

An Evaluation of Learning Materials Designed to Teach 21st Century Problem Solving Skills in Secondary Education

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Foreword

This thesis is the result of the research I have conducted for the finalisation of my Master Educational Science and Technology at the University of Twente. An evaluative study was performed to analyse curriculum materials developed by SLO (“Stichting Leerplan Ontwikkeling”, i.e. the Netherlands Institute for Curriculum Development).

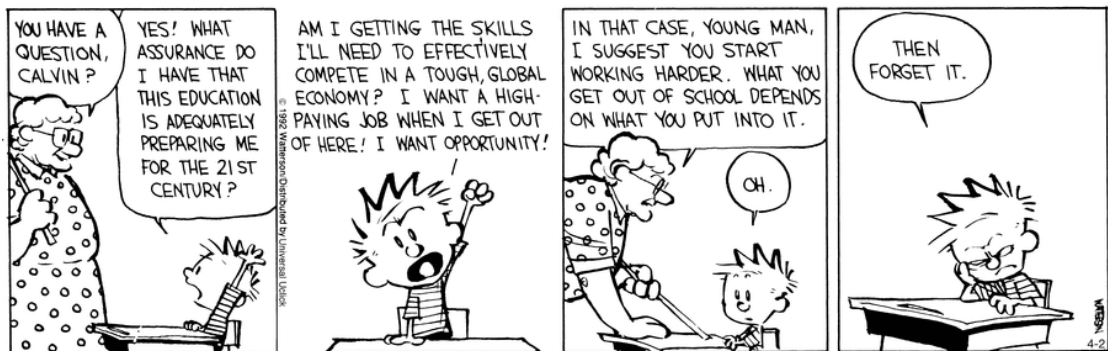
Many people have made it possible for me to realise this final project. I would like to thank a few people in particular. First, I would like to show my gratitude to Petra Fisser from SLO for all her support, encouragement, and suggestions during the entire project. I always really enjoyed our conversations! I would also like to thank all other ‘SLO-colleagues’ for their suggestions for my project, the nice lunch breaks, and the little chats during the day.

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I hope you enjoy reading this thesis!

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Hengelo, March 2016



(Bill Waterson, 1992)

Summary

In order to help teachers incorporate 21st century skills in their teaching, SLO ('Stichting Leerplan Ontwikkeling', i.e. the Netherlands Institute for Curriculum Development) has developed educative curriculum materials. The aim of this qualitative study was to evaluate such material, developed for the secondary school subjects geography and physics. The evaluation was based on three steps: an analysis of the curriculum materials based on the characteristics for teaching problem solving skills found in the literature research, lesson observations in which the materials were applied by teachers, and interviews with those teachers about their experiences with the material.

From literature it became clear that the main design criteria for teaching problem solving as a 21st century skill is that such problems need to be ill-structured, which means that they are complex and the goal state is not known in advance. After analysing the material under review, it could be concluded that the problem in the geography material was indeed ill-structured and therefore suitable for teaching problem solving as a 21st century skill. The problem in the physics material was not really ill-structured, and therefore this material was less suitable. Besides determining whether the problem in the material was ill-structured or not, it was also established to what extent steps belonging to the problem solving process were present in the material. In both materials some steps of the problem solving process were present, yet certainly not all steps were given adequate attention in the material. Especially the identification of a problem, and monitoring and reflection on the first phases of the problem solving process were absent in both materials.

Based on the observations with seven teachers it was found that elements that were explicitly part of the material as student activities were also most of the time present as such in the lessons. Elements that were less explicitly part of the material were sometimes observed, however more as teacher-directed activities. In the observation scheme the elements were explicitly stated as student activities, since incorporating elements of the material in a more student-active way would be desirable when teaching a 21st century skill such as problem solving. Based on the observations it was found that most teachers applied a teacher-centred teaching method, despite what the problem solving material suggested.

From the interviews it appeared that using the material was a valuable experience for several teachers, and some teachers expressed the wish to adapt their own material based on this experience. Although the composition of the material should be taken into account, i.e. regarding the context dependency of the material, afford easy usage and practical applicability, also learning from colleagues was mentioned as a beneficial means of support. However, it should be recognised that use of material is also influenced by external factors, which can either be stimulating or hindering. Stimulating factors are teacher recognition and school-wide attention for skills such as problem solving, and positive effects teachers see at the student level. Factors hindering the use of the material are lack of space in the curriculum, demands posed on or felt by teachers, and lack of awareness of the existence of material.

It is recommended that the material will be adapted so that the problems posed in the material indeed resemble problem solving as a 21st century skill, and that all steps of such a problem solving process are present. These steps could best be as explicitly posed as possible, to increase their chances of being adequately implemented by the teachers using the material. In order to increase the chance of teachers actually using the material, it should be composed in a way to afford use in different contexts, promote its usability by incorporating a user-friendly lay-out, and be aimed at practical application.

1. Introduction

1.1 Background

The goal of primary and secondary education is to prepare children for their future role in society. However, due to technological developments that afford different ways of communication and elicit growing amounts of information, society changes rapidly (Thijs, Fisser & Van der Hoeven, 2014). Through its impact on education, on the economy, and on politics, information technology changes the world. This changing world poses challenges for its future citizens. In order to prepare students for such a world, new skills are necessary, which are referred to as '21st Century Skills' (Kuhltau, 2010). These skills are not 'new' per se, but are of growing importance in an increasingly complex world for all students to acquire (Thijs et al., 2014). Therefore, the Dutch Government has asked SLO ('Stichting Leerplan Ontwikkeling', i.e. the Netherlands Institute for Curriculum Development) to further explore what these skills encompass, and how they are and should be implemented in primary and secondary education in the Netherlands (Thijs et al., 2014).

As part of this exploration, Thijs et al. (2014) identified the following eight 21st century skills: creativity, critical thinking, problem solving, communication, collaboration, social and cultural skills, self-regulation, and digital literacy. The skill digital literacy is further subdivided in ICT basic skills, computational thinking, information literacy, and media literacy. Albeit the fact that there is broad consensus on the importance of such skills, to effectively implement the skills in the curriculum remains a challenge in many countries (Gallagher, Hipkins & Zohar, 2012). Although teachers believe these skills to be important and want to give attention to them in their lessons, they often do not know how exactly to incorporate the skills in their teaching practice. Especially the skill 'problem solving', which Thijs et al. (2014) define as "recognizing and acknowledging a problem, and determining a course of action in order to solve that problem" (p. 37) is perceived as difficult by teachers (Thijs et al., 2014).

In the Netherlands, schools vary in which skills they implement and the degree to which they implement those skills. In primary education, and especially in the upper grades of primary education, there is significantly more attention for 21st century skills compared to secondary education (Thijs et al., 2014). Despite these differences in attention for 21st century skills, both teachers in primary education and secondary education would like to pay more attention to these skills. In order to do so, support is required, since they do not yet feel adequately prepared to implement such skills in their lessons (Thijs et al., 2014).

Teachers are major factors in changes in educational practice, since their beliefs, attitudes, and competences shape their teaching (Voogt & Pareja Roblin, 2010). Also for the implementation of 21st century skills in education Voogt and Pareja Roblin (2010) stress the central role teachers play, and the necessity to give teachers support in this. In order to support teachers in teaching 21st century skills, Thijs et al. (2014) propose, amongst other forms of support, to provide teachers with curricular elaborative materials. In such material, a certain skill is integrated in a lesson, thus showing how a skill could be implemented in teaching practice.

1.2 Goal of the study

Since 21st century skills are not yet adequately implemented in education in the Netherlands and teachers expressed having difficulty implementing these skills (Thijs et al., 2014), SLO has started to make learning materials to support teachers. This material provides information on what a specific skill encompasses and how this skill could be taught, by providing an example of a lesson with the skill and the reasoning behind

the material. It is not yet known whether this material will actually help teachers in implementing aspects of a specific skill in their lesson. Furthermore, the way in which this support material is perceived by teachers is not known. This is important to identify as well, since teachers are the target group. To address these questions, an evaluative study was conducted.

The study focused on two materials developed for the 21st century skill problem solving in secondary education. This focus was chosen, since (as stated above) teachers especially perceive the skill problem solving as difficult, and given the fact that secondary schools pay significantly less attention to 21st century skills compared to primary schools. In one evaluated material students were asked to identify a good location for a new playground in their area. The other evaluated material challenged students to think about how a snowman could be kept from melting longest when temperature is rising.

The material was evaluated on several aspects. The extent to which a lesson taught with the material encompassed the skill problem solving as a 21st century skill was examined, as well as how teachers perceived the provided material. Furthermore, when material aims to support teachers in incorporating problem solving in their lesson, it is important that this material covers all elements of problem solving as a 21st century skill. Therefore, the content of the support material was also evaluated based on problem solving literature. Based on these evaluations, recommendations were given to further improve the developed material and to guide the design of yet to be developed material.

Research questions

The following research questions guided this evaluative study:

- 1) To what extent are the characteristics of problem solving as a 21st century skill, according to the literature, present in the material under review?
- 2) To what extent is the material under review implemented by secondary school teachers with respect to the 21st century skill problem solving?
- 3) How do secondary school teachers perceive the material under review, aimed at supporting teachers in teaching the 21st century skill problem solving?

Outline of the thesis

In the next chapter (Chapter 2) the theoretical dimensions of the research are described, by introducing concepts such as problem solving, and conditions for teaching problem solving skills. The third chapter is concerned with the methodology used for this study. The results of this study are elaborated on in the chapters 4, 5, and 6, where in each separate chapter the results concerning a research question are described. Finally, in Chapter 7 conclusions are drawn and the findings are discussed in the light of the literature.

2. Theoretical framework

In this chapter, the literature that guided this research is discussed. First, the importance for 21st century education and teaching problem solving in a changing world is described. Subsequently, the concept of problem solving and what it encompasses as a 21st century skill is illustrated. Finally, the conditions needed for implementing problem solving as a 21st century skill in education are elaborated on.

2.1 Education in the 21st century

Due to technological developments, the world has changed from an industrial age in the 20th century to an information age in the 21st century, and this changing world asks for different skills and knowledge of its citizens (Kivunja, 2015). A static body of knowledge, which was sufficient for the demands posed on people in the 20th century, is not adequate for 21st century living anymore. In the fast-paced changing world of the 21st century, although it is still necessary to acquire knowledge of core subjects, it is more valuable to know how to employ the attained knowledge and skills, so that people can adapt their knowledge to fit the changing circumstances they face (Schoen & Fusarelli, 2008; Sahin, 2009).

One of the most important goals of education is to equip students for their personal and work-related life after school (Trilling & Fadel, 2009). Kivunja (2014) states that the changed world calls for a new learning paradigm. The aim in such a new learning paradigm is not to prepare students for life in an industrial society (which was the goal of the pre-21st century learning paradigm), but rather to provide students with appropriate skills so that they will be adequately prepared for life in the 21st century (Kivunja, 2014). According to Carlgren (2013) it would be good to teach students in secondary education such 21st century skills, because although in post-secondary institutions it is aimed to implement these skills in the curriculum, they often fail to explicitly teach it to their students and provide them with support. For some students this might not be problematic since they will already be able to use such skills and therefore not need support, but some students might require support in order to adequately use the skills (Carlgren, 2013). To ensure that all students have equal opportunities in both post-secondary education and their future work-life, it would therefore be good to ensure that students learn the skills to thrive in the 21st century during their secondary education (Carlgren, 2013).

Trilling and Fadel (2009) distinguish three categories of 21st century skills that students should acquire through education, namely learning and innovation skills, career and life skills, and digital literacy skills. Together with core subject knowledge, these can be combined into a formula for job-readiness with 21st century skills, meaning that all of these categories and core subject knowledge are necessary to obtain through education in order to prepare students for work in the 21st century (Kivunja, 2015).

2.2 Problem solving

One of the skills in the learning and innovation skills domain is problem solving (Trilling & Fadel, 2009). Several authors point at the importance of this skill for students to obtain. According to Robitaille and Maldonado (2015) business owners and educators perceive problem solving, together with critical thinking, as the most important skill for high school students to achieve. Others also articulate the importance for students to attain the skill problem solving (e.g. Stoyanov & Kirschner, 2007; Zmuda, 2009), and Jonassen (2010) states that problem solving is the most important cognitive goal of education.

This skill to solve problems is important to acquire for students who attend school now, since they will in their daily life encounter many problem solving tasks, in their work-related life as well as in their personal life (Malouff & Schutte, 2008). Trilling and Fadel (2009) state that in the 21st century great

problems have to be solved, and that citizens who can help in solving these problems are needed. Therefore, students have to be equipped with the ability to deliver a contribution in solving these problems (Trilling & Fadel, 2009).

Although the concept problem solving is not new, as is indicated above it becomes even more relevant in a world with rapid societal and technological changes (Stoyanov & Kirschner, 2007), and is thus an important skill to consider when incorporating 21st century skills in the curriculum in order to adequately prepare students for after-school life. To understand how problem solving should be implemented in 21st century education, it is first important to consider what problem solving as a concept encompasses.

Types of problem solving

That the concept of problem solving is not new, is reflected in the fact that Dewey pointed out in his book dating back to 1933 that we learn by learning to think (Hermanowicz, 1961). This reflective thinking comprises three steps, namely first the identification of a problem, second studying the problem, and finally reaching a conclusion on the problem (Hiebert et al., 1996). In this context, a problem is defined as something that the person involved in the situation views as being difficult and complicated, and for which s/he thinks a solution should be found (Hiebert et al., 1996).

Another way to determine whether there is a problem, is to view problems as having two critical attributes. First, there should be a difference between a goal state and the current situation, and second, it should be worthwhile to someone to bridge that difference, for either social, cultural, or intellectual reasons. Closing that gap between the current state and the goal state is considered to be the problem solving process (Jonassen, 2000). Also according to Hayes (1980) there is a problem when there is a difference between a goal state and the current state, and is not known to the solver how to find a way to bridge that gap (Hayes, 1980).

Bodner (1987) elaborates on the definition posed by Hayes, and indicates that whether the problem solver knows a way to close the gap or not, determines whether there is a problem or an exercise. According to Bodner (1987) with an exercise the solver knows how to close the gap, whereas with a problem it is not clear to the solver how the gap could be closed. Therefore, whether there is a problem or an exercise is also determined by characteristics of the solver (Bodner, 1987). Schoenfeld (1992) also points at a dichotomy concerning problems, by referring to the definition of a problem provided by Webster's Dictionary. In this definition it is stated that a problem could either be something mathematical, in which it is required to perform a certain tasks, or it could be a question, that is both difficult and complicated (Schoenfeld, 1992).

Samson (2015) mentions Creative Problem Solving (CPS) as a teaching strategy to engage students in their learning and motivate them to learn. In CPS students have to solve 'wicked' problems, i.e. problems that are real, unsolved, vague, and without a clear answer (Samson, 2015). This definition resembles the definition that Ge and Land (2004) pose for ill-structured problems. Such problems are situated in the real world, ill defined, complex, and are open-ended, meaning that it is not known beforehand in what line the solution should be sought (Ge & Land, 2004).

Jonassen (1997) distinguishes different types of problems, which on one side resemble the previously mentioned exercises, and on the other hand 'wicked' and ill-structured problems. The three types of problems that Jonassen (1997) identifies are puzzle problems, well-structured problems, and ill-structured problems. These types of problems are not strictly separate classifications, but rather lie on a continuum from decontextualised problems with one solution to context-specific problems with multiple possible solutions (Jonassen, 1997).

Puzzle problems lie on one end of the continuum, for they are decontextualised and have one correct solution. All elements that are required to reach that solution are known, and a specific procedure

is required to reach it in the most efficient manner, which is therefore the correct procedure (Jonassen, 1997). These problems resemble the exercises that were mentioned above.

Well-structured problems are more context dependent compared to puzzle problems. Well-structured problems are well defined with a noted goal state. All elements that are required to solve the problem are known and are presented in a clear way. The problem solver has to apply a limited number and constrained set of rules and principles in order to solve the problem. A well-structured problem has a presumed solution, and there is a preferred procedure for reaching that solution (Jonassen, 1997; Ge & Land, 2004).

In contrast to well-structured problems, ill-structured problems are ill defined and possess some uncertainty. The goal state might be unclear or vaguely defined, and it is not apparent which elements are required to solve the problem. For ill-structured problems, there is often not one single solution, and there may be multiple routes to reach a solution. There are no general rules or principles that will afford success in most situations, and therefore the actions that will lead to success are ambiguous. Also, what one person views as an acceptable solution, might be considered unacceptable for another. Part of the process for solving ill-structured problems is to interpret the problem, and therefore choices made during the process have to be defended by the problem solver through the provision of arguments. Ill-structured problems are very context dependent, and are the most likely problems to encounter in everyday life. Examples of ill-structured problems include political and social dilemmas (Jonassen, 1997; Ge & Land, 2004).

By viewing types of problems as laying on a continuum from decontextualised problems with one solution to context-specific problems with multiple possible solutions, it is possible to label a problem as being more well-structured or more ill-structured in nature. This manner of labelling thus provides a way to categorise a problem based on characteristics innate to the problem, rather than it is being (partially) determined based on characteristics of the problem solver. Therefore, the typology of problems as posed by Jonassen (1997) provides a good way of interpreting problems, and is therefore taken as a basis in this study.

Problem solving as a 21st century skill

In order to determine how problem solving should be incorporated as a skill in 21st century education, it is important to examine what problem solving as a 21st century skill encompasses. To do so, the typology determined by Jonassen (1997) is taken as a starting point. This typology is suitable to use, since it does not presume a strict classification, but rather provides a continuum on which problems lie.

Because of its characteristics, puzzle problems are not consistent with most real life problems people will encounter (Jonassen, 1997). Therefore, such problems might not be most relevant to use for the educational purpose of preparing students for life after school in which they will need to be able to solve complex problems.

Well-structured problems are the type of problems that are often found in educational settings, where e.g. students have to solve problems by applying the knowledge attained through a certain chapter or lesson-series (Jonassen, 1997). Although well-structured problems are more context dependent compared to puzzle-problems, the skills that are required to solve both types of problems are only transferable to similar problems to the one that is being practiced (Jonassen 1997).

It is assumed that learning to solve well-structured problems in school will afford the ability to solve complex, situated, real-life problems, however Jonassen (1997) points out that such real-life problems ask for ill-structured problem solving skills, and learning to solve well-structured problems in a school-setting provides limited transferability and relevance for solving complex, real-life problems. Therefore, in order to adequately prepare students for work and life in the 21st century, it would be most beneficial if schools teach students how to deal with ill-structured problems, since these are the kind of

problems that they will likely encounter in everyday life (Jonassen, 1997). Problem solving as a 21st century skill can thus be described as ill-structured problem solving.

The process for ill-structured problem solving

In addition to a typology of problems, Jonassen (1997) has also articulated the processes that learners should go through when they either solve a well-structured or an ill-structured problem. Since it was concluded above that problem solving as a 21st century skill mostly resembles ill-structured problem solving, it seems logical to also take this process, which comprises seven steps, as a basis in this study. Others (e.g. Ge & Land, 2004) have also identified processes involved in ill-structured problem solving, but these processes often provide less detail in comparison to the steps distinguished by Jonassen (1997). The process for ill-structured problem solving as articulated by Jonassen (1997) is described in some detail below.

First, learners as problem solvers have to understand why there is a problem, and how this problem has emerged in the specific context (Jonassen, 1997). Such a mental representation of the situation is known as the problem space (Eseryel, Ifenthaler & Ge, 2013). This first step of articulating the problem space, is considered to be a very important step in the problem solving process, since in order to adequately solve the problem, it is necessary that one has ample knowledge on the possible causes of the problem, and contextual factors that influence the problem (Jonassen, 1997). Eseryel et al. (2013) point out that the capability of the problem solver to create an adequate mental representation of the situation, highly affects the quality of the problem solving. Ge and Land (2004) also mention the importance for the problem solver to interpret the problem by elaborating on what constitutes that problem, and to gather an understanding of the context in which the problem is situated (Ge & Land, 2004). This is the process of creating a problem representation, and is an important process in solving an ill-structured problem, since it forms the basis for decisions that will have to be made later on in the process (Ge & Land, 2004). Students however might be tempted to start with a solution process instead of devoting time and energy to understand and interpret the problem at hand (Ge & Land, 2004).

An ill-structured problem is complex, and there may be various opinions and perspectives concerning the problem space. Different stakeholders might view the problem differently, and also have different criteria on which they assess a solution. When solving a problem, it is important to consider all these different perspectives, because it demonstrates that there is not a single, straightforward solution for an ill-structured problem. Identification and clarification of these alternate perspectives constitutes the second step in the problem solving process (Jonassen, 1997).

The third step in the problem solving process is to generate possible solutions to the problem. The identification of the various positions different stakeholders may have towards the problem in the second step form the basis for generating possible solutions to the problem. Different views on the problem may ask for different satisfying solutions, and it is the problem solver's task in this third step to generate such varying solutions (Jonassen, 1997).

As a fourth step the problem solvers have to provide arguments and counterarguments for the generated possible solutions, to assess the feasibility of each possible solution. In doing so, they also have to look back at the problem representation and the generated possible solutions, to make further adjustments to improve both (Jonassen, 1997). Also according to Ge and Land (2004), the justification of actions taken and choices made is part of ill-structured problem solving.

The fifth step articulated by Jonassen (1997) is not so much a separate step, but is a reflective process that occurs throughout the first four steps of the problem solving process. In these first four steps, it is important that the learners constantly reflect on what they know and how this affects the problem space and the possible solutions (Jonassen, 1997). Most ill-structured problems are so complex,

that in a school-based context it is not possible to actually implement the suggested solution. For this reason, most school-based problem-solving activities go no further than the fifth step (Jonassen, 1997).

Ill-structured problems do often not have a single solution that is correct. Therefore, when a solution has been implemented it is necessary to monitor whether it functions as was envisioned. Both the implementation and monitoring of a solution form the sixth step in the problem solving process (Jonassen, 1997). The process of monitoring and evaluating is by Ge and Land (2004) mentioned in relation to the whole ill-structured problem solving process. This means that during the entire ill-structured problem solving-process, the problem solver should reflect on how things are going and what could be improved (Ge & land, 2004).

The seventh and final step in the problem solving process as articulated by Jonassen (1997) is to adapt the solution. Once the solution has been implemented and monitored, it might be necessary to adapt that solution. This adapted solution should again be implemented and monitored, and in that way it can become an iterative process (Jonassen, 1997).

In Table 2.1 a schematic overview is given of the process for solving ill-structured problems as described above.

Table 2.1

<i>Process for ill-structured problem solving (according to Jonassen, 1997)</i>		
5) Process of monitoring and reflecting	→	1) Articulating problem space
	→	2) Identification of stakeholders (and their perspectives)
	→	3) Generating possible solutions
	→	4) Assessing viability of possible solutions
		6) Implementing and monitoring solution *
		7) Adapting solution *

Note. Steps marked with an asterisk (*) are according to Jonassen (1997) often not possible to perform in a school-based context, because of complexity of ill-structured problems.

Related 21st century skills

In this study, problem solving as a 21st century skill is defined as ill-structured problem solving constituted by Jonassen (1997). However, in order to solve ill-structured problems, also other 21st century skills are related to some extent.

As mentioned earlier, the characteristics of ill-structured problem solving show great resemblance with CPS. Samson (2015) regards CPS as a group activity, which thus asks for collaboration (Samson, 2015). Ge & Land (2004) also point at the relatedness of the skill collaboration to problem solving. They state that peer interactions during the process of problem representation (the first step in the ill-structured problem solving process) can improve the outcomes of this step. The reasoning behind this statement is that when students work together with their peers, they will presumably identify more problem representations, and will take more factors into account (Ge & Land, 2004). Therefore, collaboration, although it is not a

prerequisite for ill-structured problem solving, is a 21st century skill that can enhance the problem solving process.

When generating possible solutions for a problem, which is the third step in the problem solving process according to Jonassen (1997), creativity is required. This will enable problem solvers not only to use their prior knowledge when generating solutions, but also to use unrelated thoughts and emotions (Jonassen, 1997). Also, as the name logically implies, in CPS creativity is a key element (Samson, 2015). Creativity is thus a 21st century skill that is necessary for at least part of the problem solving process.

Wopereis, Brand-Gruwel & Vermetten (2008) refer to the term information problem solving as a type of problem solving in which the current state is an information deficiency, which is fulfilled in the goal situation (i.e. that determines whether the problem is solved). Since in modern society an abundance of information is at hand, people need skills to locate, extract, and use relevant information to meet the information need posed by a problem. This asks for so-called information literacy skills, a sub-skill of the 21st century skill digital literacy (Wopereis et al., 2008).

Hence, when learning the skill problem solving, students automatically engage in other 21st century skills as well, either through the ill-structured problem solving process or the type of problem to be solved.

2.3 Conditions for teaching problem solving

In order to incorporate problem solving as a 21st century skill in education, three conditions could be distilled from several literature sources that are worthwhile to consider during this implementation process. First, the learning environment should endorse teaching problem solving as a 21st century. Second, teachers should be given support in teaching problem solving as a 21st century skill, and finally, educative curriculum materials could be used to provide teachers with the needed support. These three conditions are clarified below.

A student centred, active learning environment

Jonassen (1997) notes that ill-structured problem solving matches ideas of constructivism, as knowledge acquisition is dependent on the learner's experience, and therefore context dependent (Jonassen, 1997). People actively construct their own reality, based on what they experience and their currently held mental models (Samson, 2015). According to constructivism, learning occurs through such active meaning making. Knowledge cannot be transmitted as such, but has to be constructed through the mental activity performed by the learner (Michael, 2006). In order for students to gain knowledge, they therefore have to construe their own representations of reality, and cannot receive knowledge as such from e.g. their teachers (Prince & Felder, 2006).

Since, as Jonassen (1997) pointed out, problem solving matches constructivism, teaching problem solving skills to students also implies a certain activity from them. According to Michael (2006), actively engaging students in their learning process can be facilitated through a student centred, active learning environment. In such a learning environment students learn through building mental models, by testing and repairing those mental models, and subsequently using them in new situations. This way of learning is likely to achieve meaningful learning according to Michael (2006).

Active learning means that students are engaged in activities that facilitate them to reflect on ideas and ways to use those ideas. Such mental activity might be achieved in students through letting them gather information, and also through problem solving activities (Michael, 2006). By means of active learning, student learning will usually go beyond the mere memorisation and recollection of facts. Instead, students will be engaged in the process of constructing new knowledge, by integrating new experiences with prior knowledge (Newman, Lamendola, Morris Deyoe & Connor, 2015). This fits the idea of

constructivism, since its aim is to teach students how to use their mind, so they can use what they have learned in new situations (Schoen & Fusarelli, 2008). Active learning will students thus allow to transfer what they have learned to new situations they will face in their life after school (Newman et al., 2015), which is the aim of teaching students 21st century skills.

Michael (2006) mentions student centredness in education as another aspect to engage students in their learning. With student centred instruction, instruction is largely influenced by the learners. It is often explained as opposed to teacher centred, in which teacher activity in front of the class determines to a large extent what is learned (Michael, 2006). Zmuda (2009) also states that a more student centred approach is necessary to ensure 21st century education. According to her, it is not enough to merely incorporate new skills in a curriculum, the way of teaching has to be adapted as well (Zmuda, 2009).

Therefore, it would also not be sufficient to merely incorporate the aforementioned process for ill-structured problem solving by Jonassen (1997) in lessons to learn students how they can deal with ill-structured problems. A pedagogical approach that is student centred and elicits active learning should be present in schools in order to teach for the 21st century skill problem solving.

Teacher support

Although in a student centred, active learning environment focus is on the learners, it does not mean that the teacher does not have an important role (Michael, 2006). In a student centred learning environment, teachers should adapt their teaching to the needs of individual students, by recognising what an individual student needs rather than walking through the same program year after year (Zmuda, 2009). Tsoukalas (2012) states that when the goal is to promote 21st century skills in students, teachers have to guide students instead of feeding them information. Teachers' role would be that of coach and facilitator, so they can help learners become actively involved in their own learning and to facilitate an environment for learning in which students feel secure to become actively involved (Samson, 2015).

According to Schoen and Fusarelli (2008) a more active learning environment that is more personal differs from the traditional teacher directed approach, and Michael (2006) mentions that a student centred, active learning environment does not occur out of nowhere. Michael (2006) also states that implementing such a learning environment might ask for a different approach to teaching from the teacher, for which deliberate implementation is crucial. Therefore he recommends to view the teacher as a learner of this approach (Michael, 2006). Tsoukalas (2012) also points to the fact that it is not easy for teachers to change their teaching. Teachers will need to feel supported, since another approach to teaching requires risk-taking from the teachers (Tsoukalas, 2012). Given these reasons, it would be wise to give teachers support in order to implement 21st century skills in the curriculum.

Carlgrén (2013) gives another reason why it might be advisable to give teachers support when 21st century education is concerned. She poses three reasons why students in high schools do not yet properly learn skills such as problem solving. One reason concerns the western educational model, and a second reason has to do with the innate complexity of the skills. The third reason Carlgrén poses affects the competence teachers show in teaching skills such as problem solving, and is related to the need for teacher support. Some teachers lack in ability, do not feel confident, and do not comprehend the skills such as problem solving well enough to teach them appropriately. This might partially occur because they were never taught how to use and teach those skills themselves (Carlgrén, 2013). Teachers working in high schools stretch over multiple generations, which means that the education and upbringing these teachers had differs for groups of teachers. The education and upbringing that teachers have had, molds the way in which they view and use skills, and consequently also influences the way in which they teach those skills to their students. Even though teachers might adequately use the skills themselves, it does not guarantee that they have the ability to adequately teach the skills to their students (Carlgrén, 2013). Therefore,

providing teachers with support would be a good idea when incorporating 21st century skills such as problem solving in education.

Educative curriculum materials

Using educative curriculum materials is a way to support teachers in their learning (Schneider, Krajcik & Marx, 2000). Curriculum materials are resources that aim to guide teachers' instructions, which often take the shape of printed teacher guides or student workbooks. Educative curriculum materials are curriculum materials that incorporate educative features for teachers (Davis, Sullivan Palincsar, Arias, Schultz Bismack, Marulis & Iwashyna, 2014). In this way, both student learning and teacher learning is facilitated through such material. Educative features that are incorporated in these materials, are any textual or visual information that is aimed at supporting teachers in their teaching (Davis et al., 2014). Educative curriculum materials differ from standard teacher guides, since it is aimed not only to give teachers support for teaching strategies, but also to ensure teacher learning (Davis & Krajcik, 2005).

Educative curriculum materials should provide teachers with the rationale behind the choices made in the material, rather than merely guide teachers' action (Davis & Krajcik, 2005). Through the provision of such a rationale, this will help teachers in the enactment of the material. It will also help teachers in making choices that are still in line with the rationale in the material when they wish to adapt certain recommendations posed in the material, to make it more fit for their particular situation (Davis et al, 2014). As such, a rationale promotes teacher autonomy, since it gives teachers space to adapt the material and apply the information in the material more flexibly (Davis & Krajcik, 2005).

Educative curriculum materials should not be used instead of other teacher professional development programs, but because of the characteristics, its use has certain advantages (Schneider et al., 2000). Teachers can use educative materials in their own classroom, over a longer period. This is different from e.g. a professional development training that is given twice a year, outside the classroom. Teachers use curriculum materials often, since it helps them to structure and plan their activities. It is not something new teachers will have to adopt, it is just a different form of curriculum materials. Finally, since almost all teachers use curriculum materials, by incorporating educative features into curriculum material it is a form of professional development which can be relatively easy be implemented by a large number of teachers (Schneider et al., 2000).

Summary

In this chapter it was established that problem solving as a 21st century skill mostly resembles ill-structured problems. In order to determine the degree to which a problem is ill-structured, the typology for problems and the continuum on which they lie as described by Jonassen (1997), provide an adequate starting point for determining the extent to which a certain problem is indeed ill-structured, and thus suitable for teaching problem solving as a 21st century skill. In addition, when teaching for 21st century skills such as problem solving, three conditions that are important to consider were identified. These conditions are a student centred, active learning environment, teacher support, and educative curriculum materials. These are the core theoretical constructs that underly the present study. In the next chapter it will be elucidated how this study to evaluate the material under review was conducted.

3. Method

In this chapter, the methodology used in this study is described. First, the research design is explained. The material for both geography and physics is described afterwards. Subsequently, the sample and the procedure for data collection are elucidated. Finally, the instruments used to gather the data are described, and it is explained how the data were analysed.

3.1 Research design

This evaluative study was descriptive in nature, and consisted of three parts. Each part was aimed at evaluating the material under review, all with their own focus related to a research question. The first research question focused on evaluating the material on the extent to which it incorporated problem solving as a 21st century skill (as defined according to the literature). This formed the basis for the second research question, through which it was aimed to identify the extent to which the elements of problem solving in the material were indeed implemented by the participating teachers. Subsequently, the third research question's goal was to explore how teachers perceive the material under review.

In order to determine the extent of problem solving in a lesson, it was first necessary to establish to what extent elements of problem solving as a 21st century skill were indeed present in the material under review. In order to answer the first research question, it was therefore described to what extent the elements of problem solving as a 21st century skill were present in the material under review. To ascertain what problem solving as a 21st century skill encompasses (and thus what elements should be present in material for teaching the skills problem solving), a literature study was conducted, whose results can be found in Chapter 2.

After determining the extent to which the characteristics of problem solving as a 21st century skill were present in the material under review, the following step was to describe how this material was implemented by teachers with regard to the skill problem solving. The lessons taught with the material were observed, in order to describe the degree to which the teachers taught the skill problem solving in a lesson, and thereby to answer the second research question.

These first two research questions focused on the intended and implemented lesson. That is, both the degree to which the intended lesson comprised problem solving (through examining the material on the extent of problem solving in it), and the degree of problem solving in the implemented lesson (through observing how teachers taught the lesson with the material concerning the skill problem solving) were described.

The focus of the third research question was to evaluate how teachers perceive the material under review. Through interviews, teachers who worked with the material were asked to give their opinion on it, i.e. what they valued in it and what they thought could be improved.

3.2 Description of the material

Two materials were evaluated for this study: one for geography, and one for physics. Both materials are described below.

Geography material

The material for geography was developed by curriculum developers at SLO and is called 'Where should the new playground be located?'. In the lessons with this material, students are told that their local council has noticed that there are too few playgrounds in their neighbourhood, and that, in order for children to

live healthily, it is important that there should be enough facilities to play outside. The council does not know where this playground could be best located, and what the layout of this playground should be. They therefore have assigned the students with the (fictional) task to find a good location for the new playground, and also to determine what this playground should look like. Through activities specified in the material, the students are guided through the process of solving this problem. The material for geography is in Dutch and can be found in Appendix A.

Physics material

Curriculum developers at SLO also made the material for physics, which is called 'The snowman'. In the lesson taught with this material, the students need to think about a problem that they could encounter by themselves, namely how they could preserve a snowman longer, even when temperature rises. Starting point of the lesson is a so-called Concept Cartoon, in which an everyday situation is presented with comments from different viewpoints on that situation. In the case of the snowman, the concept cartoon depicts an image of a snowman and three students. These three students all express a different viewpoint. Student A states that you should not put a coat on the snowman, because it will cause it to melt faster. Student B on the other hand says that a coat will keep the snowman cold, and thereby delaying the melting process of the snowman. According to student C a coat will not make much difference. Through thinking about this by themselves and discussing their reasoning with peers, a joint decision has to be made on how the snowman could be preserved longer. The students also have to conduct an experiment, through which it is aimed to discover the soundness of their decision. By thinking of this problem and how it could be solved, it is aimed that students, apart from gaining experience with problem solving skills, will learn about the physical concepts of heat transfer and thermal insulation. The material for physics is in Dutch and can be found in Appendix B.

3.3 Sample

In this study, only secondary school teachers teaching the subjects geography or physics in the first grade (students aged 12) were asked to participate. Because of practical reasons (i.e. the participating teachers had to be observed when teaching the lesson with the material within a limited time span), only teachers working in schools in the relative proximity of the researcher (i.e. in the east of The Netherlands) were approached to participate. Also, all approached secondary school teachers teaching the aforementioned subjects that were willing to participate were included in the study, no further selection criteria were employed. The sample used in this study could therefore be described as a convenience sample, since the most efficient and convenient way to obtain the sample was used (Boudah, 2011). Yet, for this research, a convenience sample was not problematic, since its aim was not to generalise. Instead, it was a first exploration as to how the newly developed materials were used and perceived by teachers in order to gather an understanding of how the material should be further developed. This purpose fits the qualitative approach taken in this study, in which the aim is not to generalise results but rather to provide an understanding of a phenomenon in a real context (Marshall, 1996).

Contacting the respondents

Taking into account the time span of the research, contacting the teachers on schools took place shortly before the summer holidays of the school year 2014/2015. In order to ask the applicable teachers to participate (i.e. teachers teaching either geography or physics to first graders), 15 secondary schools were approached for contact details of all such teachers. Of these 15 schools, 11 teachers agreed to participate in the research. In addition, personal contacts of the researcher were used to get in touch with teachers.

Through these contacts, 4 teachers who were willing to participate were found. Thus, before the summer holidays, the total number of teachers that had agreed to participate in the study was 15.

After the summer holidays, these 15 teachers were approached again to make concrete appointments for the observation(s) and subsequent interview. Unfortunately, it was not possible to make appointments with all teachers in the allocated weeks for data collection, or made appointments could in the end not proceed because of personal circumstances of the teachers (e.g. illness), causing some dropouts. Also, some teachers withdrew from the research. The total number of teachers that eventually did participate in the research was therefore 7, of which 4 teachers were initially contacted through contacts of the researcher and the other 3 teachers were initially contacted via school secretaries. Two participating teachers worked at the same school, the other teachers all worked at different schools located in different cities.

Characteristics of participants

Seven secondary school teachers participated in this study, of which 4 taught geography and 3 taught physics. Mean age of all the teachers was 46.7 years, ranging from 28 to 61 years. Only one of the teachers was female. Mean average of the years working in education was 23.7, ranging from 7 to 38. The exact age and years of working experience of all teachers, together with other participant characteristics, are displayed in Table 1. For this report, all teachers were randomly given a letter (from A to G), thereby ensuring anonymity of the participating teachers.

Table 1

Characteristics per participant

Teacher	Subject taught	Age in years	Sex	Number of years working experience in education
Teacher A	Geography	60	Male	38
Teacher B*	Geography	41	Female	18
Teacher C	Physics	28	Male	7
Teacher D	Physics	40	Male	18
Teacher E*	Geography	59	Male	31
Teacher F	Physics	38	Male	16
Teacher G	Geography	61	Male	38

Note. The teachers marked with an asterisk (*) worked at the same school. The other teachers all worked at different schools.

3.4 Procedure for data collection

In order to collect the data, appointments with the participating teachers took place four weeks before and one week after the autumn break in the school year 2015/2016. Since secondary school teachers are bound to rosters for when they can teach a certain class, and data collection was allocated to certain weeks, it was anticipated in advance that it might not be possible to observe all lessons taught with the material under review. This was especially the case for the material developed for the geography lesson, as this material spread over 2 to 3 lessons. Therefore, it was decided upon that of all participating teachers, at least the first lesson with the material would be observed, and further as much lessons as possible. The first lesson was chosen, since in this lesson the first step of the problem solving process would be covered. As is described in Chapter 2, the first step in the problem solving process is a very important one, since in this step the knowledge is attained on possible causes of the problem and the context in which the problem is situated.

When appointments were made with the teachers, the applicable material (either for geography or physics) was sent to the teachers. This consisted of material for the students, an explanation for the teacher, and an appendix with a 'checklist' for assessing own material. In addition to this material, the observation scheme used for this study was sent to the teachers. During the observations, the researcher sat at the back of the class, in order to be as unobtrusive as possible, and in that way observe the lesson as it would normally take place. When a teacher had taught all lessons using the support material, an appointment was made for the interview. In this way, the teacher could be interviewed on all his or her experiences with the material. Teachers were asked permission to record the interview, so that a verbatim transcript of the interview could be made afterwards.

Ethics have been considered throughout the research, e.g. by asking the teachers for permission to record the interview. Also, teachers were provided with the observation scheme used in this study, thereby providing transparency to them on what they would be observed. Teachers knew they could withdraw from the research at any given time, and the names of the teachers to the corresponding data are only known to the researcher.

3.5 Instruments

To gather data for this research, two instruments were used: an observation scheme and an interview scheme. In the following section it will be explained how these were developed.

Observation scheme

The aim of the observation scheme was to observe the extent to which a teacher implemented the material under review concerning the skill problem solving. In order to do so, it was important to take the rationale that constituted the material under review in consideration, since in an ideal situation this had to be observed. Therefore, the observation scheme was based on the process for problem solving that was also used when developing the material. This process comprised 7 main steps (namely: recognising and clarifying the problem, analysing the problem, considering possible solutions, selecting a solution, applying that solution, and evaluating), each with several sub-steps.

These main steps, that together with the sub-steps constituted the observation scheme, are to a large extent consistent with the steps distinguished by Jonassen (1997) for solving ill-structured problems. One step in the process articulated by Jonassen (1997), namely to identify and clarify the perspectives of different stakeholders, is not mentioned explicitly in the process used to develop the material, and therefore also not in the observation scheme. This could however be seen as part of the process of analysing the problem. Two steps identified by Jonassen (1997) are not reflected in the process present in the material, namely the monitoring and reflecting on the problem solving process, and adapting the solution. However, as Jonassen (1997) points out, monitoring and reflecting could be viewed as being not a separate step in the process, but rather a continuous process when solving a problem. All other processes mentioned by Jonassen (1997) are present in the observation scheme, and also one extra step was included (namely selecting a solution). The exact differences and similarities between the process used during the development of the material (and thus underpinning the material under review) and the process articulated by Jonassen (1997) are portrayed in Appendix C.

Since this study focused on the extent to which there is attention for the skill problem solving in a lesson through actions taken by the teacher, the elements comprising the observation scheme are formulated as such. Another important aspect concerning the skill problem solving, is that it is crucial that teachers guide their students, but let them think for themselves, rather than providing them with 'correct answers' in each step. The importance of the role of teacher as a coach and facilitator was also elaborated

on in Chapter 2. Therefore, in the observation scheme, it is stated explicitly that the teacher lets the students do something.

In the observation scheme, by ticking the box for 'yes' or 'no', per sub-step it could be scored whether the teacher did a certain step in the lesson or not. Apart from ticking the boxes per sub-step, some space per (sub-)step was given in the observation scheme to add notes, so that the reason for ticking a certain box could be further specified. This enabled interpreting the reasoning behind ticking a certain box. Besides 'yes' or 'no', it could be the case that a certain step was not applicable for an observed lesson (e.g. when this step would be covered in another lesson). To provide for such circumstances, the category 'not applicable' ('n.a.') was added.

Although the observation scheme was based on the process for ill-structured problem solving as articulated by Jonassen (1997), it was not derived from literature as a whole, and therefore it was not validated through research. That is why the proposed observation scheme was showed to experts and a pilot was conducted first. A blank observation scheme can be found in Appendix D.

Interview scheme

The second instrument used in this study was an interview scheme, which was semi-structured in nature. The goal of the interview was to discover how teachers perceive the material. Therefore, the interview was partially structured based on the different elements constituting the material (i.e. the material for the students, the explanation for the teacher, and the checklist). Also how the teachers thought they could use the material for transferring it to their own lessons, which is a goal of the material under review, was a topic to be covered in the interview. These topics had to be commented on by the teachers, but further topics to be covered, and the exact order of topics was not determined beforehand. Since it was a first exploration on how teachers perceive the material, it was chosen to question them on certain elements in an as open as possible way, to give them the chance to come up with things that they find important, but may not be mentioned in the research literature. Therefore, this semi-structured interview format was chosen, because it would give enough room to let the teachers mention certain elements that were not anticipated in advance.

This instrument was very context-specific, and therefore an existing instrument was not available. The instrument used in this study was validated to some extent by letting an expert on qualitative research examine it and through piloting it first. The interview scheme can be found in Appendix E.

Piloting of the instruments

Both the observation scheme and the interview scheme were piloted. During the pilot of the observation scheme, a lot of notes were taken in addition to ticking 'yes' or 'no' to elements in the observation scheme. This was to some extent anticipated when constructing the observation scheme, since there was space dedicated for comments with every (sub-)element of the observation scheme. This space was however a bit limited, and thus with the subsequent observations, notes were also taken on additional paper. The observation scheme as such was not changed based on the pilot. The formulation of the elements in the observation scheme did not lead to problems during the observation, and therefore no alterations to it were made.

The interview structure was also not changed based on the pilot, since it provided sufficient structure to cover certain elements, but at the same time let the teacher venture his own experiences with and visions on the material. Also, it gave the teacher space to raise related thoughts which were not anticipated on in advance by the researcher. Since no changes were made to either instrument, the results obtained through the observations and interview with the teacher that was involved in the pilot were included in the study.

3.6 Data analysis

The evaluation of the material under review was done guided by the three research questions. In order to answer these questions, the retrieved data had to be analysed. In the following section, the methods for these analyses will be elaborated on.

Analysing the material for answering the first research question

The first research question was answered based on the literature on problem solving, as was described in Chapter 2. First, the material for both physics and geography was described, and subsequently, based on the literature, it was examined to what extent this material contained the skill problem solving as a 21st century skill. This focused both on the degree to which the problem to be solved was ill-structured (i.e. where on the "continuum" for problems, ranging from decontextualised problems with one solution to context-specific problems with multiple solutions as proposed by Jonassen (1997) one could position the problem), and the degree to which the steps of the ill-structured problem solving process were part of the material.

Observational data for answering the second research question

Data obtained through the observations were meant to answer the second research question and were mostly qualitative in nature. For each participant, an overview was made of the presence (or not) of a (sub)step in the observed lesson(s). The overviews of all teachers of one subject were afterwards combined in one figure, thus providing a visual overview of all observed geography and physics lessons. Subsequently, the notes for all observed lessons were compared and summarised per step, so that the outcomes in the two figures could be further explained, giving a complete overview of how the steps in the problem solving process were represented in the observed lessons.

Interview data for answering the third research question

Data retrieved from the interviews were meant to answer the third research question, and were strictly qualitative in nature. Attride-Stirling (2001) stresses the importance of analysing qualitative data in a methodical way if produced results are to be both useful and meaningful. According to Attride-Stirling (2001) thematic networks is a tool that helps to organise and structure text, so that a thematic analysis can be performed, and underlying themes and structures can be procured. Such networks comprise three levels, which become increasingly abstract: basic themes, organising themes, and global themes. These levels are represented in a network, thus giving an overview of a theme derived from the text (Attride-Stirling, 2001). Although there are also other methods to analyse qualitative data in a methodical manner, the thematic networks method was chosen in this study since the interview scheme was semi-structured, and the thematic network method provided a way to structure the obtained data.

To create such thematic networks, the interviews were recorded so that of each interview a verbatim transcript could be made. This could in turn be analysed in order to interpret the results yielded through the interviews. In the analysis process, the interview transcripts were read and meaningful segments were coded, i.e. a little summary for that piece of interview data was given. After doing this for all interview transcripts, based on the codes a short summary (of one or two pages maximum) was made for each transcript, in which the most important aspects were listed. Elements were regarded as being important when a teacher had spoken of these elements multiple times, had said relatively much about them, or placed emphasis on them. The summaries of the transcripts thus provided an overview per interview of the most important elements that emerged during the interviews with the teachers on how they perceived the material that aimed to support teachers with teaching the 21st century skill problem solving.

All summaries of the transcripts were placed next to each other, and read multiple times in order to get familiar with the most important elements that came forth in the interviews. Also, elements in the summaries were printed on little cards, so that they could be physically shuffled and (re)grouped based on similarities or overlapping content. By making the summaries and shuffling the printed cards, it was aimed to discover overarching themes and structures in the data. Based on the shuffling with the elements and (re)reading the interview summaries, basic themes and subsequently patterns in those basic themes (i.e. the organising themes) could be determined. Grouping of these organising themes eventually led to two global themes, which together with the corresponding organising and basic themes constituted the first versions of the thematic networks, through which the interview data can be structured and visually represented. Several weeks later, the entire interview transcripts were read again, this time with the previously constructed thematic networks next to it, in order to see whether indeed all important elements were covered in the networks or whether adaptations should be made to the content or the wording in the networks. Based on this final analysis, some changes were made, which led to the final thematic networks.

In Chapter 6, the content of these networks and how they originated based on the content of the interviews are clarified. Appendix F, 'Pictures of stages in the analysis process', provides a visual insight in how the analysis process (as described above) that led to these networks occurred.

Since the observations and the interviews in this study yielded (mostly) qualitative data, interpretation of the researcher is a major part during analysing the data and, with the interviews, constructing the thematic networks. The analysis performed for this research was therefore subjective to quite some extent, no matter how methodical it was performed. According to Attride-Stirling (2001) objectivity is not always the fundamental aim of qualitative research, since it is viewed that meaning and deep understanding of a phenomenon can be understood only in its social context (Attride-Stirling, 2001). Therefore, analysing the data in the way described above was suitable for the goals of this research, which focused on the specific context of teachers who have worked with material under review.

4. Results of the evaluation based on the literature

The material under review was evaluated using three sources. In this chapter, the evaluation of the material based on the literature is reported. First, the content of the material is described, and subsequently it is reported to what extent the skill problem solving as a 21st century skill is actually present in the material. This is determined both on the degree to which the problem resembles an ill-structured problem and on whether the steps in the process for solving ill-structured problems are present in the material.

4.1 Elements to consider when analysing the material

As came forward in the theoretical framework presented in Chapter 2, problems are not strictly distributed into strictly separate classifications for well- or ill-structured problems, but rather lie on a continuum (Jonassen 1997). There are however characteristics that are more associated with either well- or ill-structured problems. Very well-structured problems are decontextualised and have a single, correct solution. Very ill-structured problems on the other hand are context specific, and have multiple possible solutions (Jonassen, 1997). With this in mind, it is possible to determine the degree to which a certain problem is more a well-structured or an ill-structured problem. It was also determined in Chapter 2 that for problem solving in education in order to prepare students for the more complex 21st century world, it would be best to expose students to ill-structured problems in school. This will help them in attaining transferable skills necessary for complex, real-life problem solving. Therefore, to teach problem solving in 21st century education, problems to be solved should be more ill-structured than well-structured. Consequently, when analysing the material it was examined to which extent the problem in the material reflected an ill-structured problem.

For the process of solving an ill-structured problem, Jonassen (1997) distinguished seven steps, which have been elucidated in Chapter 2. These steps show great resemblance to the process for problem solving taken into account during the development of the material under review. Since this chapter is aimed at analysing the material based on the literature, the steps as articulated by Jonassen (1997) are taken into account when evaluating the extent to which the process for ill-structured problem solving is present in the material. In the next chapter, when the data retrieved from observing the lessons are analysed, the process of problem solving as used during the development of the material is taken into account, since that formed the basis for how the material was composed, of which the enactment was observed.

4.2 Geography material

As was described in Chapter 3, in the geography material the students are assigned with the fictional task to identify a suitable location for a new playground in their area. Below, the lesson activities and the rationale behind this lesson is specified. Subsequently, it is reported how ill-structured the problem in the material is and to what extent the steps of the problem solving process are present in the material.

Lesson activities

In the first lesson, the teacher has to explain the problem the local council has noticed, and the task that the students have (fictionally) received from them. In their first assignment, the students must determine what elements have to be taken into account when choosing a location and a layout for the new playground. They should first ponder on this by themselves, and subsequently discuss it with a peer.

Afterwards, this is also discussed with the whole class. In the second assignment, which is a homework assignment to be finished before the second lesson, the students have to determine a possible location individually based on the elements that they have identified in assignment 1, and mark this location on a map.

In the second lesson, the students are arranged in small groups (two to three students) that ideally live in the same neighbourhood. In these small groups, the students have to share the locations that they have picked individually, and exchange the arguments that underpin their decision for the chosen location. Through discussing these different options, they must conclusively choose a location for the playground together, and determine the layout of it. When they have chosen the location and the layout, they have to draw this on a map, thereby also considering the elements which should be present in a map (such as a title and scale). Besides this map, they need to write on an additional paper the layout they have chosen for the playground, and their arguments for why their chosen location is the most suitable one for the playground.

In the third lesson, the maps of the different groups are discussed with the whole class, and groups may be asked to explain their map and the choices they have made. This class-discussion is aimed at evaluating how each group has considered the elements identified in the first assignment for their final choice for a location, what the students thought of this assignment, what they have learned, whether collaboration in the groups went well, and what they would or should alter when doing a similar assignment in future.

Rationale

Through this material, it is aimed by the developers of the material that students are exposed to a recognisable, concrete problem that is situated in the own environment of the students. It is stated in the material that such an assignment contributes to meaningful geography education. It is aimed to teach students to pose questions and attain an expository attitude. This will help them identify and support different perspectives based on ample information, and to make decisions based on arguments. Through the lessons, students will learn to explore the problem, by considering which actors are important, what interests play a role, and what environmental characteristics should be taken into account. It is emphasised in the material that students should take sufficient time to explore the problem before they start to think about possible solutions. It is stated that this is essential in order to make a well-thought out and sensible decision. When students experience difficulties in devising such criteria, the teacher is advised to give hints to these students. Through the exploration, criteria are determined which form the basis for decisions taken later in the process. Also in the discussion at the end with the whole class, these criteria should be reflected on.

Problem solving as a 21st century skill in the geography material

The problem posed for the students in the geography material is situated in a specific context, namely the own environment of the students. This environment has certain characteristics that have to be taken into account when considering possible solutions. In the process of solving the problem, the students therefore have to analyse this context and what it means for the problem, in order to find an appropriate solution.

Also, there is not one possible, correct solution. Since there are multiple stakeholders, which all view the problem and optimal situation from their own perspective, these stakeholders may all deem different locations and layouts for the playground a good and acceptable solution. There are thus multiple locations and layouts of the playground that could solve the problem the council has recognised. The reasoning and arguments given for the chosen location and layout determine whether the solution is appropriate.

This problem resembles a real life, political and social problem, in which there is uncertainty about what to consider during the problem solving process. This, and the characteristics mentioned before, make that the problem in the geography lesson shows greater resemblance to an ill-structured problem than a well-structured problem. Therefore, based on the theory of Jonassen (1997), it is a suitable problem to incorporate in a lesson for teaching the 21st century skill problem solving.

Coherence with the ill-structured problem solving process

Table 4.1 portrays the steps for the process of ill-structured problem solving as articulated by Jonassen (1997), which was also shown at the end of Chapter 2. In this table, for each step of the problem solving process it is displayed whether that step is present in the material for geography, either completely, to some extent, or not at all. Below the table, the scoring per step is clarified.

Table 4.1

Presence of the process for ill-structured problem solving (according to Jonassen, 1997) in the geography material

5) Process of monitoring and reflecting	→	1) Articulating problem space	
	→	2) Identification of stakeholders (and their perspectives)	
	→	3) Generating possible solutions	
	→	4) Assessing viability of possible solutions	
		6) Implementing and monitoring solution *	
		7) Adapting solution *	

Note. Steps marked with an asterisk (*) are according to Jonassen (1997) often not possible to perform in a school-based context, because of complexity of ill-structured problems.

	Present in the material
	To some extent present in the material
	Not present in the material

According to Jonassen (1997), the first step when solving a problem is to articulate the problem space and contextual constraints. In the geography lesson, the students have to analyse the problem, but the problem and why the problem is important is already given to them. It is namely expressed in the material that the local council has noticed a problem (i.e. there are not sufficient playgrounds), and that it is important to have a sufficient amount of playgrounds, since it will help children in living healthily by providing a space outside for them to play in. The students are not encouraged to elaborate on this more. The first assignment for the students is to determine which elements should be taken into account in order to solve this problem, namely that it is not known where the playground could be best located and what it should look like. When determining the elements to be taken into account, this also touches the second step in the problem solving process, namely to identify the different stakeholders that are involved and

their perspectives. This is not explicitly in the material stated for the students to identify, but it should logically be an element to take into account. The third step in the problem solving process is to generate possible solutions, based on the alternatives perspectives identified in the second step. In the geography lesson, the students do have to generate a possible location for the playground by themselves, however it is not asked of them to generate multiple locations (and thus multiple solutions). Assessing (multiple) possible solutions based on arguments, which is the fourth step in the problem solving process, does take place in the lesson. This is possible, since in the small groups the contributions of all group members are considered, thus leading to multiple possible solutions that have to be considered. Therefore, although the third step is not part of the geography lesson, the fourth step is. The fifth step that Jonassen (1997) poses, is not really a separate step, but rather a process which should be present throughout the first four steps. This process involves the constant monitoring of the steps taken. This is not explicitly present in the material developed for geography, and although it could be implemented relatively easy by the teacher, there are no suggestions in the material to point this out to teachers. As Jonassen (1997) already pointed out, it might in a school-based setting not be possible to implement the selected solution to a real-life problem. This is also the case for the problem in the geography material. Therefore, the sixth and seventh step are not part of this material.

Although the problem in the geography material resembles an ill-structured problem, and therefore seems very suitable to use in a lesson aimed at teaching problem solving as a 21st century skill, not all steps of the process for an ill-structured problem are adequately present in the material.

4.3 Physics material

In the physics material, the students are asked to reason about how a snowman could be kept from melting longest when temperature rises (see Chapter 3 for a more elaborate description of the material). As was the case with the geography material, first the lesson activities and the rationale behind the material will be described. Thereafter it is elaborated how ill-structured the problem in the material is, and to what extent the steps of the problem solving process are present in the material

Lesson activities

The lesson starts with the teacher explaining the idea of concept cartoons in general to the students, and subsequently showing the concept cartoon of the snowman to the students. First, every individual student has to think about and decide which of the students in the concept cartoon they think is correct and write down the arguments for that decision. Subsequently, the students will discuss their choices in groups of three students, thereby exchanging their viewpoints and the corresponding argumentation.

After these group discussions, the groups of students are asked to design an experiment through which they could verify whether their chosen statement is correct. For the experiment the snowman could be imitated by ice cubes, and a sock or a mitten could serve as a coat. When the design of the experiment is approved by the teacher, the students have to collect the necessary material and actually conduct the experiment. During the execution of the experiment, the students write down all observations, so they can subsequently draw conclusions based on the experiment.

As a final assignment, the groups of students are asked to evaluate and reflect on the process, by discussing with each other how they cooperated in the group, and what could be improved on the found solution to the problem. They are also prompted to think about ways in which the experiment could be improved. After the completion of the experiment and evaluation, the outcomes are discussed with the whole class.

During the conducting of the experiments by the different groups and the class discussion, the teacher is expected to ask questions to the students, so that the physical concepts underlying this problem can be ascertained by the students.

It is stated in the material, that one or two lessons are needed to cover the material, depending on whether it is possible to conduct the experiment in the first lesson, or that a second lesson should be allocated for that activity and the subsequent class discussion.

Rationale

It is stated in the material that an important aspect for lower secondary students to achieve through physics education is to learn to observe phenomena that are related to their own situation. This implies that students have to learn to recognise such phenomena, and also to develop a curious attitude towards these phenomena. This is also the case for this material, since the students are triggered to think about something which they may actually encounter. It is likely that students will once have made a snowman, and have seen it melting. Through the material, they are stimulated to think about how this process might be delayed. Such a recognisable problem contributes to meaningful physics education.

Through the group discussion, it is first aimed that they ponder about the situation and provide arguments for the different viewpoints the students in the concept cartoon pose. The primary goal of this group discussion is not to achieve consensus on a statement, but rather to learn to listen to each other, construct a line of reasoning, and consider different arguments. Besides this argumentation, it is important that the students learn that through conducting an experiment and making connections of what is observed, they can provide empirical evidence for a certain statement.

In addition to experiencing the process of solving a problem, it is also aimed that students will acquire knowledge on physical concepts concerning heat and insulation.

Problem solving as a 21st century skill in the physics material

The problem that the students encounter in the physics material, is the fact that a snowman has been made, but with rising temperatures, it is unknown how the snowman could be prevented from melting as long as possible.

This problem is context specific only to some extent. Although there could be context variables that influence the melting process of the snowman (e.g. whether the snowman is placed directly in the sun or more in a shady place, and the size of the snowman), these are not given in the assignment or requested from students to consider. The key elements in this problem (namely the snow, a warmer temperature outside the snowman, and a coat) can be situated in many different contexts. In that respect, the problem and the solution for that problem remain the same, whether the problem is situated in for example a village in The Netherlands or a city in America.

With this problem, along with incorporating the skill problem solving in a lesson, it is aimed to teach students the physical concept of heat transfer and thermal insulation. In the material, a 'correction template' is provided. There it is stated that it is a common misconception that some materials, such as a coat, can make things warm. Instead, a coat functions as an insulator and keeps the temperature inside the coat more constant. Therefore, in the case of the snowman, a coat will delay the rise in temperature and thereby the melting of the snowman, even when the outside temperature increases. So, with this problem there is a correct answer instead of multiple answers, of which the suitability depends on the viewpoints of stakeholders.

The characteristics described above cause the problem in the physics material to be more well-structured than ill-structured based on the theory of Jonassen (1997), and therefore it does not really represent a problem to be solved as a 21st century skill.

Coherence with the ill-structured problem solving process

As was done with material for geography, in a table (Table 4.2) it is displayed which steps of the problem solving process are present in the material for physics. The scoring in the table is clarified below.

Table 4.2

Presence of the process for ill-structured problem solving (according to Jonassen, 1997) in the physics material

5) Process of monitoring and reflecting	→	1) Articulating problem space	
	→	2) Identification of stakeholders (and their perspectives)	
	→	3) Generating possible solutions	
	→	4) Assessing viability of possible solutions	
6) Implementing and monitoring solution *			
7) Adapting solution *			

Note. Steps marked with an asterisk (*) are according to Jonassen (1997) often not possible to perform in a school-based context, because of complexity of ill-structured problems.

	Present in the material
	To some extent present in the material
	Not present in the material

The Concept Cartoon is taken as a starting point in the material. In this Concept Cartoon the problem, and to some extent the situation in which the problem is situated, are already given. Also, different possible solutions to this problem are given through the statements uttered by the three students in the Concept Cartoon. Therefore, when teaching a lesson with this material, the students start in the fourth step of the problem solving process, in which they have to provide arguments for the different statements, i.e. assessing the viability of the possible solutions. The first three steps of the problem solving process are not part of the lesson with this material. Although the articulation of the problem space and the generation of possible solutions could have been implemented for the problem in this material, it is questionable whether this is the case for the second step. In the second step of the problem solving process, it is aimed to identify the different stakeholders and their perspectives. With the problem of a melting snowman, there are however not really multiple stakeholders who all view the problem differently and desire a different solution, and therefore they can also not be identified. The fifth step, in which the problem solver has to monitor and reflect on the first four steps in the problem solving process is logically not present for the first three steps, but it is also not asked of the students to monitor and reflect when assessing the viability of possible solutions. Although Jonassen (1997) remarks that in school-based context the proposed solution for an ill-structured problem often cannot be implemented, this sixth step is present in the physics material. When conducting the experiment, the students test whether a coat would increase the rate at which the snowman melts or not, and also monitor the chosen solution. During the evaluative and reflective assignment after the experiment, the students are encouraged to think about the chosen

solution and how this could be improved. This is consistent with the seventh and last step Jonassen (1997) identifies in the problem solving process.

The problem to be solved in the physics material does not really resemble an ill-structured problem as defined by Jonassen (1997), and therefore seems to be less suitable for teaching problem solving as a 21st century skill. Although the later steps of the problem solving process are present in the material, the first steps, in which the problem is clarified and analysed, are not part of the material as a task for the students.

5. Results of the evaluation based on the observations

The lessons taught with the material under review have been observed, and the results of these observations are described in this chapter. The filled out observation schemes formed the basis for this analysis, and the notes taken during the observations have been used to complement these results, in order to make meaning out of them. In this chapter per subject the results of the observations are specified. Per subject first a table is shown in which it is stated whether a certain element in the observation scheme was present in the observed lesson or not. Since not all lessons could be observed and also not all steps of the problem solving process were present in the material (see Chapter 4), this is specified in the table as well. Subsequent to the table, its content is clarified.

5.1 Geography lessons

The material under review for geography expanded multiple lessons, ranging from 2 till 3 lessons. Because of practical reasons, unfortunately not all lessons could be observed. As is specified in Chapter 3, the aim was to observe at least the first lesson taught with the material by all teachers, and furthermore to observe as much lessons as possible. Table 5.1 shows the results of the observations of the 4 geography teachers, and the separate steps in the observation scheme are further specified below.

Step 1

As appeared from the analysis performed which was reported in Chapter 4, the step "clarification of the problem" is already elaborated on in the assignment of the support material. Since this step is not really part of the assignment, it could be expected beforehand that it would not be really present in the student actions in the lessons, and therefore is it marked as "not applicable" for all teachers. Although this first step was not part of the assignment for students, clarification of the problem did receive some attention by the teacher actions in most lessons.

Step 2

In the second step of the problem solving process (i.e. "analysing the problem"), all teachers let the students mention the elements which are important to consider when dealing with the problem. All teachers stimulated the students to write down as many elements they could find that would be important to consider when dealing with the problem as stated in the assignment. Doing this was also a subtask in the assignment, and therefore 'logical' for the teachers to ask of the students.

Most of the other components that constitute this second step in the problem solving process do receive some attention in the lessons, but mainly through actions performed by the teacher. The context of the problem is for example somewhat elaborated on by the teachers, and the same goes for stating why there is a problem. These elements are however never asked of the students to determine.

Actively involving the students in a moment of reflection at the end of this second step was only done by one teacher (Teacher E). In this lesson, the teacher involved the students in examining the list containing all the elements the students had suggested for taking into account when dealing with the problem. This teacher asked the students to think about and express what elements could still be added or could be omitted from this list. Other teachers did reflect to some extent on the elements that were suggested by the students, but this was done rather quickly and implicitly, and they did not actively involve the students in it.

Only the component "devising a solution plan" was not present in any of the lessons, neither by student nor teacher activity. The steps the students would go through in order for them to solve the

problem are already somewhat fixed through the composition of the lesson. Therefore, it would not seem logical if the teachers would ask their students to construct such a solution plan.

Table 5.1

Results observations with the geography material

			Teacher			
			A	B	E	G
Step 1	Clarify the problem	Recognition	N.A.	N.A.	N.A.	N.A.
		Defining	N.A.	N.A.	N.A.	N.A.
		Formulate (research) question	N.A.	N.A.	N.A.	N.A.
Step 2	Analyse the problem	Why a problem				
		Elements				
		Context				
		Devising a solution plan				
		Reflection on defining				
Step 3	Inventorise solutions	Multiple solutions		N.O.	N.O.	N.O.
		Various directions		N.O.	N.O.	N.O.
		Reflection on solutions		N.O.	N.O.	N.O.
Step 4	Examine solutions	Effectiveness		N.O.		N.O.
		Efficiency		N.O.		N.O.
		Accuracy		N.O.		N.O.
		Questioning		N.O.		N.O.
Step 5	Select solution	Choose solution		N.O.		N.O.
		Reasoning		N.O.		N.O.
Step 6	Apply solution	Devise a plan	N.A.	N.A.	N.A.	N.A.
		Execute solution	N.A.	N.A.	N.A.	N.A.
Step 7	Evaluation	Problem solving process	N.O.	N.O.	N.O.	N.O.
		Solution	N.O.	N.O.	N.O.	N.O.
		Recommendations for improvement	N.O.	N.O.	N.O.	N.O.

Note. Elements constituting the observation scheme, based on Jonassen (1997)

	"yes"
	"no"
N.A.	"Not Applicable" (i.e. not in material)
N.O.	"Not Observed"

Step 3

Out of the four teachers, three teachers gave the students the task to inventorise possible solutions for the problem as homework. Therefore, this step could only be observed taught by one teacher (Teacher A), who besides giving this as homework also let the students think about this in class.

Teacher A did stimulate the students to consider multiple aspects of a solution, but focus for the individual students was on generating one solution rather than multiple solutions. This might however be caused by the composition of the assignment, since all individual students in one group had to generate

their own solution, which subsequently would be considered by all group members in order for them to make a choice for one solution. When generating a possible solution, the teacher stimulated students to consider various directions for a possible solution, by telling the students that in this phase everything was still possible. The teacher also questioned the students, to check whether they had taken into account certain elements, and stimulated them to question each other's solutions.

Step 4

Examining the generated solutions did explicitly come forward in the second observed lesson taught by Teacher E, but not so explicitly in the second observed lesson taught by Teacher A. Teacher E stimulated the groups of students to discuss the different solutions in the light of the previously suggested important elements to consider (step 2). The teacher also encouraged the students to be critical towards each other's solution, and pose questions for each other. Thoroughly examining the generated solutions was thus emphasised by teacher E in the lesson. Focus was however mostly on examining the accuracy of the solution, and not so much on the other 'flavours' of examining (effectiveness and efficiency).

Teacher A did not really stress the importance of examining the different solutions. Rather, this teacher encouraged the students to make a decision for a solution as quickly as possible, so that the remainder of the time in the lesson could be spent on drawing the map. This teacher seemed to feel pressure to complete all the elements in the lesson.

Step 5

In the second lesson with the material, both observed teachers (Teacher A and Teacher E) made the groups of students choose a solution. This component also takes a central role in this assignment in the illustrative lesson, since every group has to make one map, and therefore also has to select one location for the playground (i.e. their solution). Because of this, it seems only logical that both teachers have incorporated this in their lessons. Besides the choice for a location, both teachers made the students write down their reasoning behind the chosen location (i.e. their solution). Both teachers emphasised the importance of the 'why' for the chosen solution multiple times in the lesson.

Step 6

Applying the chosen solution is not possible for this assignment, because the playground will not actually be built on the chosen locations. Hence, this step cannot be observed in lessons with the material.

Step 7

Evaluating the problem solving process and the chosen solution, and formulating recommendations for improvement is part of the 'example' material, but due to practical constraints it was unfortunately not possible to observe this last step in any of the lessons.

5.2 Physics lessons

In contrast to the geography material, all the lessons taught with the physics material could be observed. The results of these observations are shown in Table 5.2 and are subsequently further specified.

Table 5.2
Results observations with the physics material

			Teacher		
			C	D	F
Step 1	Clarify the problem	Recognition	N.A.	N.A.	N.A.
		Defining	N.A.	N.A.	N.A.
		Formulate (research) question	N.A.	N.A.	N.A.
Step 2	Analyse the problem	Why a problem	N.A.	N.A.	N.A.
		Elements	N.A.	N.A.	N.A.
		Context	N.A.	N.A.	N.A.
		Solution plan	N.A.	N.A.	N.A.
		Reflection on defining	N.A.	N.A.	N.A.
Step 3	Inventorise solutions	Multiple solutions	N.A.	N.A.	N.A.
		Various directions	N.A.	N.A.	N.A.
		Reflection on solutions	N.A.	N.A.	N.A.
Step 4	Examine solutions	Effectiveness			
		Efficiency			
		Accuracy			
		Questioning			
Step 5	Select solution	Choose solution			
		Reasoning			
Step 6	Apply solution	Devise a plan			
		Execute solution			
Step 7	Evaluation	Problem solving process			
		Solution			
		Recommendations for improvement			

Note. Elements constituting the observation scheme, based on Jonassen (1997)

	"yes"
	"no"
N.A.	"Not Applicable" (i.e. not in material)
N.O.	"Not Observed"

Step 1

It was stated in the previous chapter that this step is not really part of the material, since the first task the students receive in the lesson based on this material is to formulate reasons why a certain student in the Concept Cartoon is right according to them. Although clarifying the problem as such could have been done by the students in this lesson, since it is not part of the assignment it is defensible that the teachers did not ask their students to do this. This step is therefore marked for all teachers as "not applicable".

One teacher (Teacher D) did let the students formulate a research question. This was however done at a later stage in the lesson, and was not directly linked to clarification of the problem.

Step 2

As stated above, the lesson essentially starts with the Concept Cartoon and therefore to analyse the problem is not part of the assignment for the students. During the lessons the teachers did elaborate to some extent on the concept cartoon, which hints at analysing the problem. One teacher (teacher D) introduced the assignment and the therein present Concept Cartoon to a greater extent in comparison to the other two teachers. However, the teacher told this to the students, rather than actively involving them in this step. The other two teachers (Teacher C and Teacher F) showed the Concept Cartoon to their students, and let them read the assignment by themselves, after which it was a bit elaborated on in class by the teacher.

Step 3

Inventorising possible solutions for the problem is not part of the assignment, since in the Concept Cartoon possible solutions are already provided. The students do not have to generate their own solutions to the problem, and this is also not seen in the lessons.

Step 4

The assignment basically starts with this step (examining solutions), because the students have to give reasons why they think a certain student in the concept cartoon is right. All teachers let their students examine the solutions. They all stimulated the students to try and convince their group members why a certain solution was the right one, thus asking from the students to reason about the accuracy of a solution. The teachers did not indicate the efficiency and effectiveness of these solutions as possible factors to consider. Only one teacher (Teacher C) explicitly told the students to critically question each other about their reasoning for a solution. The two other teachers do not do this.

Step 5

This step takes a central role in all observed lessons, which is not surprisingly since it is a key-element in the assignment. All teachers let the groups of students choose a solution and additionally, all teachers indicated to the students the importance of specifying the reasoning behind a choice.

Step 6

All teachers let the students devise a plan for applying the chosen solution (in this case through an experiment). The degree of freedom that students received from their teachers differed for this step. The students taught by Teacher D received most freedom, since this teacher devoted an extra lesson for this step in which all the groups of students had to devise a plan for the experiment. Because the lesson in which the experiment was conducted took place on a different day, the teacher had some days in between to collect all relevant materials in order for the students to perform their designed experiment. In the last lesson, all groups of students could conduct the experiment which they themselves had designed.

The students taught by teacher F could also devised their own plan for the experiment in the groups and subsequently conduct the experiment. They were however slightly limited compared to the students taught by Teacher D, since the entire example lesson was taught in one long (100-minute) session. This did not give the teacher the opportunity to collect all necessary material the students could come up with to use for the experiment e.g. in between lessons. The teacher had prepared some material in advance (e.g. ice in plastic cups) that the students could use when conducting the experiments, but if they came up with something entirely different to apply and test the solution, this was not possible. Still, because of the length of the session, there was ample time for the students to come up with other ways

to conduct the experiment if not all material was available, which made it possible for all groups to conduct their own designed experiment.

Teacher C also taught the entire example lesson in one consecutive session. This was however a much shorter session, namely lasting 50 minutes. Because of this, the teacher had a tight schedule in mind for the students. The students did receive some time to devise a plan for testing the solution, but after a while, the teacher and the teaching Assistant (who was also present in this lesson) told the students that they had already prepared elements for the experiment (namely plastic cups containing ice and a thermometer, and thick black socks). All groups of students would thus conduct the same experiment (using the same kind of material). Even though the students could not conduct the exact experiment they might come up with, the teacher did let the students think about what the experiment could look like, and let them conduct an experiment to apply the solution. Also in reality, most students of Teacher C already came up with similar plans for conducting the experiment, so it was not a major transition to the actual conducted experiment.

Step 7

In the lessons taught by two teachers (Teacher C and Teacher F), evaluation occurred to some extent. Both teachers let the students discuss in the groups about the found solution, and how the experiment might be improved. One teacher (Teacher F) also let the students reflect on the process they went through in the lesson. All these elements were afterwards discussed with the whole class, in which the teacher also hinted to the physical concepts underlying this assignment.

The other teacher (Teacher D) had some questions prepared for the students, which they had to fill in by themselves at the end of the last lesson. These questions were however mainly directed at unravelling how the students viewed the lessons, and how they experienced collaboration in the groups.

Based on all observations, it seemed that the elements that were explicitly part of the material as activities for students to perform were also most of the time adequately present in the lessons, i.e. present in a more student-centred than teacher-directed way. When elements were less explicitly or not at all part of the material, it was observed that sometimes these components were indeed part of the lesson, however more as teacher-guided activities rather than student activities. Although some teachers seemed to sense that these activities, even though they were not made very explicit in the material, would be important to cover in the lesson, it was not performed in a way that best suits teaching 21st century skills such as problem solving.

6. Results of the evaluation based on the interviews

After the lessons were observed, the teachers were interviewed on how they perceived the material, e.g. on what they valued in it, what they thought could be improved, and whether they thought the material would give sufficient support for teaching the skill problem solving. All interviews were recorded, so that of each interview a verbatim transcript could be made, which in turn could be analysed in order to interpret the interview data. This analysis process led to the creation of two thematic networks, through which it is aimed to visually represent the main themes and the elements that constitute those themes. In this chapter, the content of these networks and how they originated based on the content of the interviews are clarified. The thematic networks can be found in Figure 6.1 on page 38 and Figure 6.2 on page 42.

6.1 Influence of the material as support for teaching problem solving

The first thematic network that derived from the interview data is concerned with the influence the material in itself can have to support teaching the skill problem solving. Below, the construction of this network is elaborated on. Figure 6.1 shows this first thematic network.

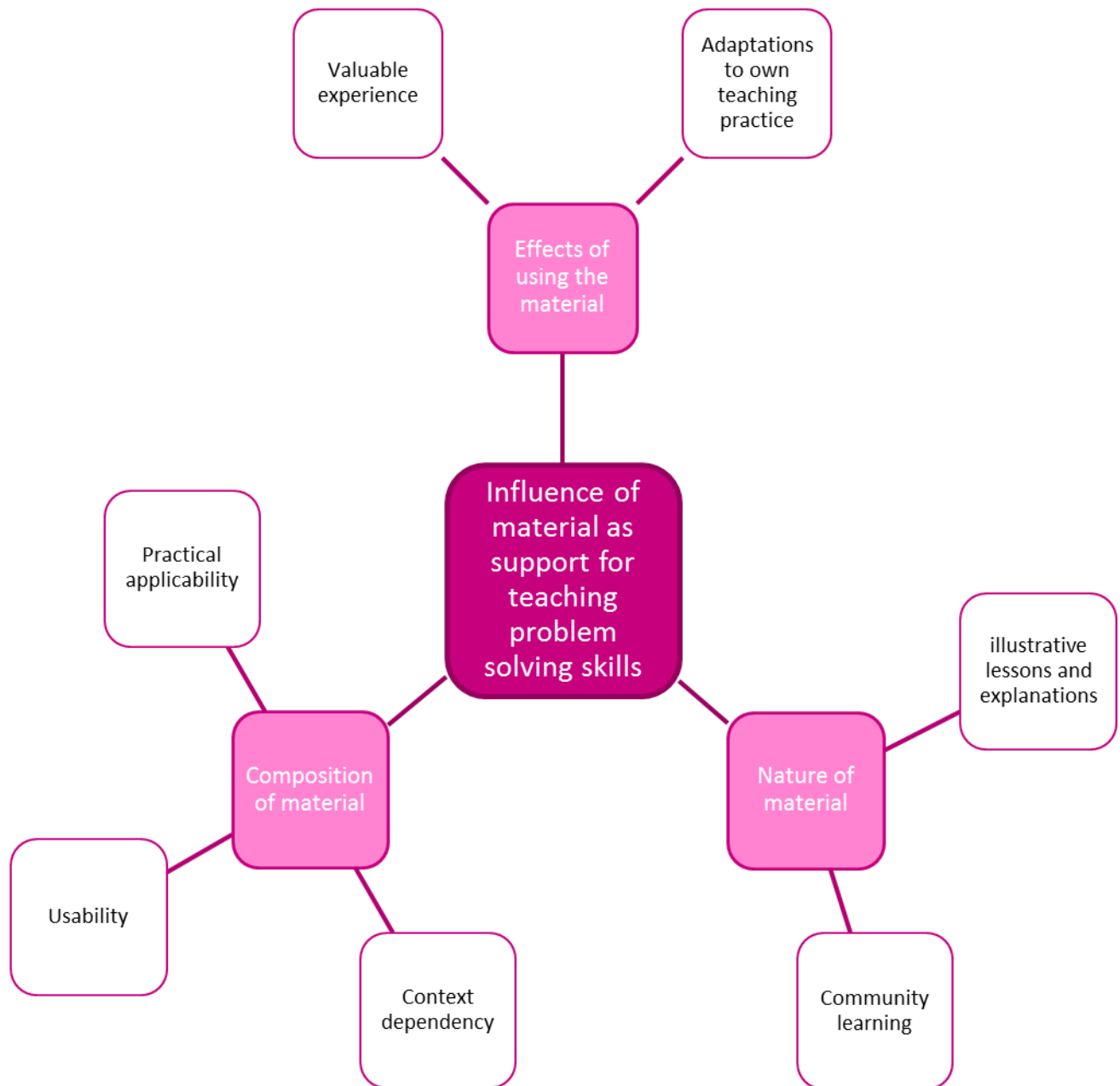
Effects of using the material

Several teachers mentioned that they wished to adapt their own material based on the experiences with the material under review. One teacher said that he initially found the provided material too open in nature, but after working with the material, he considered making adaptations to his own lesson materials, so that they would perhaps be less closed and more open in nature. Also, a teacher expressed the wish to use the structure that constituted the lesson in the provided material more often.

Besides these wishes to adapt their own material, it could be deduced from the statements of teachers that working with the material was a valuable experience. Some teachers expressed that working with the material had challenged them to give more freedom to the students, and to allow the students more time to think about it by themselves first. A teacher stated that the material made him more conscious of this, and where he otherwise would have stepped in much sooner, he now had let the students think about a suitable approach for the assignment by themselves first, only providing some guidance. Another teacher mentioned that using this material confirmed his wish to teach more in a way that promotes student activity, rather than a more lecture-based approach. Using the material had made him more enthusiastic, and therefore provided a positive experience for this teacher. One teacher said that at first he viewed the content of the material as being something extra to be done, in addition to the 'regular' curriculum. However, through working with the material, this teacher noticed that the material actually took over something of the 'regular' curriculum, and the material thus was perceived by him as substitutional instead of extra.

The remarks that teachers made on their intention to adapt their own teaching and how working with the material provided a valuable experience were both identified as basic themes, which were grouped together based on the fact that both are effects of using the material under review (organising theme).

Figure 6.1. Thematic Network 1: Influence of material as support for teaching problem solving skills



Nature of material

In the interviews, all teachers were asked whether the provided material was indeed useful as support for incorporating the skill problem solving, or that perhaps other support would be more useful or desired. Two different views on the nature of support could be distinguished when analysing the interview data, which formed the two basic themes that together constitute the organising theme 'Nature of material'.

The majority of the teachers expressed that the nature of the provided material would for most teachers offer sufficient support for incorporating the skill problem solving in their lessons, i.e. they appreciated the idea of an illustrative lesson with an explanation. However, although the majority of the teachers expressed that illustrative lessons and an accompanying explanation would be a suitable means of support, many teachers also made some comments that have to be taken into account when designing such material, in order for the material to indeed be helpful. Comments uttered by teachers were e.g. that there should not be too much theoretical information, it should facilitate scanning while reading and thus allow the teacher to only read what that teacher would need at that moment, and it should take into account the structures in which things are already organised at the school. This does however not change the nature of the material (i.e. an illustrative lesson and an accompanying explanation). Therefore, these remarks were not made part of this organising theme, but constitute another organising theme, composition of the material, which is clarified later.

Not all teachers considered illustrative material as provided the most satisfactory way to offer support. Some teachers stressed that it would be beneficial to learn from colleagues. It was said that sharing experiences with colleagues working at the same school would mean more, since they are situated in the same context and therefore can give each other more tailored advice on how to handle certain things, adapted to the own school situation. This would according to some teachers be more helpful compared to material that is made to serve teachers working across the land and in different types of schools. One teacher stated it as follows:

"I think practice should make it happen together, the bottom-up way. You should know it from one another. That's why I think communities are very important, because in those we constantly share. [...] Because there it is from colleagues, for colleagues." (Teacher G)

Composition of material

As stated above, when asked about the nature of material aimed at supporting teachers, several teachers pointed at how such illustrative material should be composed according to them. Also at other moments in the interview, teachers made remarks on what they would wish to see in material, or not. These remarks could be grouped in three basic themes, which together represent the organising theme 'composition of material'.

When comparing the remarks teachers made when they were asked about how they regarded certain elements in the material, it became clear that sometimes what one teacher thought was appropriate, another teacher might not deem at all important and sometimes even unsuitable. For example, some teachers thought providing students with learning goals at the beginning of the assignment (in the student material) would be advantageous for the students, while other teachers thought this would only confuse students and could therefore better be omitted. Also, some teachers thought their students were not yet up to dealing with a main question and sub-questions, whereas others said their students were used to handling such questions. How the material could be best composed according to the teachers, is thus dependent on the context of their teaching. Other elements that they expressed that are related to this context dependency were the number of lessons with the material for which there was time available, the type of class and students in that class (which would ask for different approaches from the

teacher, e.g. a certain degree of freedom for the students or more guidance from the teacher), and the time of the day on which the lesson was scheduled. It was also mentioned that a beginning teacher might need more background information and clarification accompanying the material, while a more experienced teacher might not need so much information. All these elements that were voiced by the teachers were related to a certain context dependency, which should be taken into account during the composition of the material.

All teachers stated that the material should be composed in a way that facilitated ease of use, e.g. by providing images or visual overviews and a certain compactness and clarity of the provided information, thereby facilitating quick and easy application of it in the lessons. Many teachers also expressed the wish to be able to scan the material, and thereby easily selecting what would be relevant for them. One teacher mentioned that the material should trigger some enthusiasm in teachers so that they would want to do something with it, and should for that purpose be clear, compact, and visually attractive in layout. These statements were all related to a usability aspect that should be considered when composing the material.

Besides the context dependency and usability of the material, teachers expressed that the information in the material should be practical applicable, since teachers are very practically oriented. For some teachers, this meant that they wished less theoretical information in the material. They deemed it more useful to know what they should do in their lessons (e.g. through the provision of concrete hints) rather than why that would be advisable according to theory. Although some teacher thought it a good thing that there would be some theoretical background knowledge in the material, they also stressed the importance of the material being as accessible and approachable as possible. Many teachers said that when preparing the lessons with the material, they mostly used the material designed for the students, since that gave them very concrete, practical information on what had to be done in the lessons. Also, some teachers liked the clarity of the entire material and the fact that it was readily applicable, and one teacher said that the provided observation scheme offered concrete handles of what was expected from him as teacher during the lesson, and this guidance was appreciated by the teacher.

It thus appeared from the interviews that when material aimed at supporting teachers in incorporating skills such as problem solving in their lessons is composed, it should take into account (and give room for) contextual differences, the usability of the material, and its practical application.

The aforementioned three organising themes (effects of using the material, nature of material, and the composition of material) can be grouped together and form a global theme based on the fact that they all affect the influence such material can have on the implementation of skills such as problem solving. The combination of these three organising themes and their basic themes in this global theme constitute the first thematic network. The second thematic network, which is presented hereafter, focuses on the external factors that influence the implementation of material made to support teachers in teaching skills such as problem solving.

6.2 External factors influencing use of the material

The second thematic network is concerned with external factors that influence the use of support material. The construction of this network is described below, and the network can be found in Figure 6.2.

Stimulating factors

Several teachers mentioned that they think problem solving skills, and 21st century skills in general, are important skills for students to acquire through education. One teacher mentioned that although he acknowledges that teaching from a book is the easiest way to teach, he believes teaching should be different, and should allow more student autonomy. This teacher expressed not wanting to recite 'routine

narratives' anymore. Another teacher stated that, according to him, problem solving should be applied in every lesson. This teacher was also aware of the importance for students to learn to analyse a situation first before actually starting to work on a solution. He was conscious of the fact that for most students this does not come naturally.

Not just teachers deem problem solving skills and 21st century skills to be important aspects to consider in education. During the interviews, teachers were asked whether the school in which they work already gave some attention to either problem solving skills or 21st century skills in general. Not all teachers indicated that the school in which they work gave attention to such skills, but according to the interviewed teachers, some schools did (although the degree in which the schools gave attention to them varied). In some schools, they tried to incorporate such skills to some extent, e.g. by increasing the exposure of education with such skills for each year. In another school it was aimed to gradually incorporate such skills in a more structural way, by increasing the amount of skills in education in the following years, starting with the implementation of skills for the second-year students. One teacher explained that in the school where he worked the subjects physics, chemistry, and engineering were merged into one subject for first-year students, and a problem would be the starting point in every assignment in this subject. Another teacher told that he worked at a Geo Future School (i.e. a school in which students follow a certain amount of modules in which they are challenged to deal with so called 'Grand Challenges', in which it is also aimed that students learn to apply 21st century skills (KNAG, 2015)). In this school, the attention for skills (especially in subjects as geography which this teacher taught) in education is thus already quite extensive.

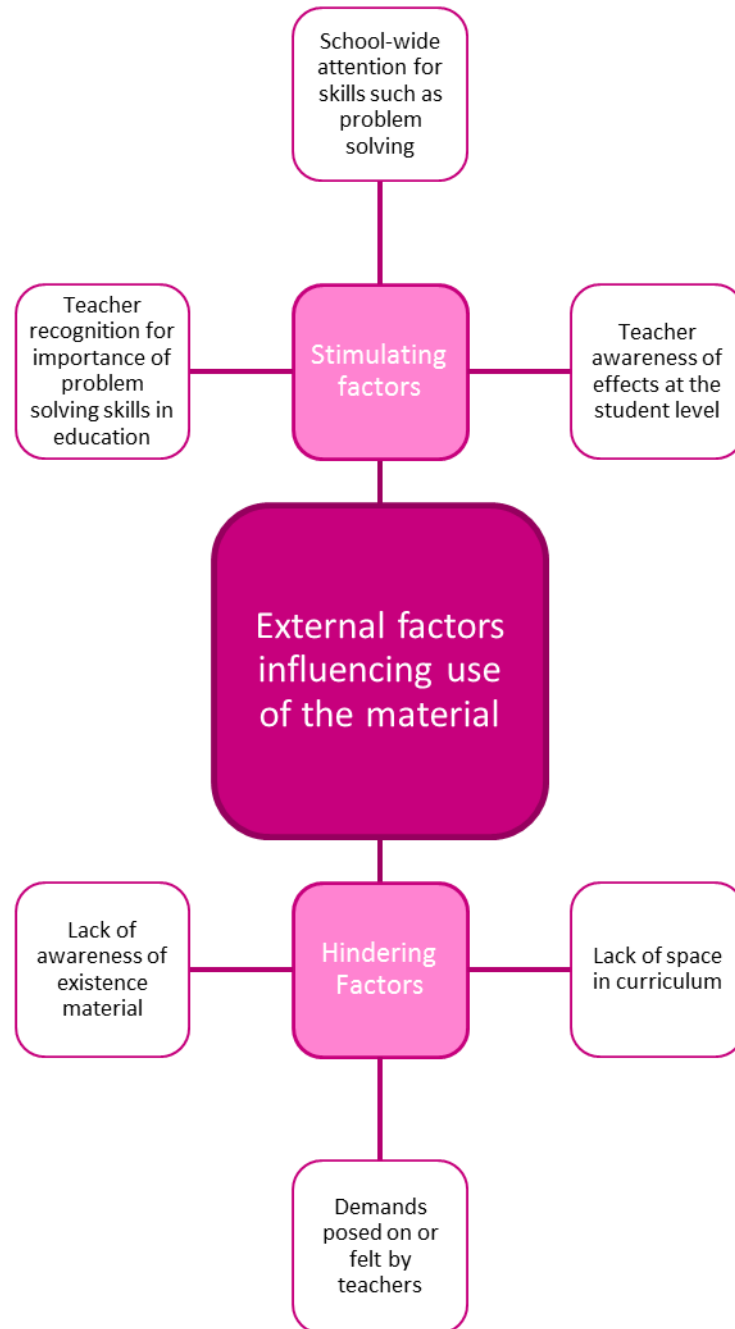
The recognition of teachers for skills as problem solving, and school-wide attention for such skills can be viewed as stimulating factors for using support material for teaching problem solving skills. Another aspect that emerged when analysing the interviews that can be viewed as a stimulus for implementing the material under review, is the awareness teachers expressed of the benefits teaching problem solving skills has on students. Several teachers pointed at the added value of teaching students problem solving skills through assignments as given in the material under review. They expressed that students working on such assignments would be more motivated and learn more. One of these teachers mentioned that such assignments are much more enjoyable for students than working through chapters in a book. Another teacher also stated that it is more rewarding for students to be actively involved in a lesson compared to silently listening to a teacher that tries to transmit knowledge. A teacher stated that students learn very much when working on such assignments, and he questioned the amount students learn when they are being taught from books. One teacher expressed the benefits on the student level as follows:

“Preferably, they [the students] receive an example which they can imitate. And that's exactly what I don't want. I want them to go completely out-of-the-box, and make something which they have invented by themselves. Yes, of course within certain specified boundaries, so there are some requirements given with each assignment, but that's it, the remainder is for them to resolve. And then you just notice that the students, once they're used to it, will go much further in their problem-solving strategies, and come up with things that they haven't considered in advance. And then I think you can get the most out of your students.”

(Teacher F)

The three factors mentioned above all have a stimulating element to them for incorporating material to teach problem solving skills in education, and therefore together form one organising theme, labelled stimulating factors.

Figure 6.2. Thematic Network 2: External factors influencing use of the material



Hindering factors

Besides the stimulating factors mentioned above, also comments were made by the teachers that could be seen as factors that hinder the use of material aimed at the implementation of teaching problem solving skills. These can be grouped together in an organising theme which comprises the lack of space in the curriculum, demands posed on or felt by teachers, and lack of awareness of the existence of the material.

Several teachers pointed out that they would normally not have picked up this material. They perceive it as something extra, and declared that there is hardly any room in the curriculum for such extra activities. Many teachers declared that they use the book that is published as part of the method used for the subject as starting point, and they base the entire year planning on this book. Even when there is room to do something extra, there are a lot of things teachers can choose from, therefore the chances of them using the material under review would be rather small according to one teacher. Another teacher made the following remarks on this subject:

"I don't think I would do this very often. And this decision to not use the material has nothing to do with me not wanting to do it, or because it would not function or not be good or whatever, but is purely based on the fact that you have your own curriculum. You have a certain program to deliver in a year, and something like this would be very suitable for a final lesson just before the summer holidays, you know. When there is some time left, well, then we could do such an assignment." (Teacher C)

Although the majority of the teachers declared that they did not see space in the curriculum for such activities, this view was not shared by all interviewed teachers. Even though one teacher acknowledged that it is easier to take the book as a base, he saw possibilities to let go of the book, and incorporate lesson activities as provided through the material under review. Another teacher was very clear on the possibilities of implementing activities such as posed in the provided material, and stated that:

"Every teacher who says there is no room denies himself, because it's really nonsense. Yes, of course there is room for such things. Eventually it will only yield more than it costs." (Teacher F)

In addition to the fact that many teachers do not see room in the curriculum for implementing such material, the feasibility to apply the material in daily practice was according to some teachers also reduced by demands posed on or felt by teachers. Teachers mentioned the time pressure they face, the unruly practice, and the amount of paperwork that they must deal with. Even one teacher who expressed the wish to perhaps receive some theoretical information accompanying the illustrative lesson, realised that in practice this would probably never be feasible to really examine. Another teacher also mentioned the amount of text that teachers have to go through as an obstacle:

"We are being assaulted by paper tigers, I sometimes say. That leaves way to little time to really do your actual job. And we would so much like to do that..." (Teacher G)

Some teachers also mentioned that they feel pressure to produce grades for students, which becomes a primary goal that has to be met. In this light, a teacher also mentioned that he would like to see how such skills could be graded, and that when schools should incorporate such skills more in education, the central examination should also take into account that students in schools do more than just learning facts.

A final hindering factor that could be extracted from analysing the interviews, was that for teachers to be supported by the material in order to implement skills such as problem solving, they should know of the existence of such material. These teachers uttered that material aimed at supporting teachers could

be made well, but if those teachers do not know of the existence of the material, it would not facilitate supporting teachers with the implementation.

The two networks each focus on a different aspect to consider when developing material aimed at supporting teachers to teach skill such as problem solving. On the one hand it appeared that most teachers would value such material, provided that certain elements are taken into account (which were labelled together under the term 'composition of material'). On the other hand, the developers should be aware of the fact that there are also factors external to the material that have to be taken into account, since these can influence whether the material is actually implemented or not by the target group, i.e. the teachers. Therefore, the networks that emerged from the interviews provide an insight in the elements to consider when developing support material for teachers.

7. Conclusion and discussion

The purpose of this study was to evaluate educative curriculum materials for the secondary school subjects geography and physics, which were specially designed to teach problem solving skills. In the geography material students were asked to identify a good location for a new playground in their area, thereby considering multiple aspects. In the physics material students were asked to establish how the snowman could be kept from melting longest, which was visually presented to them at the start of the lesson by means of a Concept Cartoon. The evaluation of these two materials was based on three sources. First, the material was analysed based on characteristics for teaching problem solving skills. Subsequently, lessons in which the material was applied by teachers were observed, and finally, these teachers were interviewed on how they experienced the material.

In this chapter, conclusions are drawn based on these results and the results are further discussed. Also, recommendations are given based on these results. In the last section, the limitations of this study are discussed and some final remarks are made.

7.1 Evaluation based on the literature

The material for the subjects geography and physics were both analysed on the degree to which they incorporate problem solving as a 21st century skill and the process for such problems, as defined by Jonassen (1997).

Ill-structuredness of the problem in the material

From literature it was derived that the main characteristic of problem solving as a 21st century skill is its ill-structuredness. Both the geography and physics material were therefore first analysed to determine the degree of ill-structuredness of the problem in both material. It could be concluded that the problem posed in the geography material reflects an ill-structured problem more, and is therefore more congruent with problem solving as a 21st century skill, in comparison to the problem in the physics material. The problem posed in the geography material reflects an ill-structured problem to a large degree, since it is very context-specific and there are multiple possible solutions to the problem. The problem in the physics material on the other hand shows greater resemblance to a well-structured problem than an ill-structured problem, since in this problem there is a correct solution, and the problem is far less context specific.

Presence of the problem solving process in the material

When analysing the material to determine the degree in which the steps of the problem solving process were present, it was noticed that two steps were absent in both materials. This was the case for the first step of the problem solving process, namely articulating the problem space, and for the fifth step, which is to monitor and reflect on the first 4 steps of the problem solving process.

The first step was not present in either material, since it is not for the students to determine what the problem actually is under the given circumstances. In the most optimal situation, this step would also be part of the material as a student activity. It might however cause problems for the teacher when problem solving skills are to be incorporated within conventional teaching, since also certain subject knowledge will have to be covered during a year. When students have to determine what the problem is in a certain situation, this might result in them formulating an entirely different problem than the teacher might have envisioned in advance for that specific lesson. It would be valuable to ascertain a scenario in which the students are asked to articulate the problem space, which would also ensure the coverage of certain subject knowledge determined by the teacher. A possible approach might be to let the students

ponder on it by themselves first, but after a while take the lead as a teacher to ensure that all students will eventually adopt the same problem to consider in the lesson. It is however not known how students will react to such an approach when it would happen too often, i.e. they might become indifferent to the process of identifying a problem in a given situation.

Despite the fact that in the physics material some reflection is expected from the students, it is not sufficient to match the fifth step in the problem solving process as articulated by Jonassen (1997). This was also the case for the geography material. Reflection is to some extent present in both materials, however not as a continuous process for the first four steps, but rather as a final step at the end of the material. Reflection as a more continuous process could be added to both materials. To ensure that the reflective monitoring process is part of the material, several directions could be taken. It could be incorporated in the material through adding certain assignments for the students in which they have to reflect on what they have done so far. It could also be added in the form of hints for the teacher, so that he or she can prompt the students to engage in these reflective processes during the first phases in the lesson.

Besides these two steps that were absent in both materials and should therefore be regarded, also other improvements could be made to make both materials more suitable for teaching problem solving as a 21st century skill. Although in the geography material the problem in itself is appropriate, more improvements could be made on how the process for problem solving is incorporated in the material. In the geography material only one step in the problem solving process established by Jonassen (1997) is adequately present, namely the assessment of the viability of possible solutions. Two other steps are present to some extent (the identification of stakeholders and the generation of possible solutions), but these could have been more elaborated on in the material to enhance their presence in the material. The students using the material are invited to analyse the problem and thereby take into account the different stakeholders, but it is not explicitly stated in the material that all these stakeholders might hold different views, and therefore provide different possible solutions to the best location for the playground. Also generating possible solutions is not entirely present in the material, since all students are asked to determine one possible location for the playground, but are not challenged to identify multiple possible spots. These two steps could however be relatively easily added to the current material.

The other steps of the problem solving process are not present in the geography material. For the last two steps in the process (implementing and monitoring the solution, and adapting the solution) this is not illogical, since, as Jonassen (1997) also states, when problems are ill-structured and therefore context-specific and real-world-alike, it is in a school-based context often not possible to actually implement a possible solution and see how it works. The first and fifth step of the process are also not present in the material. These could however possibly be part of material aimed at teaching problem solving in a school-based context, as was elaborated on before.

In the physics material three steps of the problem solving process are adequately present in the material. The students have to assess the viability of possible solutions, implement and monitor solutions, and are asked to think about how the solution could be improved. All these steps are at the end of the process (namely step 4, 6 and 7). The other steps of the problem solving process are not adequately present. The problem is already given in the material and the students do not have to determine the problem space. In the literature it was suggested that these first steps in the problem solving process are very important for the remainder of the process (e.g. Jonassen, 1997; Eseryel et al., 2013; Ge and Land, 2004). It would therefore be good to expose students to this process as well in material aimed at incorporating problem solving in a lesson.

The third step of the problem solving process is also not adequately present in the material, because in the Concept Cartoon possible solutions are already given since the students in the cartoon all pose different statements, and it is therefore not up to the students to consider what might solve the

problem. It could additionally be reasoned that only one possible solution is given to this problem, namely to put a coat on the snowman. The students in the Concept Cartoon either agree, disagree, or remain neutral to this solution, but no other ways to prevent the snowman from melting are given. The third step of the problem solving process, i.e. generating possible solutions, is therefore not adequately present in the material. A possible way to include the possibility for students to also generate a possible solution by themselves is to add a fourth student. For this student, the speech balloon could be empty, so that the students could fill in a possible solution to keep the snowman from melting there. It would however be even better to alter the problem in this material altogether, so that it would be more ill-structured and contain multiple possible solutions, and thus also be more appropriate for teaching problem solving as a 21st century skill.

Conclusions based on the review (based on design criteria of Jonassen, 1997):

- The problem posed in the geography material is appropriate for teaching problem solving as a 21st century skill, whereas the problem in the physics material is not.
- Both the first and the fifth step are not present in either material, although they could be present in problem solving in a school-based context.
- Some small adjustments could be made to the geography material so that step two and three of the problem solving process will be more adequately present in the material.

Recommendations based on the review (based on design criteria of Jonassen, 1997):

- The problem in the physics material could be altered in a more ill-structured problem containing multiple solutions, so that it is more suitable for teaching problem solving as a 21st century skill.
- A means should be found to integrate the first step of the problem solving process as a student activity, so that students are aware of the fact that a problem is very much dependent on the situation, but also allows the teacher to guarantee the coverage of certain topics in the lessons.
- Reflection and monitoring the first four steps in the problem solving process should receive a more prominent role in both material.
- Some assignments in the geography material could be adapted, so that the second and third step of the problem solving process are fully present.

7.2 Evaluation based on the observations

Both the material for geography and physics was used by multiple teachers in their lessons, and the majority of these lessons were observed. During these observations, an observation scheme was used that resembled the steps for problem solving as distinguished by Jonassen (1997) to a large degree, but also showed some differences (See Appendix C and D). Since it appeared from literature that student activity is important in problem solving as a 21st century skill, the elements in the observation scheme were formulated as the teacher letting the students do something.

From the observations it could be concluded that whether elements of the problem solving process are reflected as student actions in a lesson or not is to a great extent dependent on how explicit they are presented in the material. When an element is explicitly mentioned as a student activity in the material, teachers most of the time let students do this. Some elements were however less explicitly stated in the material as student activities. It was observed that some of these elements were present in some of the lessons taught by teachers, however when it was present it would be more as teacher activity rather than student activity. In these cases, the teachers took a leading role and told it to their students, rather than helping the students to think about it for themselves.

As was concluded from analysing the material based on the literature, some elements of the problem solving process were not present in the material. Some of these steps were however touched upon by several teachers in the lessons. For example, even though analysing the problem was not part of the material, the physics teachers all more or less specified the situation in which the Concept Cartoon was set. However, despite doing so, they all took the lead rather than activating their students in this process.

Allowing the students to perform steps in the problem solving process by themselves, rather than taking the lead as teacher does not seem natural for most teachers based on these observations. Only when it is explicitly stated in the material the teachers challenge their students to be actively involved and to think about e.g. a certain situation by themselves. This finding is corroborated by the results found by Michael (2007). He identified multiple barriers mentioned by teachers for implementing an active learning environment. Among these was the fact that such a learning environment does not seem to align with the cultural norms both teachers and students hold for teaching. This is also found by Anderson and Helms (2001), who state that roles both students and teachers hold in an educational setting are deep-rooted in the school culture. Teachers therefore often find it difficult to change their style of teaching (Anderson & Helms, 2001). For the current study, this could thus imply that teaching in a way that facilitates student activity is not a natural teaching style and is found to be difficult for at least some teachers.

Based on the observations it would therefore be recommended for an illustrative lesson that aims to help teachers incorporate problem solving as a 21st century skill, to state very explicitly in the material what is expected from teachers. This should especially be done in relation to what teachers should ask of their students to do, in order to ensure a more student-centred, active learning environment.

Conclusions based on the observations:

- Elements that were explicitly part of the material as student activities were generally performed as such.
- When elements were less explicitly or not at all part of the material, they were sometimes present in some observed lessons, however more as teacher-guided activities rather than student activities.
- Incorporating student activity rather than teacher directed teaching does not seem to come natural for most observed teachers.

Recommendations based on the observations:

- Explicitly state in the material what is expected of teachers, in order to ensure appropriate implementation of teaching problem solving as a 21st century skill, especially to warrant a student-centred, active learning environment.

7.3 Evaluation based on the interviews

When analysing the interviews held with teachers to discover how they perceived the material, a dichotomy was identified. On the one hand the material in itself could influence the usage of support material for incorporating problem solving skills (Thematic Network 1, see Figure 6.1 on page 38), but on the other hand also external factors should be considered (Thematic Network 2, see Figure 6.2 on page 42).

Influence through the material

The material in itself provided a positive experience for most teachers, with some of them expressing the wish to incorporate some of its elements to their own lessons. Most teachers viewed the given material

as being an adequate means to support teachers in teaching the skill problem solving. They did however pose some requisites that the material according to them had to meet in order to be indeed beneficial. Among these was their wish for the material to be practical applicable. Most teachers expressed that they did not need much theory, and often took the material for students as a starting point when preparing the lesson. This could be linked to the observations, in which it was seen that when an element is explicitly stated in the material as a student activity, it was also reflected in the lesson. Besides the practical applicability, also usability and context dependency were wishes for the composition of the material that could be distilled from the interviews. With regard to usability, Sherin and Drake (2009) also signalled the importance to design curriculum materials in a way that facilitates teachers to focus on specific areas in the material. This should according to them however be achieved in such a way as to ensure that it offers enough information for teachers to teach the lesson successfully (Sherin & Drake, 2009). When analysing the interviews it was noticed that teachers all had different (and sometimes contrasting) wishes for the material based on their specific teaching context (e.g. the number of students in a class and the educational level of a class). The material should therefore ideally not contain a lot of details that are very context specific, so that when implementing the material each teacher would be able to adapt it to their own specific situation with a class. This is in agreement with Remillard (2000), who states that when designing curriculum materials for teachers no decontextualised decisions should be made for them, but rather the material should provide teachers with the freedom to make choices to best implement it in their own teaching context (Remillard, 2000).

As was referred to in the theoretical framework (Chapter 2), in the literature it is stressed that although educative curriculum materials have a unique role and can therefore be a suitable way of providing teachers with support, it should not be provided as a sole means for teacher learning (Schneider, Krajcik & Marx, 2000). Some teachers too suggested that, besides the material as provided, other ways of support would be appreciated. In this light, the beneficial aspects of learning from colleagues were mentioned by some teachers. This is also reflected in the literature, where several authors point at the importance of teachers learning together, i.e. the social element of teachers' professional development (e.g. Tsoukalas, 2012; Davis & Krajcik, 2005).

External factors

Besides the influences that are inherent to the material, it could be distilled from the interview data that when such material is to be implemented, external factors should be considered as well. The fact that materials and teacher professional development do not function in isolation, but are influenced by the context of teaching is also stated by Remillard (2000). Based on the interviews it was noted that such external factors could either stimulate or hinder the implementation of the material.

Stimulating factors that arose from the interview data are the value both teachers and schools place on implementing skills such as problem solving in education. The importance of teacher involvement and school wide attention in relation to a change in teaching is reflected in the literature as well, where Callagher, Hipkins and Zohar (2012) maintain that teachers should thoroughly understand and own a proposed change, thereby being supported by facilitators in the school, in order to acquire a systematic change in teaching (Callagher et al., 2012).

Although school-wide attention and perceived importance for skills such as problem solving can be seen as a stimulating factor, school structures can also be seen as hindering the actual usage of materials such as given to the teachers in this study. Many teachers expressed in the interviews that they often feel burdened by the numerous demands posed on them by structures in school, and therefore do not see opportunities to adopt the provided material on a more regular basis. This is in accordance with Remillard (2000), who states that the choices teachers make for adopting certain materials are affected by the demands school structures pose on teachers, either explicitly or implicitly (Remillard, 2000). Among

the demands teachers feel, the pressure to produce grades and the many other responsibilities teachers have besides teaching were raised by several teachers. This is in agreement with one of the reasons Carlgren (2013) poses for why skills are not yet being learned by students in high school. She points at the western education model in which emphasis is placed on testable outcomes and hierarchical administrative levels. Because of this educational model, teachers feel pressured to live up to everything that is expected from them with regard to student results and other job expectations (Carlgren, 2013). A further hindering factor concerning grades and implementing skills such as problem solving is the difficulty to grade students' problem solving ability, which was expressed by one interviewed teacher. This difficulty is confirmed by Eseryel et al. (2013), who state that assessing ill-structured problems is indeed challenging, since such problems do not possess a standard, correct answer. Additionally, since these problems often involve collaboration, it would be complicated to determine the performance of individual students (Eseryel et al., 2013). Voogt and Pareja Roblin (2010) also express that although assessment is an important prerequisite when implementing 21st century skills, new forms should be found to adequately evaluate students' ability on that score. Focus therein should not only be on subject matter knowledge, but also on skills that transcend those subjects. Furthermore, the assessment of 21st century skills should receive attention in nationally standardised tests, such as the final exams at the end of secondary education, as well (Voogt & Pareja Roblin, 2010).

Other hindering factors that came forward from the interviews were the lack of awareness by teachers of the existence of support material, and the lack of space in the curriculum. Many teachers do not see how they could incorporate material such as given to them in this study in their current curriculum, since most interviewed teachers deem the curriculum already quite full as it is. This result is confirmed by Anderson and Helms (2001), since they also state that many teachers do not seem to have enough time to teach all content they deem important to teach their students. Teachers often find it difficult to make choices in what to teach and what to exclude (Anderson & Helms, 2001).

Even though many teachers expressed that they take the textbook as a starting point for planning the lessons, and that this book consumes most of their teaching time, also several teachers were aware of the positive effects teaching with material such as given has on students. Teachers expressed that when working on such projects as given in the material under review, students are often more motivated and will learn more in comparison to working from a book. Despite the fact that some teachers seemed to contradict themselves by recognising the beneficial features of the material but at the same time not seeing opportunities to use that material, it can be seen as a stimulating factor that teachers are at least aware of the positive influence the material can have. Michael (2007) also states that material involving active learning will be beneficial for students, since eventually more learning will occur in comparison to just covering certain material.

Recommendations based on the interviews

The elements influencing the usage of the material under review that are inherent to the material are most likely in the direct control of the developers of the material. These elements should therefore be taken into account when (re)designing the material, and form the basis for the recommendations stemmed on the interviews.

Since teachers mentioned in the interviews that they are very practically oriented and mostly used the material for the students, this student material could be taken as a basis for the support material. Concrete tips for teachers could be added to this material, in order to help teachers in applying the specific elements in the material and providing them with a rationale why certain elements were chosen. This rationale could also help teachers to incorporate the material to their own specific context and perhaps adapt it, but in such a way that the key ideas behind the material are still standing.

Not including many details in the material could also help teachers to see opportunities to implement the material in their own teaching context. Elements such as group sizes or number of lessons could (given that they are not crucial elements of the skill problem solving) be given as suggestions rather than compulsory, so that teachers can perhaps more easily see how they could use the material. Only the elements that are crucial to teaching the skill problem solving should be made very explicit in the material, so that the chances that these will be employed by the teachers are increased.

Besides the recommendations that relate to the content of the material, it is also recommended that the layout of the material should be considered during the development. Many teachers expressed the wish to be able to scan the material and that the material should be perceived as manageable, to increase the chances of teachers actually using the material.

The recommendations for the material mentioned above are in accordance with Sherin and Drake (2009), who state that when designing material it should be considered how teachers will use the material. They noted that teachers are likely to merely glance at the material, in order to look for a general idea of the lesson. When designing the material this should therefore be taken into account, i.e. the material should facilitate easy focus on key elements. In doing so it is however important to provide teachers with sufficient crucial information so that they will be able to do justice to the material when they teach with it, to ensure appropriate implementation regarding the content which it aims to support (Sherin & Drake, 2009).

When the material has been designed while taking into account the identified factors inherent to the material, use of the material is not yet guaranteed since it was also noted that external factors are of interest to consider. On the majority of these external factors the developers of the material do not have a direct influence. They do however more or less have an influence on one external factor, namely the visibility of the material. In addition to thinking about the best way to compose the material for the target group, it is therefore recommended that the developers also consider how this target group could be best reached, since it is important that teachers know of the existence of the material in order to actually use it.

Some of the elements that are inherent to the material, and thus have to be considered when composing the material can be linked to some external factors hindering the use of the material. Teachers' wish for the material to be easy in use can be connected to the fact that teachers feel pressured by the demands that are posed on them. Since they feel as if they already have to do quite a lot, it might therefore be argued that for something extra to be done, they wish it to be as little inconvenient to their current practice as possible, and thus easy applicable. Also, when the material is composed in a way that facilitates adapting it to the own teaching context of the teacher, it might be easier for them to find space in the curriculum to actually incorporate the material. Therefore, the material can be designed in such a way as to possibly 'bypass' certain hindering external factors.

The aforementioned recommendations all relate to the material in itself or its visibility for the target group. As appeared from the interviews, another important factor to consider is the school-based context in which the material will have to be employed. It is important that teachers receive and perceive the space to incorporate skills such as problem solving in education. This is beyond the influence of developers of the specific material, but is important to consider when it is aimed to let teachers increase their teaching of skills in education.

Conclusions based on the interviews

- Both the material in itself and external factors influence the use of the material under review.
- The material under review was by most teachers deemed an appropriate means of support, although there are some aspects to consider regarding its composition.

- When composing the material the practical applicability, usability and context dependency should be considered.
- External factors could be either stimulating or hindering the use of the material, with possibly the demands felt by teachers and the perceived lack of space in the curriculum as the most important hindering factors to consider.

Recommendations based on the interviews

- Student material should be taken as base, complemented with concrete tips for teachers.
- The material should not contain too many details, so that it leaves room for teachers to make the material suitable for their own teaching context.
- The material should facilitate scanning, by ensuring a 'user-friendly' lay-out.
- Although the material should not contain many details, the key aspects of the applicable skill (and the rationale behind certain elements in the material with regard to that skill) should be made explicitly present in the material.
- Besides suggestions for the material in itself, also the distribution and visibility of the material should be considered to ensure usage by the target group.

7.4 Limitations

The present study was restricted by some limitations, which likely influence the obtained results. The most important of these was the fact that the material under review was unfortunately already developed when the literature study was conducted. Therefore, the model by Jonassen (1997), i.e. the typology of problems and the process for ill-structured problem solving, did not match the process for problem solving used by the development of the material one-to-one. It would have been interesting to observe teachers using materials that matched the design requirements of problem solving better. In future investigations, it is therefore recommended to first establish what a specific skill encompasses, before the material is actually developed.

Other limitations of this study lie in the sample used and the materials that were evaluated. The sample used in this study was relatively small, partially due to the fact that the study was qualitative in nature. Also less teachers than aimed for could eventually participate in the study, because of the difficulty to make appointments in the timeframe allocated for data collection. The results should therefore be interpreted with caution and cannot be generalised to secondary school teachers in general, also because of the fact that the material for two subjects (geography and physics) has been evaluated. Additionally, the teachers who did participate in the study might be a selected group, in the sense that they all consented to participate and put effort in it by agreeing to teach one or more lessons with the material. Therefore, it might be the case that these teachers are perhaps more open to trying something new, are more interested in 21st century skills, or are a bit more flexible in their planning compared to other teachers who did not participate in this study. This could have biased the interview results. The interviews were however aimed at exploring how this newly developed material was perceived by teachers, in order to further improve it. It was thus more a formative evaluation than a summative one. It was considered to be more worthwhile to question a limited number of teachers on their experiences with the material, so that they could be interrogated further when they gave an answer to really understand what they meant, and give them full opportunity to introduce other topics which were not considered by the researcher in advance. This open structure could not have been achieved in the same way when e.g. a large number of teachers would have been asked to fill out a questionnaire. Further research is required to establish whether the obtained results can be found in secondary school teachers in general. To do so, a more quantitative approach could be taken, in which more teachers of various subjects will use developed

material, and are subsequently asked about how they perceive the material. This could be accomplished by designing a questionnaire, based on the requirements for the composition of the material the teachers expressed in the interviews.

Regrettably, not all geography lessons taught with the material could be observed. By at least observing the first lesson, it was aimed to in any case observe the most important part of the problem solving process, since it was stated by multiple authors (e.g. Jonassen, 1997; Eseryel et al., 2013; Ge and Land, 2004) that this is the most important step in the entire process.

The data collection and analysis in this study were performed by one researcher, which could have biased the results. It would have been more suitable when the lessons, or at least the first few lessons, were observed with a second observer. When that would have been done, the interrater reliability could have been determined, and thereby providing a higher reliability on the use of the observation scheme. The reliability of the results obtained through the observations were however aspired to make more reliable, by taking additional notes during the observations, so that the scoring in the observation scheme could be understood with the classroom situation in mind. Another consideration for observing the lessons with only one researcher was to resemble the 'normal' lesson situation as much as possible, and therefore be as unobtrusive as possible during the observations.

The interview data was also analysed by one person, which could have influenced the construction of the networks. This was tried to overcome by analysing the data and constructing the networks first, and after a few weeks reread the interviews and check whether the entire thematic networks or elements in the networks should be altered. A more objective approach would however have been to involve a critical friend who would have scrutinised the constructed networks based on reading the interviews.

In order to ensure transparency, the observation scheme was given as part of the material teachers received. This could have influenced the way in which teachers taught the material, namely resulting in them to exhibit socially desirable behaviour. When they however would have used the observation scheme in order to help them to incorporate the skill problem solving in their lesson, this would not necessarily be a bad thing. The material was aimed at helping teachers to integrate problem solving in a lesson, and when the observation scheme would have helped them to do so, the developers of the material should perhaps consider to include it in the material as well. In the interviews, teachers were briefly asked whether they had used the observation scheme when preparing the lesson, and the majority of the teachers stated that they did not use it. Also when analysing the data retrieved from the observations, it was noticed that mostly only the elements explicitly stated in the material were observed in the lesson as student activities. Based on these data one might suggest that the addition of the observation scheme did not influence the teachers much in relation to them teaching the skill problem solving in the lesson. Because of the small sample size, these results should however be interpreted with caution.

Because of the importance of student activity in problem solving as a 21st century skill, actions in the observation scheme were formulated as such. When analysing the observation data it was however noticed that some elements were part of the lesson, however more teacher guided than through student activity. Being able to analyse this as well was accommodated for through the note-taking during the observations, in addition to the observation scheme. Nevertheless, in future it would be good to accommodate for this difference in teacher or student activity. This could be facilitated by adding the possibility to score an element on its presence as teacher guided as well as student activity in the observation scheme.

7.5 Final thoughts

Besides the SLO project concerning 21st century skills, there are also other initiatives that are directed at the importance to adequately prepare students to participate in the 21st century society. A major initiative in The Netherlands today is "Platform Onderwijs2032". The idea of this initiative is to establish what children that have started school in 2015 will need when they graduate from school (which is likely to be in 2032). Platform Onderwijs2032 (2016) states that, besides certain subject knowledge, students need to acquire skills that transcend those subjects. Among these skills is problem solving, and also the other 21st century skills as determined by Thijs et al. (2014) can be identified in the final advise reported by Platform Onderwijs2032 (2016). Furthermore, one goal of the initiative "Onderwijs2032" is to determine what pertains to the core of what should be taught, and what schools and teachers can choose to teach. This can be linked to one particular result of this study, namely that not all teachers did perceive room in the curriculum to implement material such as given to them in this study, in order to give attention to skills such as problem solving. Making clearer to teachers and schools what is part of the core of the curriculum, and what they can choose, might have a freeing effect on them.

Although it is good to support teachers in teaching skills, and evaluate how they use and perceive these materials, the ultimate goal of teacher professional development activities should be to increase student results (Van Veen, Zwart, & Meirink, 2012). Therefore, future research to evaluate the effectiveness of support material for teachers should also take into account the progress students make on certain skills when their teachers utilise the material. When focussing on students, it is recommended that attention is given to the fact that each student is different, and that the ability of students to solve a problem might be diverse as well. Although Jonassen proposes a typology to scale problems, he also acknowledges that the ability to solve a problem is not only inherent to the problem and how it is presented, but it depends on the ability of the problem solver as well (Jonassen, 2000). Bodner (1987) too indicates that the status of a problem is not a distinctive characteristic of the problem, but rather lies in the interaction between the issue and the one that wants to resolve that issue. What teachers might consider an exercise for which they immediately know how to reach a solution, might be a problem for students, to whom the issue at hand seems a lot less structured (Bodner, 1987). The ability of students would therefore be good to consider when designing material to teach students problem solving skills as well as when analysing their obtained results. When future research is aimed at tracking student results, it is however first important to establish how skills such as problem solving could be assessed, and thereby monitored.

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Appendix A: Geography material

Waar moet de nieuwe speelvoorziening komen?

Opdracht in het kader van de 21^e eeuwse vaardigheid probleemoplossen

vak(gebied)	Aardrijkskunde
schooltype / afdeling	Onderbouw VO
leerjaar	Leerjaar 1
tijdsinvestering	2-3 lesuren, incl. huiswerk
vakinhoud	De locatie voor een nieuwe speelvoorziening bepalen
kerndoelen	De opdracht sluit (enigszins) aan bij de kerndoelen: <i>38. De leerling leert een eigentijds beeld van de eigen omgeving, Nederland, Europa en de wereld te gebruiken om verschijnselen en ontwikkelingen in hun omgeving te plaatsen.</i> <i>42. De leerling leert in eigen ervaringen en in de eigen omgeving effecten te herkennen van keuzes op het gebied van werk en zorg, wonen en recreëren, consumeren en budgetteren, verkeer en milieu.</i>
21^e eeuwse vaardigheid	Probleem oplossen (en tevens: kritisch denken, creatief denken, samenwerken)
bron	-

Leerlingenmateriaal

Waar moet de nieuwe speelvoorziening komen?

De opdracht

De gemeenteraad in jouw stad (of in jouw dorp) heeft het probleem gesignaleerd dat er te weinig speelvoorzieningen zijn. Voor een gezonde leefomgeving moeten kinderen in hun eigen buurt immers buiten kunnen spelen.

Het probleem waar je een oplossing voor moet geven:

De gemeenteraad wil graag extra speelvoorzieningen, maar weet niet goed op welke plek en ook niet hoe de voorziening er uit zou moeten zien.

Van jou/jullie wordt gevraagd om uit te zoeken wat een geschikte plek (locatie) is voor een nieuwe speelvoorziening. Daarbij is het van belang dat je (eerst) nadenkt over keuze van de doelgroep en het soort speelvoorziening. Vervolgens verken je welke plek het meest hiervoor geschikt is.

In het uiteindelijke voorstel dat je doet (doelgroep, soort speelvoorziening, de beste locatie) neem je een kaart op van de wijk/buurt met daarbij de plek waar je de speelvoorziening zou moeten komen.

Als er in jullie buurt al een goede speelvoorziening is, dan gaan we er nu van uit, dat deze speelvoorziening verdwijnt omdat op het stuk grond iets anders gebouwd wordt (woningen, een winkel, kantoor of iets anders). In dat geval moet je dus ook op zoek naar een nieuwe goede plek.

De volgende deelvragen spelen bij de beantwoording van deze vraag (oftewel de oplossing van het probleem een rol:

- Voor welke doelgroep zou deze speelvoorziening moeten zijn.
- Bedenk wat voor speelvoorziening dit kan zijn; er zijn veel mogelijkheden die afhangen van de ruimte en de doelgroep (en natuurlijk ook het budget, al hoeft je daar geen 'zorgen' over te maken).

Doe een voorstel voor een locatie, teken deze in op een plattegrond van de wijk* (voorzien van de goede schaal, windrichting, legenda en titel). Geef aan waarom dit een geschikte plek is voor een speelvoorziening. Houdt bij de keuze van de inrichting van de speelvoorziening rekening met de doelgroep (kinderen in die buurt) en met verkeersveiligheid. Kom met een voorstel voor de inrichting. Schrijf dit op in de vorm van een korte aanbeveling (advies) aan de gemeenteraad.

(in plaats hiervan kan ook eventueel ook gekozen worden voor het maken van een plattegrond van de speelvoorziening zelf.)*

Wat ga je samen leren en ontdekken?

Je leert:

- Een oplossing te bedenken voor een concreet en herkenbaar probleem uit je eigen omgeving.
- Verschillende stappen te zetten om tot een goede oplossing voor het probleem te komen.
- Rekening te houden met verschillende wensen, belangen en voorkeuren van mensen (in dit geval met name de kinderen in de buurt).
- Rekening te houden met omstandigheden in de omgeving.
- Voor- en nadelen van verschillende oplossingen te inventariseren.
- Te komen tot een goed onderbouwd voorstel.

- Op de juiste wijze een kaart van je eigen omgeving te gebruiken en in te tekenen (met een goede titel, legenda, schaal, windrichting).
- Een korte presentatie te geven van jouw/jullie oplossing van het probleem.

Maar je leert vooral ook:

- Dat je samen met een ander tot een beter resultaat kunt komen dan in je eentje.
- Creatief te zijn bij de oplossing van het probleem.
- Kritisch te denken (we nemen geen genoegen met een oplossing, waar bij nader inzien toch onvoldoende is nagedacht).
- Naderhand te benoemen wat goed en minder goed ging in het komen tot een oplossing voor het probleem en wat de volgende keer verbeterd kan worden.

Hoe lang zijn we met deze opdracht bezig en hoe doen we dat?

We gaan in totaal 2 lessen (inclusief huiswerk) werken aan deze opdracht (het advies en het kaartje van de buurt).

De lessen

- Les 1

De docent vertelt wat de bedoeling is de komende lessen en met welke opdracht jullie aan de slag gaan. Hij geeft aan welk probleem voorligt, waarvoor jullie een oplossing moeten gaan bedenken.
(Zie verder de bovenstaande omschrijving van de opdracht.)

De hoofdvraag die aan jullie moeten beantwoorden:

Welke plek in jullie eigen omgeving is geschikt om een nieuwe speelvoorziening aan te leggen.

Voordat je nadenkt over de mogelijke oplossingen (plekken) moet je eerst inventariseren waar je allemaal rekening mee moet houden. Je gaat dus eerst het probleem verder verkennen.

Deelopdracht 1 (individueel opschrijven)

Met welke zaken moet je rekening houden als je een nieuwe speelvoorziening moet aanleggen in je eigen buurt?

Let wel: denk hierover goed na en neem hiervoor de tijd. Dit is namelijk een belangrijke stap bij het oplossen van een probleem: waar moet je allemaal rekening mee houden? Als je deze stap niet goed hebt gezet, dan kom je verderop niet tot een goed antwoord.

Als iedereen voor zich zelf deze vraag heeft beantwoord, dan bespreek je dat met je buurman/buurvrouw. Daarna gaan we klassikaal inventariseren (op het bord) welke zaken allemaal van belang zijn.

- Les 1 en 2

Deelopdracht 2 (in groepjes van twee of drie leerlingen)

Nu je een overzicht hebt van alle zaken die van belang zijn voor het zoeken van de juiste plek, ga je daadwerkelijk op zoek naar de juiste plek voor de nieuwe speelvoorziening in jouw omgeving.

Bepaal eerst gezamenlijk de wijk of het dorp waarin je de nieuwe speelvoorziening wilt plaatsen.

Beschrijf: waarom is dit de beste plek voor de speelvoorziening?

Teken de speelvoorziening in op een kaart. Wees creatief en bepaal zelf hoe je aan zo'n kaart van de eigen omgeving komt.

Houd in de kaart rekening met de volgende kaartelementen:

- Titel
- Legenda
- Schaal
- Windrichting

Zorg dat de kaart overzichtelijk blijft en vooral die informatie laat zien die van belang is.

Denk na hoe je de kaart wilt presenteren in de klas: een grote kaart die je ophangt of een kaart die je presenteert op het smartboard / digibord.

Werk verder (eventueel) thuis aan deze opdracht.

In les 2 ronden we de opdracht af (keuze voor een goede plek; redenen waarom; de ingetekende kaart).

- Les 3

Deelopdracht 3 Geef een (korte) presentatie van jullie oplossing.

In de nabespreking komen de volgende zaken aan de orde:

- Wat vond je van deze opdracht? Was het leuk om zelf van alles te mogen bedenken over jullie nieuwe land?
- Wat hebben we geleerd?
- Kon je goed samenwerken in het groepje?
- Wat kan of moet de volgende keer beter als je met een zelfde soort opdracht aan de slag gaat?

Toelichting voor de docent (bijsluiter)

- Waar moet de nieuwe speelvoorziening komen?

De 21^e eeuwse vaardigheid *Probleemoplossen*

Bij deze vaardigheid vragen we van de leerlingen te komen tot de oplossing van een concreet, herkenbaar en compact probleem in de eigen omgeving.

Om zich de vaardigheid probleemoplossen eigen te maken doorlopen leerlingen systematisch het proces van probleemoplossen.

De achtereenvolgende stappen zijn: het 'zien', erkennen, verkennen en verhelderen van het probleem; analyseren van het probleem; mogelijke (deel)oplossingen inventariseren; afwegen van de mogelijke oplossingen; selecteren en toepassen van een oplossing en evalueren van de oplossing.

De stappen maken deel uit van het proces van probleemoplossen **DAMASTE** (zie bijlage voor uitgebreidere typering):

D – *duiden van het probleem*

A – *analyseren van het probleem*

M – *mogelijke oplossingen*

A – *afwegen van oplossingen*

S – *selecteren van een oplossing*

T – *toepassen van de oplossing*

E – *Evalueren van de oplossing*

Vakspecifieke toepassing. Waarom deze opdracht?

In dit lesmateriaal oefenen leerlingen met de vaardigheid Probleemoplossen. De opdracht om een voor leerlingen herkenbaar probleem in de eigen omgeving ter hand te nemen en hiervoor een oplossing te bedenken sluit aan bij betekenisvol aardrijkskundeonderwijs.

Het leergebied Mens en maatschappij (onderbouw VO).

In de karakteristiek van dit leergebied staat een aantal aspecten waarbij deze opdracht aansluit:

Voor 12-14 jarigen zijn (onder meer) de volgende zaken in het leerproces van belang:

- Vragen leren stellen, inlevingsvermogen ontwikkelen en een open, verkennende houding aannemen zijn zowel doel als middel.
- Het uiteindelijke doel is dat leerlingen gestimuleerd worden op informatie gebaseerde, beargumenteerde beslissingen te leren nemen als burgers van een (cultureel diverse, democratische) samenleving waarin de onderlinge afhankelijkheden groot zijn.
- Ze moeten leren standpunten te bepalen en te onderbouwen met behulp van veelzijdige informatie.
- In dit leergebied leren leerlingen ook nadrukkelijk de eigen omgeving te gebruiken als bron en onderzoeksobject.

In deze opdracht houden de leerlingen zich bezig met een interessante vraag/taak waarbij ze hun gedachten de vrije loop kunnen laten gaan. Zo'n opdracht krijgt meer betekenis omdat de leerlingen zelf enigszins de uitdaging ter hand nemen en 'eigenaar van het probleem' worden (*ownership*). In die zin

sluit de opdracht aan bij de doelstellingen zoals die onder meer in de SLO publicatie *Betekenisvolle taken aardrijkskunde* (Greven en Kenter, 2006) verwoord zijn. Hier wordt gewezen op het belang om voor aardrijkskunde met opdrachten aan de slag te zijn die 'alle leerlingen kunnen uitdagen, motiveren en inspireren' en die 'verder gaan dan alleen reproductie'. 'Met andere woorden leerlingen kunnen verleiden tot eigen kennisreproductie.'

Context

Eén van de relevante schaalniveaus bij aardrijkskunde is dat van de eigen omgeving. In dit geval gaat het om een herkenbaar probleem dat zich afspeelt in de openbare ruimte. Leerlingen leren dit probleem te verkennen: welke actoren zijn van belang?; welke belangen spelen een rol?; met welke specifieke kenmerken van de omgeving moet rekening gehouden worden.

Kaartvaardigheden zijn specifiek bij aardrijkskunde van belang. In deze opdracht oefenen de leerlingen met elementaire kaartvaardigheden: ze maken een eenvoudige kaart van de omgeving of tekenen een bestaande kaart in (bestaande plattegrond of een digitale kaart, zoals Google Maps). Ze zorgen voor het juist gebruik van verschillende kaartelementen: titel, legenda, schaal, windrichting).

Groepsindeling

Er wordt gestart met een klassikale instructie. Deelopdracht 1 is individueel. Na een klassikale terugkoppeling gaan de leerlingen in kleine groepjes met de opdracht aan de slag. Klassikaal worden de resultaten besproken en wordt er geëvalueerd.

Tijdschema

In deze opdracht zitten de volgende fases, verdeel over drie lessen:.

- Les 1:
Verkenning en analyse van het probleem.
- Les 1 en 2:
Verdere analyse van het probleem; inventariseren van oplossingen; afwegen en selecteren van een oplossing.
Oplossing uitwerken in een kaart en de keuze onderbouwen
- Les 3:
Presenteren van de oplossingen en evalueren.

Lesdoelen

De leerlingen kunnen:

(Probleemoplosvaardigheden)

- Een aantal elementaire stappen toepassen in het proces van probleemoplossen.

(Kaartvaardigheden)

- Een eenvoudige kaart van hun omgeving maken of intekenen, waarbij ze een correct gebruik maken van de kaartelementen: titel, legenda, schaal en windrichting.

(Communicatieve vaardigheden en samenwerken)

- Samenwerken (in groepjes van twee of drie) om tot een goed resultaat te komen
- Hun eigen keuze kort presenteren en toelichten
- Luisteren naar en reageren op de oplossingen van andere groepjes
- Reflecteren op de opdracht en verwoorden wat goed en minder goed ging en wat de leerpunten zijn voor een volgende keer.

Bijlage:

Screeningslijst lesactiviteiten probleemoplosvaardigheden

Om te bepalen in hoeverre een les bijdraagt aan probleemoplosvaardigheden van leerlingen, kan in de onderstaande lijst per item een score worden toegekend. Als op een item een - of een \pm wordt gescoord kan de les op dit punt mogelijk worden aangepast. De lijst is dus zowel te gebruiken om lesmateriaal te beoordelen, als om zelf lessen te ontwerpen met aandacht voor probleemoplosvaardigheden.

De lijst volgt het model 'D-A-M-A-S-T-E': Duiden, Analyseren, Mogelijkheden, Afwegen, Selecteren, Toepassen, Evalueren.

1. Duiden, herkennen, verhelderen, verduidelijken van het probleem	-	\pm	+	nvt
• Het materiaal laat leerlingen zelf het probleem/de problemen vinden of signaleren.				
• De leerlingen moeten zelf het probleem (verder) duidelijk maken.				
• Het materiaal doet een beroep op hogere denkvaardigheden (analyseren, creëren en evalueren)				
2. Analyseren van het probleem	-	\pm	+	nvt
• Het probleem is nog niet volledig duidelijk. De leerlingen dienen het (nader) te analyseren en te definiëren.				
• Het materiaal of de opdracht doet een beroep op het (her)kennen van bruikbare strategieën en patronen om het probleem op te lossen.				
3. Mogelijke oplossingen inventariseren	-	\pm	+	nvt
• Er is tijd en gelegenheid voor leerlingen om verschillende oplossingen te bedenken, of in verschillende richtingen te denken om tot een oplossing te komen.				
• Het materiaal geeft strategieën (om te leren en te oefenen) om met onbekende problemen om te gaan.				
• Het materiaal laat leerlingen zelf oplossingsstrategieën genereren, analyseren en selecteren.				
• Het materiaal biedt informatie over patronen en modellen, en/of laat leerlingen deze zelf creëren.				
4. Afwegen van de mogelijke oplossingen	-	\pm	+	nvt
• Het materiaal biedt houvast bij het systematisch afwegen van de mogelijke effectiviteit, efficiëntie en juistheid van verschillende oplossingen.				
5. Selecteren van een oplossing	-	\pm	+	nvt
• Leerlingen wordt gevraagd beargumenteerde beslissingen te nemen.				
6. Toepassen van de gekozen oplossing				
• De opdracht bevat ook het toepassen of uitvoeren van de gekozen oplossing.				
7. Evalueren				
• Het materiaal laat de leerling nagaan of de gekozen oplossing tot het gewenste resultaat heeft geleid.				
• Het materiaal laat de leerling reflecteren op het doorlopen probleemoplosproces.				

Appendix B: Physics material

Voorbeeld Probleem oplossen Natuurkunde: De sneeuwpop

Vak	Natuurkunde
Schooltype / afdeling	VO onderbouw
Leerjaar	Onderbouw VO
Tijdsinvestering	1 à 2 lessen
Vakinhoud	Verwarmen en warmtetransport
Kerdoelen	Aansluitend bij de kerndoelen: 32 De leerlingen leren onderzoek doen aan materialen en natuurkundige verschijnselen, zoals licht, geluid, elektriciteit, kracht, magnetisme en energie. 33 De leerlingen leren bij producten uit hun eigen omgeving relaties te leggen tussen de werking, de vorm en het materiaalgebruik.
21^e eeuwse vaardigheid	Probleem oplossen
Natuurwetenschappelijke vaardigheden	Onderzoeken, Analyseren, Creëren
Bron	Concept Cartoons in Science Education, Stuart Naylor and Brenda Keogh

De sneeuwpop

Waar gaat deze opdracht over?

Een Concept Cartoon is een cartoon van een alledaagse situatie. Vanuit verschillende gezichtspunten wordt met drie of vier korte teksten commentaar op die situatie gegeven. Aan het eind van de opdracht (in dit geval over de sneeuwpop) geef je een beargumenteerde oplossing of verklaring. In deze opdracht bedenken je vervolgens een experiment waarmee het verschijnsel onderzocht kan worden, voer je het experiment uit en verbind je er een conclusie aan.

Wat ga je leren, wat wordt er van je verwacht?

- Je leert een oplossing te zoeken voor een alledaagse verschijnsel door het verschijnsel vanuit verschillende gezichtspunten te bekijken
- Je leert een oplossing of verklaring te geven op de gegeven situatie op grond van argumenten
- Je leert hoe je met een experiment de juistheid kunt aantonen van de gevonden oplossing of verklaring

Daarvoor wordt van je gevraagd, dat

- je alleen maar ook samen tot een beargumenteerde oplossing of verklaring komt;
- je een experiment bedenkt dat de juistheid aantoont van de gevonden oplossing;
- je samen dat experiment opzet en uitvoert;
- je de meetresultaten op een duidelijke, overzichtelijke manier presenteert;
- je de conclusie helder verwoordt.

21^e eeuwse vaardigheden

- ***Je gaat in deze opdracht werken aan het verbeteren van je probleem oplosvaardigheden verbeteren;***
- *daarnaast heb je bij de opdracht de vaardigheid creativiteit nodig.*

Groepsgrootte

Je voert deze opdracht uit in een groepje van 3 leerlingen

Aan het werk!

Je maakt de opdracht met de cartoon eerst zelf, daarna bespreek je de stellingen in een groepje van drie. Nadat je het experiment hebt uitgevoerd, wordt de opdracht in de klas besproken.

Oriënteren

- Bekijk onderstaande cartoon;
- Beredeneer welke stelling het meeste hout snijdt en schrijf de argumenten daarvoor op;
- Bespreek in je groepje de verschillende stellingen met elkaar.

De sneeuwpop

Wat denk JIJ?



Bron: Concept Cartoons in Science Education, Stuart Naylor and Brenda Keogh

Als je van mening verschilt is dat prima, maar schijf de argumenten altijd op.

Naam leerling	Kiest voor student A, B of C	Argument(en)

Schrijf op voor welke stelling jullie op grond van argumenten het meeste voelen.

Onderzoeken

- Bedenk met je groepje een experiment waarmee je kunt aantonen dat de gekozen stelling de juiste is. Bespreek de opzet van dit experiment met je docent
- Zoek daarvoor spullen bij elkaar en voer het experiment uit;
- Schrijf op een overzichtelijke manier de waarnemingen op;
- Trek conclusies en schrijf de argumenten op waarmee je de gekozen stelling kunt verdedigen;
- Bespreek dit met de klas.

Evaluëren en reflecteren

- Bespreek met elkaar of je goed hebt samengewerkt en wat er nog aan de gevonden oplossing of verklaring nog beter zou kunnen.
- Wat zou nog verbeterd kunnen worden aan het experiment?

Toelichting voor de docent

Inleiding

In deze opdracht staat de vaardigheid probleemoplossen centraal

Bij deze vaardigheid gaat het om het (h)erkennen van een probleem en tot een plan kunnen komen om het probleem op te lossen. Om zich de vaardigheid probleemoplossen eigen te maken doorlopen leerlingen systematisch het proces van probleemoplossen.

De achtereenvolgende stappen zijn: het 'zien', erkennen, verkennen en verhelderen van het probleem; analyseren van het probleem; mogelijke (deel)oplossingen inventariseren; afwegen van de mogelijke oplossingen; selecteren en toepassen van een oplossing en evalueren van de oplossing.

De stappen maken deel uit van het proces van probleemoplossen DAMASTE (zie bijlage voor uitgebreidere typering):

- D – duiden van het probleem
- A – analyseren van het probleem
- M – mogelijke oplossingen
- A – afwegen van oplossingen

S – selecteren van een oplossing
T – toepassen van de oplossing
E – Evalueren van de oplossing

Waarom deze opdracht?

Deze opdracht leent zich heel goed om expliciete aandacht te geven aan probleemoplossen. Zonder al teveel voorkennis wordt van leerlingen gevraagd om een oplossing te vinden voor het tegengaan van het smelten van een sneeuwpop. Door met elkaar te discussiëren wordt van leerlingen gevraagd om tot een oplossing te komen. Daarbij zal een verklaring moeten worden gevonden voor de verschijnselen die daarbij een rol spelen! De opdracht is een voor leerlingen herkenbaar probleem waarvoor een oplossing bedacht moet worden en dit sluit aan bij betekenisvol natuurkunde onderwijs.

Context

Belangrijk voor natuurkunde is dat in de onderbouw leerlingen leren kijken naar de verschijnselen die zich afspelen in hun eigen omgeving. Dat betekent dat leerlingen moeten leren om deze verschijnselen ook daadwerkelijk te herkennen en dat zij een houding ontwikkelen om hierover vragen te stellen, bijvoorbeeld wanneer en hoe kunnen bepaalde verschijnselen gebeuren. Maar ook hoe kunnen bepaalde problemen worden opgelost, bijvoorbeeld waarom vat iets vlam en hoe kan vuur daarom bestreden worden. In dit geval gaat het met name om de conceptie warmte en warmtetransport, in het bijzonder warmte uitwisseling en isolatie.

Aanpak

De docent legt uit dat een Concept Cartoon de visuele presentatie is van een alledaagse situatie. Vanuit verschillende gezichtspunten wordt met drie of vier korte teksten commentaar op die situatie gegeven. Het is de bedoeling dat na discussie en onderzoek ieder groepje een beargumenteerde oplossing of verklaring geeft op de gegeven situatie. Dit moet in dit geval ondersteund worden door resultaten van een zelfbedacht en uitgevoerd experiment, waaraan een conclusie wordt verbonden. Tijdens de les bespreekt de docent de resultaten met ieder groepje en stelt een aantal denkvragen. De leerlingen proberen op deze vragen zo goed mogelijk antwoorden te vinden op basis van de resultaten van het experiment en door benodigde natuurkundige kennis daarbij te betrekken.

Groepsindeling

Plenaire momenten en samenwerken in groepjes wisselen elkaar af. Zoals eerder vermeld is het de bedoeling is dat in drietallen de stellingen worden besproken en een experiment wordt ontwikkeld. Vervolgens kunnen de experimenten klassikaal worden besproken bijvoorbeeld aan de hand van een aantal denkvragen (zie onder Voor de docent).

Lesdoelen

(kort geformuleerd)

Probleemoplosvaardigheden

De leerlingen passen een aantal elementaire stappen toe in het proces van probleemoplossen.

Communicatieve vaardigheden en samenwerken

Leerlingen werken samen om tot een goed resultaat te komen, presenteren en luisteren naar en reageren op de oplossingen van andere groepjes

Onderzoeksvaardigheden

De leerlingen verhelderen een probleem, formuleren een mogelijk oplossing/verklaring, zetten een experiment op, voeren dat uit, leggen waarnemingen vast en trekken conclusies.

Nadere toelichting

Deze opdracht gaat over een alledaags probleem dat zich voordoet in de winter, namelijk hoe kunnen we een sneeuwpop zo lang mogelijk behouden, vooral wanneer de temperatuur weer gaat stijgen en weer boven nul gaat uitkomen? Met welke natuurverschijnselen moeten we dan rekening houden? Gevraagd wordt niet alleen om het antwoord, maar vooral om de argumentatie. Daarnaast wordt gevraagd proefondervindelijk aan te tonen dat het antwoord het juiste antwoord is.

Van de leerlingen wordt verwacht dat zij basiskennis hebben over fases van stoffen, faseovergangen, temperatuur, warmte en nog kennis moeten opdoen over warmtetransport en isolatie. Deze opdracht vereist verder het kunnen oproepen van benodigde kennis, het kunnen leggen van verbanden en het doen van onderzoek. Van leerlingen wordt verwacht, dat zij op grond van een logische redenering eerst individueel en daarna in groepsverband komen tot een oplossing of verklaring.

In deze opdracht wordt gerefereerd aan communiceren. Vooral het luisteren naar elkaar en komen tot een gezamenlijke (of juist geen gezamenlijke) oplossing/verklaring is van belang.

De opdracht kan op verschillende momenten gegeven worden. Juist het verwoorden van de argumenten voor en tegen de verschillende gezichtspunten die op de cartoon staan, is essentieel. Laat de cartoons daarom een startpunt zijn voor een klassen- of groepsdiscussie met de werkvorm denken-delen-uitwisselen. U kunt de cartoon overnemen op een bord of projecteren, waarna u een klassendiscussie start of de leerlingen in groepjes laat discussiëren.

Daarnaast kan leerling worden geadviseerd om bronnen te raadplegen.

Experiment

In deze les wordt een beroep gedaan op de vaardigheid onderzoeken door van de leerlingen te vragen om een experiment te bedenken en uit te voeren. De situatie kan worden onderzocht door bijvoorbeeld twee flesjes of plastic zakjes met bevroren water als modelsneeuwpoppen te nemen. Vervolgens kan een want of sok dienst doen als jas voor één van de flesjes. Een uitbreiding van het experiment zou kunnen zijn om de aard (wol of katoen), kleur of dikte van de 'jas' te variëren. Laat ieder groepje een experiment bedenken dat zij met u eerst bespreken en laat hun de benodigde spullen bij elkaar zoeken. Spreek af wanneer en waar het groepje het experiment kan uitvoeren. Reserveer daarvoor voldoende tijd.

Denkvragen

Tijdens de les en ook tijdens de nabespreking met de klas kunnen leerlingen denkvragen gesteld worden. De conclusie kan zijn dat de jas de transport van warmte van en naar de sneeuwpop belemmert, met name vanwege de stilstaande lucht die in de structuur van de vezels (wol) van de jas zit. Dan kunnen nog de volgende aanvullende vragen gesteld worden om het begrip te verbeteren:

- Waarom zal de jas uiteindelijk toch smelten?
- Beschrijf welk verschil er is tussen de functie van een jas die gedragen wordt door een mens en die gedragen wordt door een sneeuwpop.
- Wat moeten de eigenschappen van de vezels van de jas zijn?
- Hoe zou de (micro)structuur van de vezels van de jas er uit zien? Maak er een tekening van om je antwoord te illustreren
- Welke onderdelen kun je onderscheiden in die structuur?
- Waar is de structuur van gemaakt en wat zijn de eigenschappen van het materiaal?
- Kan de eigenschap van een stof (en dus waar een stof voor gebruikt kan worden, de functie) bepaald worden vanuit de microstructuur?
- Hoe zou de structuur verbeterd kunnen worden om de isolatie nog beter te laten zijn?

Antwoordmodel

Een bekende misconceptie is dat sommige materialen de eigenschap hebben om dingen warm te maken. In dit geval hebben we de neiging te denken dat als we een sneeuwpop een jas aantrekken deze jas de sneeuwpop warm houdt en de sneeuwpop daarom eerder en/of sneller smelt.

Maar in werkelijkheid werkt de jas als een isolator en reduceert het de uitwisseling van energie in beide richtingen: van binnen naar buiten en van buiten naar binnen. De reden dat juist een jas dit bewerkstelligt, komt doordat een jas relatief veel stilstaande lucht vasthoudt. Stilstaande lucht is een goede isolator (vergelijk spouwmuren). Bij een mens zorgt een jas ervoor dat de persoon warm blijft en dat er geen warmte verloren gaat aan de omgeving. Bij een sneeuwpop zorgt een jas ervoor dat de sneeuwpop niet warmer wordt als de omgeving warmer wordt.

Bijlage:

Screeningslijst lesactiviteiten probleemoplosvaardigheden

Om te bepalen in hoeverre een les bijdraagt aan probleemoplosvaardigheden van leerlingen, kan in de onderstaande lijst per item een score worden toegekend. Als op een item een - of een \pm wordt gescoord kan de les op dit punt mogelijk worden aangepast. De lijst is dus zowel te gebruiken om lesmateriaal te beoordelen, als om zelf lessen te ontwerpen met aandacht voor probleemoplosvaardigheden.

De lijst volgt het model 'D-A-M-A-S-T-E': Duiden, Analyseren, Mogelijkheden, Afwegen, Selecteren, Toepassen, Evalueren.

1. Duiden, herkennen, verhelderen, verduidelijken van het probleem	-	\pm	+	nvt
• Het materiaal laat leerlingen zelf het probleem/de problemen vinden of signaleren.				
• De leerlingen moeten zelf het probleem (verder) duidelijk maken.				
• Het materiaal doet een beroep op hogere denkvaardigheden (analyseren, creëren en evalueren)				
2. Analyseren van het probleem	-	\pm	+	nvt
• Het probleem is nog niet volledig duidelijk. De leerlingen dienen het (nader) te analyseren en te definiëren.				
• Het materiaal of de opdracht doet een beroep op het (her)kennen van bruikbare strategieën en patronen om het probleem op te lossen.				
3. Mogelijke oplossingen inventariseren	-	\pm	+	nvt
• Er is tijd en gelegenheid voor leerlingen om verschillende oplossingen te bedenken, of in verschillende richtingen te denken om tot een oplossing te komen.				
• Het materiaal geeft strategieën (om te leren en te oefenen) om met onbekende problemen om te gaan.				
• Het materiaal laat leerlingen zelf oplossingsstrategieën genereren, analyseren en selecteren.				
• Het materiaal biedt informatie over patronen en modellen, en/of laat leerlingen deze zelf creëren.				
4. Afwegen van de mogelijke oplossingen	-	\pm	+	nvt
• Het materiaal biedt houvast bij het systematisch afwegen van de mogelijke effectiviteit, efficiëntie en juistheid van verschillende oplossingen.				
5. Selecteren van een oplossing	-	\pm	+	nvt
• Leerlingen wordt gevraagd beargumenteerde beslissingen te nemen.				
6. Toepassen van de gekozen oplossing				
• De opdracht bevat ook het toepassen of uitvoeren van de gekozen oplossing.				
7. Evalueren				
• Het materiaal laat de leerling nagaan of de gekozen oplossing tot het gewenste resultaat heeft geleid.				
• Het materiaal laat de leerling reflecteren op het doorlopen probleemoplosproces.				

Appendix C: Comparison process Jonassen and the observation scheme

Process for ill-structured problem solving (according to Jonassen, 1997)		Main steps in the observation scheme (as used in this study)
5) Process of monitoring and reflecting ^b	→ 1) Articulating problem space	1) Recognising and clarifying the problem
	→ 2) Identification of stakeholders (and their perspectives)	2) Analysing the problem ^a
	→ 3) Generating possible solutions	3) Generating possible solutions
	→ 4) Assessing viability of possible solutions	4) Considering possible solutions
		5) Selecting a solution ^c
	6) Implementing and monitoring solution *	6) Applying that solution
		7) Evaluating ^d
	7) Adapting solution *	

Note. Steps marked with an asterisk (*) are according to Jonassen (1997) often not possible to perform in a school-based context, because of complexity of ill-structured problems.

^a Part of analysing the problem could be to identify the stakeholders and their perspectives. This is however not explicitly mentioned in the observation scheme, and therefore this step is only partially aligned to the second step distinguished by Jonassen (1997).

^b The process of monitoring and reflecting on the first steps in the problem solving process is not included.

^c Selecting a solution is not a separate step in the process articulated by Jonassen (1997).

^d In the observation scheme, the process of evaluating is not only targeted at evaluating the solution, but also at reflecting on the whole problem solving process (somewhat similar to the fifth step articulated by Jonassen (1997), only afterwards rather than during the problem solving process).

Appendix D: Observation scheme

Algemene gegevens			
Datum	Tijd		
Naam leraar	Geslacht		
Naam school	Klas	Leerjaar	Niveau
Vak	Gebruikt voorbeeldlesmateriaal		Les ____ van ____ (bij lessenserie)
Aantal leerlingen	Opstelling		

1. Duiden, herkennen, verhelderen, verduidelijken van het probleem		Opmerkingen	Ja	Nee	N.v.t.
<ul style="list-style-type: none">De leraar laat leerlingen de probleemstelling(en) herkennen					
<ul style="list-style-type: none">De leraar laat leerlingen het probleem formuleren in een gegeven situatie					
<ul style="list-style-type: none">De leraar laat leerlingen een (onderzoeks)vraag opstellen bij het probleem					
Opmerkingen					

2. Analyseren van het probleem		Opmerkingen	Ja	Nee	N.v.t.
<ul style="list-style-type: none">De leraar laat leerlingen benoemen waarom het een probleem is					
<ul style="list-style-type: none">De leraar laat leerlingen elementen benoemen waaruit het probleem bestaat					
<ul style="list-style-type: none">De leraar laat leerlingen de context van het probleem benoemen					
<ul style="list-style-type: none">De leraar laat leerlingen zelf een plan van aanpak voor het oplossen van het probleem opstellen					
<ul style="list-style-type: none">De leraar laat leerlingen nadenken of het probleem voldoende gedefinieerd is om te kunnen gaan nadenken over mogelijke oplossingen					
Opmerkingen					

3. Mogelijke oplossingen inventariseren		Opmerkingen	Ja	Nee	N.v.t.
<ul style="list-style-type: none">De leraar laat leerlingen verschillende oplossingen bedenken voor het probleem					
<ul style="list-style-type: none">De leraar moedigt leerlingen aan om in verschillende richtingen te denken bij het bedenken van mogelijke oplossingen voor het probleem					
<ul style="list-style-type: none">De leraar laat leerlingen reflecteren of de bedachte mogelijke oplossingen het probleem daadwerkelijk zouden oplossen					
Opmerkingen					

4. Afwegen van de mogelijke oplossingen		Opmerkingen	Ja	Nee	N.v.t.
<ul style="list-style-type: none">De leraar laat leerlingen redeneren over de effectiviteit van mogelijke oplossingen					
<ul style="list-style-type: none">De leraar laat leerlingen redeneren over de efficiëntie van mogelijke oplossingen					
<ul style="list-style-type: none">De leraar laat leerlingen redeneren over de juistheid van mogelijke oplossingen					
<ul style="list-style-type: none">De leraar moedigt leerlingen aan om vragen te stellen bij mogelijke oplossingen					
Opmerkingen					

5. Selecteren van een oplossing		Opmerkingen	Ja	Nee	N.v.t.
<ul style="list-style-type: none">De leraar laat leerlingen een keuze selecteren uit de bedachte mogelijke oplossingen					
<ul style="list-style-type: none">De leraar laat leerlingen argumenten geven waarom de geselecteerde oplossing het beste is					
Opmerkingen					

6. Toepassen van de gekozen oplossing		Opmerkingen	Ja	Nee	N.v.t.
<ul style="list-style-type: none">De leraar laat leerlingen een plan maken om de gekozen oplossing toe te passen					
<ul style="list-style-type: none">De leraar laat leerlingen de gekozen oplossing toe passen					
Opmerkingen					

7. Evalueren		Opmerkingen	Ja	Nee	N.v.t.
<ul style="list-style-type: none">De leraar laat leerlingen het probleemoplosproces evalueren					
<ul style="list-style-type: none">De leraar laat leerlingen analyseren of de oplossing adequaat het probleem heeft opgelost					
<ul style="list-style-type: none">De leraar laat leerlingen aanbevelingen doen voor verbetering van het probleemoplosproces en/of de oplossing					
Opmerkingen					

Appendix E: Interview scheme

Inleiding	Aan bod gekomen?
<ul style="list-style-type: none"> Kort herhalen doel onderzoek <ul style="list-style-type: none"> Evalueren van het voorbeeldlesmateriaal van SLO, door enerzijds te observeren hoe het in de lessen geïmplementeerd wordt en anderzijds leraren te interviewen over hun ervaringen en hoe zij het materiaal waarderen 	
<ul style="list-style-type: none"> Verwachte tijdsduur <ul style="list-style-type: none"> ± 45 minuten 	
<ul style="list-style-type: none"> Anonieme/vertrouwelijke gegevensverwerking <ul style="list-style-type: none"> Toestemming voor SLO-medewerkers? (ja/nee) Naam in principe alleen bij mij bekend; verwerking in verslag sowieso anoniem; toestemming vragen om contactgegevens gekoppeld aan interviewgegevens aan direct betrokken SLO medewerkers te geven (als zij nog graag aanvullende informatie zouden willen) 	
<ul style="list-style-type: none"> Toestemming vragen voor geluidsopname 	

Algemene gegevens	
Datum	Tijdstip
Naam leraar	Geslacht
Leeftijd	Aantal jaar werkzaam onderwijs

Materiaal SLO (Materiaal doorlopen met leraar)	Aan bod gekomen?
<ul style="list-style-type: none"> Algemene indruk van het materiaal <ul style="list-style-type: none"> Positief/negatief (zwakke punten, overbodig)/wat mist Hoeveelheid informatie? Aard van informatie? 	
<ul style="list-style-type: none"> Bijdrage materiaal voor het vak (voorbeeldmateriaal ook voldoende vak inhoud?) 	
<ul style="list-style-type: none"> Leerlingenmateriaal <ul style="list-style-type: none"> Positief/negatief (zwakke punten, overbodig)/wat mist 	
<ul style="list-style-type: none"> Toelichting voor de docent <ul style="list-style-type: none"> Nuttig bij voorbereiding van les/tijdens les? Positief/negatief (zwakke punten, overbodig)/wat mist 	
<ul style="list-style-type: none"> Bijlage (screeningslijst) <ul style="list-style-type: none"> Nuttig bij voorbereiding van les/tijdens les? Positief/negatief (zwakke punten, overbodig)/wat mist 	

<ul style="list-style-type: none"> • Kijkwijzer (= <i>observatieschema</i>) Nu gegeven in het kader van het onderzoek (transparantie), maar misschien als materiaal ook nuttig voor leraren zelf, als 'checklist'? <ul style="list-style-type: none"> ○ In hoeverre daarnaar gekeken/gebruikt? ○ Nuttig? (zou je die vaker gebruiken; bijv. bij collegiale consultatie?) 	
<ul style="list-style-type: none"> • "Alternatieve bijsluiter" (4-bladige; laten zien) <ul style="list-style-type: none"> ○ Positief/negatief (zwakke punten, overbodig)/wat mist ○ Nuttig? (Bij voorbereiding van/tijdens les?) 	

21 ^e EV 'probleemoplossen' (en ondersteuning daarvan)	Aan bod gekomen?
<ul style="list-style-type: none"> • Wat vinden ze van de gegeven informatie over 'probleemoplossen' in het materiaal? <ul style="list-style-type: none"> ○ Nuttig? Gebruikt? Genoeg? Teveel? Zelf extra informatie gezocht? (leraar evt. al ervaring met 'probleemoplossen' → voorkennis) ○ Soort informatie? (goed, of juist meer praktisch/theoretisch/... gewenst?) 	
<ul style="list-style-type: none"> • Transfer andere lessen <ul style="list-style-type: none"> ○ Leuk om nu zelf een les te maken met 'probleemoplossen' erin/ 'probleemoplossen' te integreren in een eigen les? (→ stimuleert het materiaal daartoe?) ○ Genoeg handvatten voor het maken van een les met 'probleemoplossen'? 	
<ul style="list-style-type: none"> • Doel voorbeeldlesmateriaal is leraren ondersteunen in het lesgeven met de specifieke 21^e EV <ul style="list-style-type: none"> ○ In hoeverre slaagt het materiaal daarin? ○ Evt. nog andere ondersteuning wenselijk? (evt. combinatie van soorten ondersteuning?) 	
<ul style="list-style-type: none"> • Vaardigheid 'probleemoplossen' bij leerlingen <ul style="list-style-type: none"> ○ Door deze les stappen/stapjes gezet in 'probleemoplossen' door leerlingen? <ul style="list-style-type: none"> ▪ Waarom wel/niet? (Redenen? → Wat moet evt. anders (in materiaal)?) (leerlingen al eerder opdrachten/ervaringen met 'probleemoplossen'?) ○ Rol materiaal/leraar daarin? (Anders handelen van leraar?) 	

O.b.v. observaties (Misschien o.b.v. observaties nog punten, van tevoren per leraar noteren)	Aan bod gekomen?
<ul style="list-style-type: none"> • • • 	
<p>(Bij observatie van 1 les uit lessenserie) → Terloops naar vragen, op plek die logisch is in interview)</p> <ul style="list-style-type: none"> • Hoe gingen de andere les(sen)? <ul style="list-style-type: none"> ○ Wat ging naar eigen mening goed? ○ Wat zouden ze een volgende keer anders doen? 	

Afsluiting	Aan bod gekomen?
<ul style="list-style-type: none"> • Nog vragen/opmerkingen? 	
<ul style="list-style-type: none"> • Vervolg onderzoek <ul style="list-style-type: none"> ○ Wat gebeurt er met de gegevens → interview wordt getranscribeerd, samen met alle andere interviews geanalyseerd, quotes kunnen (vertaald) in het onderzoeksrapport komen te staan ○ Op de hoogte stellen van resultaten (Waar de resultaten t.z.t. op gevonden kunnen worden → website?; Ze t.z.t. iets toesturen?) ○ Mogelijkheid tot inzicht eigen gegevens (transcriptie) 	
<ul style="list-style-type: none"> • Contactgegevens nog keer noemen (Ook voor als er later nog vragen zijn) 	
<ul style="list-style-type: none"> • Bedankje 	

Appendix F: Pictures of stages in the analysis process

Teschel A

beetje theorie nog niet in praktijk

Leraar F

Maastricht

probleem

op school al wel aandacht voor leraar

eraring prim. 2e EV?

op school al wel aandacht voor leraar

eraring prim. 2e EV?

op school al wel aandacht voor leraar

eraring prim. 2e EV?

Teschel B

beetje theorie nog niet in praktijk

Leraar F

Maastricht

probleem

op school al wel aandacht voor leraar

eraring prim. 2e EV?

op school al wel aandacht voor leraar

eraring prim. 2e EV?

op school al wel aandacht voor leraar

eraring prim. 2e EV?

beetje theorie nog niet in praktijk

Leraar F

Maastricht

probleem

op school al wel aandacht voor leraar

eraring prim. 2e EV?

op school al wel aandacht voor leraar

eraring prim. 2e EV?

op school al wel aandacht voor leraar

eraring prim. 2e EV?

