are the different domains of teacher knowledge interrelated? (Chapter 2 and 5)

2. To what extent is teacher knowledge of technology related to pupils’ concept of and attitude towards technology? (Chapter 2 and 5)

3. How to construct and validate a multiple choice test to measure primary school teachers’ PCK of technology education? (Chapter 3 and 4)

4. What latent factor structure underlies primary school teachers’ PCK of technology education? (Chapter 4)

In the next section a brief answer to these questions, based on the findings of the studies reported in chapters 2 to 5, is formulated.

6.2 Results and conclusions

6.2.1 Teacher knowledge domains

In chapter 2, the relations between three different domains of technology-specific teachers knowledge, i.e., subject matter knowledge (SMK), PCK, and attitude and self-efficacy (the affective domain), were theoretically explored. Scientific literature on teacher knowledge for science and technology education was thoroughly reviewed with the help of a diagram that specified the hypothetical relations between the teacher knowledge domains. Teachers’ ‘general’ SMK (i.e., conceptual and procedural knowledge) and concept of technology (i.e., understanding the nature of technology) were both reported to be important knowledge aspects for good technology teaching (e.g., Parkinson, 2001; Davis et al., 2002; Jarvis and Rennie, 1996a). Furthermore, it was assumed by many researchers that SMK is a prerequisite for the development of PCK (Van Driel et al., 1998).
Besides, teachers’ SMK was said to be positively related to their confidence in teaching technology (McRobbie et al., 2000). With respect to teachers’ PCK, knowledge of pupils’ (mis)conceptions (Davis et al., 2002; Jarvis and Rennie, 1996b; Lewis, 1999) and knowledge of the nature and purpose of technology education (Jones and Moreland, 2004) were both supposed to positively affect technology teaching.

In chapter 5, the hypothesised relations between the three teacher knowledge domains were empirically analysed with use of path analysis. From the analysis of test scores, it was concluded that primary school teachers have basic levels of SMK and PCK of technology. Furthermore, both teachers’ confidence (or self-efficacy) in teaching technology and their attitude towards technology were found to be moderately positive. From the path analysis, it was concluded that SMK is an important factor for PCK as well as for self-efficacy beliefs in teaching technology. Subsequently, self-efficacy beliefs in teaching technology were shown to have a strong influence on teachers’ attitude towards technology.

6.2.2 Teacher knowledge and pupils’ concept and attitude

As reported in chapter 2, previous research empirically showed that PCK is associated with enhanced learning of pupils in technology, with increased motivation, and with increased interest in technology (Jones and Moreland, 2004). Concerning the relation between teachers’ attitude and pupils’ attitude, it is often intuitively expected that teachers’ attitude affects pupils’ attitude towards technology, though empirical evidence on this relation was not found. Furthermore, pupils’ concept of technology was reported to be strongly related to their attitude towards technology (De Vries, 2000), which implies that it is highly important that teachers help their pupils developing a correct and comprehensive concept of technology.

The results of the path analysis, reported in chapter 5, showed that all effects of teacher knowledge on pupils’ concept and attitude were non-significant. However, teachers’ PCK appeared to be the most important of the three teacher knowledge domains in affecting pupils’ concept. Besides, through correlating individual test scores, it was found that pupils’ concept of technology was weakly, but significantly and positively, related to their attitude towards technology. It was also found that pupils’ attitude towards technology is more rigid than pupils’ concept of technology. That is, pupils’ attitude did not change significantly from grade 3 to 6, whereas pupils’ concept did.
6.2.3 Construction and validation of PCK test

In chapter 3, it was reported how a multiple choice test to measure primary school teachers’ PCK of technology education, the Teaching of Technology Test (TTT), was constructed and validated on a small scale. It was concluded that the rational method of test construction, i.e., making use of rationally estimated (or content-oriented) item indices, was effective. Experts in the field of primary technology education agreed that the items measured PCK of technology, which means that content validity of the test is supposed to be good. However, regarding the production of items, it turned out to be difficult to formulate best answers and plausible distracters. The experts particularly struggled with creating best answer alternatives that reflected a good blend of SMK and pedagogical knowledge.

In chapter 4, a large-scale validation of the TTT was reported. It was concluded that the instrument is valid in terms of content and convergent validity. As was expected from the literature on PCK in science education (Van Driel et al., 1998; Park and Oliver, 2008), the test scores correlated significantly with the test scores on SMK and self-efficacy. Concerning the reliability of the test, internal consistency (Cronbach’s alpha) was found to be low, but this could be theoretically explained by the heterogeneous nature of PCK (Lucke, 2005). Calculation of test-retest reliability showed that the TTT was satisfactory consistent over time ($r = 0.622, p < 0.01, n = 31$). Although in a far advanced stage, the TTT was said not to be a ready-to-use instrument for evaluative or diagnostic usage yet. However, it could be concluded that an important step forward was made regarding the measurement of PCK with a multiple choice test.

6.2.4 Latent factor structure of PCK

With regard to the latent factor structure of primary school teachers’ PCK in technology education, as reported in chapter 4, the hypothetical factor structure of three independent knowledge components was confirmed by latent factor modelling. The first factor, labelled *knowledge of pupils’ general concept and misconceptions related to technology*, could be indicated as ‘knowing how to adjust activities to pupils’ experiences of the technological world around them and their (mis)conceptions of technological topics’. The second factor, *knowledge of the nature and purpose of technology education*, was described as ‘knowing the core characteristics of technology education, i.e., hands-on experiences and authentic problem solving’. The third factor, *knowledge of pedagogical approaches and teaching strategies*
for technology education, was characterised as ‘the art of asking questions that encourage pupils to think critically about the technological problem encountered’. However, the factor structure turned out to be obscured by many other elements, which is in agreement with the idea that PCK is a highly heterogeneous construct.

Furthermore, it was concluded that the technological topic of a PCK item, e.g., electricity or constructions, could not be determined to be an inherent component of primary school teachers’ PCK of technology. This finding could be theoretically explained by the nature of the profession of a primary school teacher, which requires a broad, instead of a specialised, development of teacher knowledge. That is, primary school teachers might not develop specific PCK for each technology topic, but rather develop more generic PCK of technology, which is in agreement with the ideas of Appleton (2008), but in contrast with many other researchers’ assumptions (e.g., Magnusson et al., 1999).

6.2.5 General conclusion

In summary, the studies reported in this thesis gave useful insights into three domains of teacher knowledge regarding technology education: (1) SMK, (2) PCK, and (3) attitude and self-efficacy. Particularly, the domain of PCK was intensively studied, resulting in a better understanding of the construct of PCK and the way to measure this construct quantitatively. As a more concrete result, a multiple choice test to measure PCK was designed and validated. However, the hypothesised relations between teacher knowledge and pupils’ concept and attitude could not be empirically confirmed, because the measured effects were non-significant.

6.3 Critical remarks

6.3.1 On the research aim

The investigation of teacher knowledge and its relations with pupils’ concept and attitude in the context of technology education in primary schools had certain limitations. First, primary technology education is a relatively new learning area in the Netherlands, introduced around the year 2000 as part of the integrated domain of science and technology education. Although technology education is now part of the compulsory learning goals in primary education, it is structurally implemented in the curricula of only 12% of all primary schools in the Netherlands. Infrequently and
non-regularly, 73% of the schools offer technology lessons (Inspectorate of Education, 2005). Hence, technology education had no chance yet to develop into an established learning domain, i.e., it is not clearly defined and is lacking an explicit structural framework including key learning concepts, suggestions for the sequence of learning activities (in relation to pupils’ cognitive development), and detailed standards. Consequently, most teachers did not yet develop profound teacher knowledge in this field, which is reflected in a high variety of perceptions of technology education among primary school teachers. Furthermore, the levels of teacher knowledge in technology education had never been studied before in the Netherlands, and, therefore, a reference point of teachers’ knowledge levels was missing. Comparing their knowledge levels on an international scale is complicated while contexts and contents differ too much to make a valid comparison.

Another point of discussion is whether teacher knowledge is the most obvious factor to examine with respect to the influence on pupils’ concept of and attitude towards technology. It could be argued that other factors within the school context, e.g., frequency and duration of technology activities (‘time on task’), learning materials and textbooks, or more informal learning experiences, e.g., excursions and guest lectures, have a stronger influence on pupils’ concept and attitude than teacher knowledge, especially when teacher knowledge is not yet fully developed. Apart from factors within the school context, other influential factors might be identity, parents, peers, and media. It would be useful to know the relative influence of all of these factors on pupils’ concept of and their attitude towards technology, in order that attempts to affect pupils’ concept and attitude could be more efficient. However, low direct effects of teacher knowledge on pupil variables should not be regarded as a permit to neglect teacher knowledge. Due to the complexity of learning environments, in which these effects were attempted to be measured, direct effects between teachers and pupils are hard to confirm empirically. It is beyond doubt that what a teacher knows affects what is done in the classroom and, consequently, affects what pupils learn.

6.3.2 On the methodology

Critical remarks can be made when reflecting on the methods used in the presented studies. In the first place, participation in all of the studies was voluntary. Although the sample size was considerably large and the demographics, such as age, gender, and denomination of the schools, were representative for the population of primary school teachers in the
Netherlands, the sample might have been biased in terms of knowledge of and affinity with technology education. It is likely that teachers with relatively more knowledge and higher affinity were over-represented in the sample. The percentage of teachers working in schools that participated in a governmental programme regarding the implementation of science and technology education (the VTB-programme), was about 60% in the studied sample, which is by far higher than the percentage of all primary schools in the Netherlands (about 25%). Because of the absence of large scale data on teacher knowledge and affinity regarding technology education in primary schools, this potential bias in the sample could not be verified. On the other hand, a biased sample with respect to teacher knowledge can also be interpreted as an advantage. The variance in test scores on the PCK and SMK tests was large enough to carry out statistical analyses, which could have been problematic when teacher knowledge levels were (too) low. Put it simple, if teacher knowledge would have been nearly absent in the sample, hardly anything could have been measured.

Concerning the instruments used to measure teacher knowledge and pupils’ concept and attitude, it should be remarked that one of the instruments showed psychometric problems. For the questionnaire that measured pupils’ concept of technology, the Technology Questionnaire A, a Cronbach’s alpha of 0.43 (0.48 for the design sub scale and 0.49 for the diversity sub scale) was observed. This implies that the internal consistency (i.e., reliability) of this scale was low. The pupils might have answered in an unsystematic way because they misunderstood the questions. It was found that the alpha improved from 0.34 to 0.44 with pupils’ grade (from 5 to 8). Hence, the younger pupils might have had more difficulties with understanding the questions than the older ones, though even for the older pupils the alpha was low. Another explanation might be that the concept of technology in young children is difficult to measure in essence, because they have not yet developed a stable concept at that age. This might also explain why the authors of the original questionnaire reported alpha’s of only 0.56 (diversity sub scale) and 0.49 (design sub scale) in their validation study with 12 to 13-year-old pupils (Rennie and Jarvis, 1995).

Another instrument with low internal consistency was the self-constructed TTT ($\alpha = 0.34$). However, this low alpha could be explained by the heterogeneous nature of PCK. As an alternative measure, test-retest reliability was calculated and found to be 0.622. This implies that the reliability of the test, in terms of consistency over time, is adequate. Although with test lengthening the internal consistency of the test could theoretically be
improved, the test would loose (part of) its validity. The new items would need to be parallel to the original ones to avoid adding more heterogeneity to the scale. Hence, certain aspects of PCK would over-represented.

The method that was used to construct the TTT is called the ‘rational’ method (Oosterveld and Vorst, 1996). Other terms that are used for this test construction method is ‘judgmental’ and ‘content-oriented’ (DuBois and DuBois, 2000). The most important feature of this method is the use of experts’ judgments in all steps of test construction, from construct analysis to judging the items. This method is especially useful when empirical data on the construct are scarce. At the same time, the strong dependency upon experts could be a pitfall. The experts involved in the construction of the TTT were all specialists in teaching of technology on the primary school level. Their knowledge of this field was high, but they were no experts in the field of knowledge testing or teacher assessments in general. Especially in the phases of defining the item characteristics and judging the produced items for acceptance in the first version of the instrument, judgments of experts in the field of knowledge testing would have been helpful and would probably have increased the quality of the test. Besides, the procedure of judging the items could have been structured more systematically. During the TTT construction, two experts co-judged items produced by other experts on a 3-point scale (‘accept’, ‘not accept’, or ‘accept with revisions’). Ideally, experts, who were not involved in writing the items, judge the items individually on a more detailed scale. Then, inter-rater reliability is calculated and only accepted items of which the inter-rater reliability is high enough are admitted to the test. This procedure might have resulted in a higher quality of the test items.

The research questions addressed in the scope of this thesis were all approached in a predominantly quantitative manner. Because quantitative methods are more time and labour efficient than qualitative methods, this is highly beneficial when investigating large sample sizes. However, within the context of teacher knowledge of technology education in primary schools, little research has been reported. Little is known about the knowledge levels of technology teachers have, what the effects of these knowledge levels on technology teaching are, and how this knowledge could be trained and developed. One could argue that a more explorative or qualitative approach would therefore have been more appropriate to gain some first insights into this research topic. Fortunately, teacher knowledge, and specifically PCK, is a popular field of study in science education, which has a strong affiliation with technology education. Therefore, many research
findings in science education are supposed to be transferable to the context of technology education. Hence, in the studies presented in the previous chapters, it was assumed to be legitimate to build upon findings on teacher knowledge in science education.

6.3.3 On the findings

When critically reflecting on the findings in this thesis, one thing that should be noticed is the context in which the studies took place. As mentioned before, technology education for primary schools is not yet an established learning domain in the Netherlands. Plausibly, primary school teachers did not yet develop deep and profound teacher knowledge in this field. Considering this, it is not surprising that teacher knowledge only had a small influence on pupils’ concept and attitude. To improve teacher knowledge, teachers should be better trained for technology teaching. In agreement with the line of reasoning in a scientific report about an Australian primary science programme (Hackling and Prain, 2005), teachers who develop more SMK and PCK of technology, will have more confidence in teaching technology and, in turn, will increase the frequency of technology activities in their classroom. In chapter 5, it was reported that the frequency of technology activities is positively correlated with pupils’ concept and attitude. Thus, increasing the frequency of technology education will improve pupils’ concept and attitude. Besides, more technology teaching will stimulate the development of teachers’ PCK, because PCK is said to be mainly developed through teaching experience (Van Driel et al., 1998). Hence, first of all, more technology education is needed in order to find stronger and clearer relations between teacher knowledge and pupils’ concept and attitude.

With respect to the construction and validation of the TTT, it was concluded that the TTT is not a ready-to-use instrument yet, though a big step forwards was made in measuring PCK in a quantitative way. This could raise the question why the TTT cannot be used as a diagnostic tool for (pre- and in-service) teachers at this stage. Despite the fact that test-retest reliability is high enough for diagnostic usage, many intrinsic aspects of PCK obscure the factor structure and cause a low value of Cronbach’s alpha. In other words, the degree of heterogeneousness of the construct was underestimated. However, the large scale validation of TTT with use of confirmatory factor analysis, reported in chapter 4, gave useful insights into the construct of PCK. These insights are supportive for the further development of the instrument. Besides, qualitative methods to measure
Suggestions for further research

PCK have to deal with the same heterogeneous nature of PCK, but this is not made explicit by psychometric indices.

Another issue that should be addressed is the generalisability of the results and conclusions. It could be questioned to what extent the findings of this thesis are transferable to other contexts than the context of technology education in primary schools in the Netherlands. Regarding the studies presented in chapter 2 and 5 (research questions 1 and 2), it is assumed that the findings could be generalised to those contexts that are similar with respect to the development of primary school technology education as a learning domain. In situations where technology education is still a subject ‘under construction’ or where technology is simply low-prioritised (i.e., infrequently taught), the findings of these studies are applicable. Regarding the studies presented in chapter 3 and 4 (research questions 3 and 4), the findings are thought to be valid in a broader context than merely technology education in primary schools, because these studies dealt with a more fundamental problem. These findings are of value to all researchers who are interested in the conceptualisation and measurement of PCK.

6.4 Suggestions for further research

In continuation of this thesis, a logical next step in research would be a further development of the TTT towards a diagnostic instrument for pre- and in-service teachers. Based on the validation results so far, this implies that some of the items need to be rewritten and possibly new items need to be added. Validity of the instrument could be improved by having expert teachers, i.e., teachers with relatively much experience in technology education, verbally explain why they choose a certain answer alternative of an item. In this way, the TTT would be used as a structured interview protocol. Reliability of the instrument could be analysed more profoundly by using more sophisticated and appropriate psychometric theories that focus on heterogeneous instruments, such as the congeneric test theory (Lucke, 2005). Moreover, it would be interesting to see whether the TTT is reliable and valid when testing pre-service teachers and usage in different countries and cultures. Thinking about the instrument’s evolution on the longer term, it could be considered to use video clips as scenarios instead of written descriptions. Videos can provide more detailed information, which is expected to improve the validity of the test.

In this thesis, the question to what extent teacher knowledge affects pupils’ concept and attitude regarding technology was attempted to be
answered. Because the analysed domains of teacher knowledge (i.e., SMK, PCK, attitude, and self-efficacy) were found to have only a small influence on pupils’ concept and attitude, it would be interesting to know what other factors determine pupils’ concept and attitude. When focussing on the school context, it could be argued that, for instance, frequency and duration of technology activities, learning materials and textbooks, or more informal learning experiences such as excursions and guest lectures, affect pupils’ concept and attitude as well. When considering factors out of the school context, parents, peers, and media, but also pupils’ identity, could be thought of as influencing factors. Research that is aimed at creating a complete picture of the most important factors that affect pupils’ concept and attitude would be valuable.

Another intriguing question is to what extent pupils’ concept and attitude regarding technology at the age of 12 predict their study and career choices later in life. A helpful framework to investigate academic and career choices is the social cognitive career theory (SCCT) developed by Lent et al. (1994). This theory, derived from Bandura’s social cognitive theory (Bandura, 1986), aims to explain vocational interest development, career choice, and career performance. According to the SCCT, self-efficacy beliefs and outcome expectations affect vocational interest and career choices directly. The path from vocational interest to career choice goes through career intentions, i.e., plans to engage in a particular career direction, and is mediated by contextual influences, for instance, networks and job availability. However, this framework deals primarily with the period just before, during, and just after career entry. In order to find out whether attitudes at the age of 12 can predict career choices, one should examine the stability of vocational concepts and interests. In a meta-analytic review, Low et al. (2005) found that vocational interests were moderately stable, even in early adolescence (age 12-18) and increased to highly stable at the age of 18 to 22. The researchers suggest to use interest assessments even below the age of 16 to guide students more purposeful in their study and career choices.

Other researchers stressed the importance of paying attention to vocational interests even before the age of 12. In a review of empirical literature on children’s vocational development, Hartunga et al. (2005, p. 412) concluded that “vocational development begins much earlier in the life span than generally assumed, and what children learn about work and occupations has a profound effect on the choices they make as adolescents and young adults, and ultimately, on their occupational careers”. A suggestion
for future research could be to use a longitudinal design to study the effects of science and technology education in primary schools on study and career choices later in life.

### 6.5 Theoretical and practical implications

An important theoretical implication of this thesis is the way the construct of PCK is perceived. In chapter 4, PCK was conceptualised by means of analysing the latent factor structure of the PCK test (the TTT). It was empirically shown that PCK is a heterogeneous construct, consisting of multiple intrinsic elements which are difficult to unravel. This finding is in agreement with Shulman, who chose his words carefully when he defined PCK as “a special amalgam of content and pedagogy” (Shulman, 1987, p. 8). In chemistry, an amalgam is a metallic alloy formed by a chemical reaction of mercury and another metal element, e.g., silver, copper, or zinc. An amalgam has other, preferably better, characteristics than the two elements of which it is composed. Besides, it is impossible to distinguish the elements of an amalgam with the eye or even with a microscope. Thus, the amalgam of PCK is more than a mixture of content knowledge and pedagogical knowledge, in which the elements would be easily recognised, and the elements of PCK are difficult to resolve in their ‘pure’ forms. Moreover, in the study presented in chapter 4, it was shown that PCK is not only an amalgam of content and pedagogy, but also an amalgam of its numerous subelements. Indeed, PCK is a special amalgam.

Several lessons for educational practice can be learned from the findings in this thesis. At first, regarding pre-service and in-service teacher training in technology education, as reported in chapter 5, it is recommended to focus on acquiring and developing SMK as well as PCK. Teachers should be stimulated to acquire relevant SMK and, above all, should be trained to use their SMK to foster pupils’ learning in technology, i.e., develop PCK. This implies that teachers should become familiar with pedagogical approaches that are suitable for technology education, e.g., inquiry-based and problem-based learning. Moreover, they should be made aware of the nature, purpose, and characteristics of technology education. It also implies that they should learn to ask provoking questions, use powerful analogies, explain the subject matter in various ways, and recognise common misconceptions. Finally, it is recommended that in teacher training most time is spend on hands-on technology activities (‘teach what you preach’). Actually doing and experiencing technology education is expected to increase
teachers’ confidence in teaching technology themselves.

An implication for policy makers and curriculum developers, which is indirectly derived from the studies carried out in the context of this thesis, is that the learning domain of science and technology education should be defined more precisely. Teachers are in need of concrete content for their science and technology lessons and are often confused about the differences and similarities between science and technology. It would be beneficial to provide primary school teachers with a clearly defined framework, including key learning concepts and standards, for science and technology education. In a study on primary science education, it was found that beginning teachers had two strategies to cope with science teaching, i.e., avoiding science teaching and using ‘activities that work’ (Appleton, 2003). Supporting teachers with a set of activities that work, will prevent them from avoiding to teach science and technology. In this way, teachers can focus more specifically on developing their SMK and PCK in this field and, consequently, the quality of science and technology education will increase.

Serving as an example of good practice with regard to the above mentioned implication for teacher training, a large scale governmental programme to professionalise primary school teachers in the field of science and technology education recently started in the Netherlands. This programme, called ‘vtb-pro’, is aimed at developing teachers’ SMK as well as PCK and attempts to positively affect teachers’ attitude towards science and technology. Besides, the programme offers teachers a framework of science and technology education by using five concepts to categorise the learning domain: (1) physical systems, (2) living systems, (3) earth and space systems, (4) technological systems, and 5) mathematical systems. Future experiences will show whether this approach of training teachers in science and technology was a fruitful one. Irrespective of the results of the VTB-pro training, it is highly recommended to ground professionalisation programmes as these on scientific research.

When SMK and PCK are both highly important for effective and high quality technology education, what about educating teachers to become specialists in teaching technology? Being a primary school teacher means you need to have knowledge about many different subjects. It could be questioned whether it is realistic to presume that all teachers have profound SMK and PCK of all subjects they teach. A way to tackle this issue, might be to educate more specialist instead of only generalist teachers. Similar to the education of general medical practitioners and medical specialists, teachers should be able to specialise in a certain learning domain,
e.g., science and technology, after they achieved their basic teaching licensure. Another way might be to include a specialist track within the general primary teacher education programme. In this way, all licensed teachers are specialists in a certain domain, though an included programme is obviously more restricted in depth and time than a separate follow-up training. In either way, specialist teachers in science and technology will most probably have more and better SMK and PCK than their colleagues without this specialisation, which will lead to higher quality science and technology education. However, first of all, science and technology education should simply be given higher priority in primary teacher training and primary school curricula.

Bibliography


Summary

Testing Teacher Knowledge for Technology Teaching in Primary Schools

Today’s pupils grow up in a world full of technology. Education’s duty is to offer them the opportunity to develop the ability to use, manage, assess, and understand technology in order to ‘survive’ in today’s technological society, and to provide them with a comprehensive and realistic concept of technology. Besides, stimulating pupils’ natural curiosity for science and technology by offering science and technology education at school, is expected to increase the number of students in the field of science and technology. In the Netherlands, as in other European countries, only a relatively small number of students choose to start a study and career in this field, which is worrying with regard to the pursued development towards a more knowledge-based and technology-intensive economy (expressed in the Lisbon Strategy of the European Council in the year 2000).

Although new standards for science and technology education in primary schools have been developed and governmental programmes have been started in the Netherlands since the beginning of this century, science and technology education has not yet a strong and established position in the curriculum of most primary schools and teacher training colleges. Teachers express to be confused about the content and learning activities that belong to science and technology education. Moreover, insufficient expertise of teachers is often mentioned as a restraint to offer science and technology education more regularly. Clearly, primary school teachers need to be trained to improve their knowledge of science and technology teaching. Therefore, teacher training colleges for primary education need to know what knowledge domains to train in order to educate pre-service and in-service teachers effectively.

This thesis is specifically focussed on technology education, as part of the learning domain ‘science and technology education’, in the upper
grades of primary schools. The general research aim of the presented studies is to investigate three domains of technology-specific teacher knowledge: (1) subject matter knowledge (SMK), (2) pedagogical content knowledge (PCK), and (3) attitude and self-efficacy (the affective domain). Moreover, the impact of these teacher knowledge domains on pupils’ concept of and attitude towards technology is examined. Based on scientific literature, it is assumed that primary school teachers need to have sufficient SMK and PCK of technology, as well as a positive attitude towards technology and high self-efficacy in teaching technology, in order to stimulate their pupils’ development of a realistic and comprehensive concept of technology and a positive attitude towards technology. Because teachers’ PCK is generally considered to be a central and vital domain of teacher knowledge, a major part of this thesis concerns the measurement and conceptualisation of teachers’ PCK of technology education. The research questions addressed in this thesis are as follows.

1. What teacher knowledge of technology do primary school teachers have and how are the different domains of teacher knowledge interrelated?

2. To what extent is teacher knowledge of technology related to pupils’ concept of and attitude towards technology?

3. How to construct and validate a multiple choice test to measure primary school teachers’ PCK of technology education?

4. What latent factor structure underlies primary school teachers’ PCK of technology education?

In chapter 2, entitled “Reviewing the relations between teachers’ knowledge and pupils’ attitude in the field of primary technology education”, research questions 1 and 2 are addressed theoretically. Scientific literature on teacher knowledge for science and technology education is thoroughly reviewed with the help of a diagram that specifies the hypothetical relations between the three teacher knowledge domains (SMK, PCK, and attitude and self-efficacy). Teachers’ SMK is reported to be an influential knowledge aspect for technology teaching. It is generally assumed that SMK is a prerequisite for the development of PCK and it is said that SMK is positively related to teachers’ self-efficacy beliefs in teaching technology. Previous research empirically showed that PCK of technology education is associated with enhanced learning of pupils in technology, with increased motivation, and with increased interest in technology. Concerning the relation between
teachers’ attitude and pupils’ attitude, it is often intuitively expected that teachers’ attitude affects pupils’ attitude towards technology, though empirical evidence on this relation is not found. Furthermore, pupils’ concept of technology is reported to be strongly related to their attitude towards technology.

In chapter 3, entitled “Measuring teachers’ pedagogical content knowledge in primary technology education”, research question 3 is addressed. The construction and small-scale validation of a multiple choice test to measure primary school teachers’ PCK of technology education, the Teaching of Technology Test (TTT), is reported. The ‘rational’ method of test construction proved to be effective and the content validity of the test is approved. However, regarding the production of items, it turned out to be very hard to formulate best answers and plausible distracters. The experts who wrote the items particularly struggled with creating best answer alternatives that needed to reflect a proper blend of SMK and pedagogical knowledge.

In chapter 4, entitled “Conceptualising pedagogical content knowledge by analysing the latent factor structure of a multiple choice test”, research questions 3 and 4 are addressed. In this chapter, a large scale validation of the TTT and an analysis of the latent factor structure of PCK is reported. As was expected from literature on PCK in science education, the test scores correlate significantly with the test scores on SMK and self-efficacy. It is therefore concluded that the TTT is also valid in terms of convergent validity. Concerning the reliability of the test, internal consistency (Cronbach’s alpha) is found to be low, but this can be theoretically explained by the heterogeneous nature of PCK. Calculation of test-retest reliability shows that the TTT is satisfactory consistent over time. Although it can be concluded that an important step forward has been made regarding the measurement of PCK with a multiple choice test, the TTT is not a ready-to-use instrument yet.

With regard to the latent factor structure of teachers’ PCK of technology, a factor structure of three independent knowledge components is confirmed by means of confirmatory factor analysis. The first factor, labelled knowledge of pupils’ general concept and misconceptions related to technology, can be indicated as ‘knowing how to adjust activities to pupils’ experiences of the technological world around them and their (mis)conceptions of technological topics’. The second factor, knowledge of the nature and purpose of technology education, can be described as ‘knowing the core characteristics of technology education, i.e., hands-on experiences and authentic
problem solving’. The third factor, *knowledge of pedagogical approaches and teaching strategies for technology education*, can be characterised as ‘the art of asking questions that encourage pupils to think critically about the technological problem encountered’. However, the factor structure turned out to be obscured by many other elements, which supports the idea that PCK is a highly heterogeneous construct, consisting of multiple intrinsic elements that are difficult to unravel.

In chapter 5, entitled “Analysing teacher knowledge of technology education and its effects on pupils’ concept and attitude”, research questions 1 and 2 are addressed empirically. From test scores on a content knowledge test and the TTT, it is concluded that primary school teachers have basic levels of SMK and PCK of technology. Besides, both teachers’ self-efficacy in teaching technology and their attitude towards technology are found to be moderately positive. Based on path analysis, it is concluded that SMK is an influential factor for PCK as well as for self-efficacy beliefs in teaching technology. Subsequently, self-efficacy beliefs are shown to have a strong influence on teachers’ attitude towards technology. Furthermore, it is found that all effects of teacher knowledge on pupils’ concept and attitude are non-significant, though teachers’ PCK proved to be the most important of the three teacher knowledge domains in affecting pupils’ concept. Through correlating test scores of individual pupils, it is shown that pupils’ concept of technology is weakly, but significantly and positively, related to their attitude towards technology.

Based on the findings in this thesis, it is recommended to focus on acquiring and developing SMK as well as PCK in primary school teacher training. Pre- and in-service teachers should be stimulated to acquire relevant SMK and, above all, should be trained to use their SMK to foster pupils’ learning in technology; i.e., develop their PCK. Besides, it would be helpful if the learning domain of science and technology education is defined in more detail. With clearly formulated key learning concepts, learning activities, and standards, teachers could focus more specifically on developing their SMK and PCK. However, it could be questioned whether it is realistic to presume that all primary school teachers have profound SMK and PCK of all subjects they teach. Educating more specialist instead of only generalist teachers could also be a way to increase SMK and PCK. One way or the other, it is highly recommended to ground regular teacher training and special professionalisation programmes on scientific research. But most importantly, science and technology education should first be given higher priority in primary teacher training and primary school curricula.
Samenvatting

Toetsen van kennis van leerkrachten voor techniekonderwijs op de basisschool

Leerlingen van nu groeien op in een wereld vol techniek. De plicht van het onderwijs is hen de gelegenheid te bieden zich zodanig te ontwikkelen dat ze techniek kunnen gebruiken, beheren, beoordelen en begrijpen, om te kunnen ‘overleven’ in de technologische samenleving, en hen een alomvattend en realistisch beeld van techniek mee te geven. Daarnaast zal door het stimuleren van de natuurlijke nieuwsgierigheid voor wetenschap en techniek, door het aanbieden van wetenschap- en techniekonderwijs op school, naar verwachting het aantal studenten op het gebied van wetenschap en techniek toenemen. In Nederland, net als in andere Europese landen, kiest maar een relatief klein aantal studenten een studie en loopbaan op dit gebied, wat zorgwekkend is met betrekking tot de gewenste ontwikkeling naar een meer op kennis en technologie gebaseerde economie (zoals geformuleerd in de Lissabon-strategie van de Europese Raad in 2000).

Alhoewel in Nederland sinds het begin van deze eeuw nieuwe kerndoelen voor wetenschap- en techniekonderwijs ('natuur en techniek') op de basisschool zijn opgesteld en overheidsprogramma’s zijn gestart, heeft het nog geen sterke en gevestigde positie in het curriculum van de meeste basisscholen en pabo’s. Leerkrachten geven aan het onduidelijk te vinden welke vakinhoud en leeractiviteiten tot wetenschap- en techniekonderwijs behoren. Bovendien wordt onvoldoende kennis van leerkrachten vaak als oorzaak genoemd voor de terughoudendheid van scholen om wetenschap- en techniekonderwijs structureel aan te bieden. Het is duidelijk dat basisschoolleerkrachten goed moeten worden opgeleid om hun kennis van wetenschap- en techniekonderwijs te verbeteren. Daarom moeten pabo’s weten aan welke kennisdomeinen aandacht besteed dient te worden om pabo-studenten en zittende leerkrachten effectief op te kunnen leiden.
Dit proefschrift is specifiek gericht op techniekonderwijs, als onderdeel van het leergebied ‘wetenschap- en techniekonderwijs’, in de bovenbouw van de basisschool. Het algemene doel van de gepresenteerde studies is het onderzoeken van drie techniek-specifieke kennisdomeinen: (1) vakinhoudelijke kennis, (2) vakspecifieke pedagogisch-didactische kennis, oftewel ‘pedagogical content knowledge’ (PCK) en (3) attitude en vertrouwen in het eigen lesgeven (het affectieve domein). Bovendien wordt de invloed van deze kennisdomeinen op het beeld en de attitude ten opzichte van techniek bij leerlingen onderzocht. Op basis van wetenschappelijke literatuur wordt ervan uitgegaan dat basisschoolleerkrachten voldoende vakinhoudelijke kennis en PCK van techniek, een positieve attitude ten opzichte van techniek en een hoog zelfvertrouwen in het doelmatig onderwijzen van techniek nodig hebben om bij hun leerlingen de ontwikkeling van een alomvattend en realistisch beeld van techniek en een positieve attitude ten opzichte van techniek te kunnen stimuleren. Omdat de PCK van leerkrachten in het algemeen wordt beschouwd als een centraal en essentieel kennisdomein, betreft een groot deel van dit proefschrift het (kwantitatief) meten en de operationalisering van PCK op het gebied van techniekonderwijs. De onderzoeksvragen, die in dit proefschrift aan bod komen, zijn als volgt:

1. Welke kennis van techniekonderwijs hebben basisschoolleerkrachten en hoe zijn de verschillende kennisdomeinen met elkaar verbonden?

2. In welke mate is de kennis van de leerkracht gerelateerd aan het beeld en de houding ten opzichte van techniek van de leerlingen?

3. Hoe kan een multiple-choice test voor het meten van PCK van basisschoolleerkrachten op het gebied van techniekonderwijs worden samengesteld en gevalideerd?

4. Welke latente factorstructuur ligt ten grondslag aan de PCK van basisschoolleerkrachten op het gebied van techniekonderwijs?

In hoofdstuk 2, getiteld “Reviewing the relations between teachers’ knowledge and pupils’ attitude in the field of primary technology education”, worden de onderzoeksvragen 1 en 2 theoretisch benaderd. Wetenschappelijke literatuur over kennis voor wetenschap- en techniekonderwijs wordt grondig doorgenomen met behulp van een diagram dat de hypothetische relaties tussen de drie kennisdomeinen (vakinhoudelijke kennis, PCK en attitude en vertrouwen) weergeeft. De vakinhoudelijke kennis van leerkrachten is naar verluidt een invloedrijk kennisaspect voor techniekonderwijs. In het algemeen wordt ervan uitgegaan dat vakinhoudelijke kennis
een voorwaarde voor de ontwikkeling van PCK is en er wordt tevens gezegd dat vakinhoudelijke kennis van leerkrachten positief is gerelateerd aan het vertrouwen in het eigen onderwijs. Eerder onderzoek heeft aangetoond dat PCK van techniekonderwijs is verbonden met een verbetering van het leren van leerlingen op het gebied van techniek en tevens met meer motivatie en meer belangstelling voor techniek. Wat betreft de relatie tussen de attitude van leerkrachten en die van hun leerlingen, wordt vaak intuïtief verwacht dat de attitude van leerkrachten invloed heeft op de attitude van hun leerlingen, al is empirische bewijs voor deze relatie niet gevonden. Overigens wordt in de literatuur vermeld dat het beeld van techniek bij leerlingen sterk te maken heeft met hun attitude ten opzichte van techniek.

In hoofdstuk 3, getiteld “Measuring teachers’ pedagogical content knowledge in primary technology education”, komt onderzoeksvraag 3 aan bod. De constructie en kleinschalige validatie van een multiple-choice test om de PCK van techniekonderwijs bij basisschoolleerkrachten te kunnen meten, de ‘Techniek Didactiek Test’ (TDT), wordt in dit hoofdstuk gerapporteerd. De ‘rationele’ methode van testconstructie bleek effectief en de inhoudsvaliditeit van de test is goedgekeurd. Echter, met betrekking tot het schrijven van de vragen (items) bleek het moeilijk te zijn om goede (of eigenlijk: beste) antwoorden en plausibele afleiders te formuleren. De experts, die de items schreven, streden met name met het beste antwoord alternatief, dat een juiste combinatie van vakinhoudelijke en pedagogische kennis moest weerspiegelen.

In hoofdstuk 4, getiteld “Conceptualising pedagogical content knowledge by analysing the latent factor structure of a multiple choice test”, worden de onderzoeksvragen 3 en 4 behandeld. In dit hoofdstuk wordt een grootschalige validatie van de TDT en een analyse van de latente factorstructuur van PCK gerapporteerd. Zoals werd verwacht op basis van de literatuur over PCK op het gebied van wetenschaponderwijs, correleren de testscores op vakinhoudelijke kennis in hoge mate met de testscores op vertrouwen in het eigen onderwijs. Er wordt dan ook geconcludeerd dat de TDT ook valide is wat betreft convergerende validiteit. Met betrekking tot de betrouwbaarheid van de test blijkt de interne consistentie (Cronbach’s alfa) laag te zijn, maar dit kan worden verklaard door het heterogene karakter van PCK. Berekening van de test-hertest betrouwbaarheid toont aan dat de TDT voldoende consistent in de tijd is. Hoewel kan worden geconcludeerd dat een belangrijke stap voorwaarts is gemaakt met betrekking tot het meten van PCK met een multiple-choice test, is de TDT nog geen kant-en-klar instrument.
Wat betreft de latente factorstructuur van PCK van basisschoolleerkrachten op het gebied van techniekonderwijs, is een factorstructuur met drie onafhankelijke kenniscomponenten met behulp van confirmatorische factoranalyse bevestigd. De eerste factor, *kennis over het beeld van techniek bij leerlingen en misvattingen met betrekking tot techniek*, kan worden omschreven als ‘weten hoe je activiteiten kunt aansluiten bij de ervaringen en belevingswereld van leerlingen en hun misvattingen van technische onderwerpen’. De tweede factor, *kennis van de aard en het doel van techniekonderwijs*, kan worden gekenmerkt als ‘het kennen van de belangrijkste aspecten van techniekonderwijs, te weten: doe-ervaringen en oplossen van authentieke problemen’. De derde factor, *kennis van pedagogische benaderingen en onderwijsstrategieën voor techniekonderwijs*, kan worden getypeerd als ‘de kunst van het stellen van vragen, die leerlingen aanzetten tot kritisch nadenken over het op te lossen, technische probleem’. De factorstructuur bleek echter te worden verduisterd door vele andere elementen, wat het idee ondersteunt dat -PCK een zeer heterogeen construct is. Dat wil zeggen, PCK bestaat uit verschillende, intrinsieke elementen die moeilijk te ontrafelen zijn.

In hoofdstuk 5, getiteld “Analysing teacher knowledge of technology education and its effects on pupils’ concept and attitude”, worden de onderzoeksvragen 1 en 2 empirisch benaderd. Op basis van de testscores op een inhoudskennistest en de TDT, is geconcludeerd dat de basisschoolleerkrachten basale niveaus van vakinhoudelijke kennis en PCK op het gebied van techniek bezitten. Bovendien is bevonden dat zowel het vertrouwen van leerkrachten in het eigen onderwijzen van techniek en hun attitude ten opzichte van techniek gematigd positief zijn. Op basis van pad-analyse, kan geconcludeerd worden dat vakinhoudelijke kennis een invloedrijke factor is voor PCK als ook voor vertrouwen in de doelmatigheid van het eigen techniekonderwijs. Vertrouwen heeft vervolgens een sterke invloed op de houding van leerkrachten ten opzichte van techniek. Verder wordt aangetoond dat alle effecten van de kennis van leerkrachten op het beeld en de attitude van leerlingen niet-significant zijn, hoewel gebleken is dat PCK van leerkrachten de belangrijkste factor van de drie kennisdomeinen in het beïnvloeden van het beeld van leerlingen is. Door het correleren van testscores van afzonderlijke leerlingen, is aangetoond dat het beeld van techniek bij leerlingen licht, maar toch significant en in positieve richting, gecorreleerd is met hun attitude ten opzichte van techniek.

Op basis van de bevindingen in dit proefschrift, wordt aangeraden om in de opleiding van basisschoolleerkrachten voornamelijk aandacht te be-
steden aan het verwerven en ontwikkelen van zowel vakinhoudelijke kennis als PCK. Pabo-studenten en zittende leerkrachten dienen te worden ge-stimuleerd relevante vakinhoudelijke kennis te verwerven en bovenal te worden opgeleid om met behulp van hun vakinhoudelijke kennis het leren van leerlingen op het gebied van techniek te bevorderen, dat wil zeggen, hun PCK te ontwikkelen. Het zou bovendien gunstig zijn als het vakgebied wetenschap- en techniekonderwijs gedetailleerder zou zijn omschreven. Met duidelijk geformuleerde kernconcepten, leeractiviteiten en leerdoelen, kunnen leerkrachten zich specifieker op de ontwikkeling van hun vakinhoudelijke kennis en PCK concentreren. Toch kan men zich afvragen of het realistisch is te veronderstellen dat alle basisschoolleerkrachten grondige vakinhoudelijke kennis en PCK van alle vakgebieden nodig hebben. Meer gespecialiseerde in plaats van breed opgeleide leerkrachten zou ook een oplossing kunnen zijn om vakinhoudelijke kennis en PCK te verhogen. Hoe dan ook is het raadzaam om de opleiding van leerkrachten en speciale professionaliseringsprogramma’s op wetenschappelijk onderzoek te funderen. Maar bovenal dient wetenschap- en techniekonderwijs allereerst een hogere prioriteit in de curricula van pabo’s en basisscholen te krijgen.
Dankwoord

Het is af. Het resultaat heb je in handen. Ook al lijkt het schrijven van een proefschrift voornamelijk een individuele aangelegenheid, en prijkt slechts mijn naam op de voorkant, zonder de hulp van anderen zou dit proefschrift niet hebben bestaan. De mensen die hebben meegewerkt aan mijn promotieonderzoek wil ik daarom allemaal heel hartelijk danken. En dat doe ik dan maar hier, op deze laatste bladzijden van mijn proefschrift, zoals dat gebruikelijk is.


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List of publications

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ESoE dissertation series

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