Teaching Science Through Inquiry

DISCOVERING THE MIRROR

in Kindergarten and Grades 1&2

by

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Abstract

This thesis reports on the development and evaluation of a lesson series about mirrors for grades 1&2 and Kindergarten. The main goals of the lesson series were to arouse interest in science in the children, to let the children work inquiry-based and to give the teacher an easy-to-use science module. The lesson series was developed with specific conditions in mind, such as easy usability and no necessity for the teacher to have prior knowledge. Two teachers were involved in the developmental phase, three more teachers tested the materials afterward. Most lessons were observed, some were videotaped. Students and teachers were post-interviewed. Afterwards, experiments were done with the children to establish how much they learned from the lessons.

The interviews and lesson analysis show that the lesson series does fulfill the initial conditions (such as being inquiry-based and easy-to-use). The students and teachers were all very enthusiastic about the lessons and students’ interest in science was aroused. The students also remember the lessons very well and could reproduce the results of the lessons months after the lessons took place. What exactly they learned about the science behind mirrors remains unclear. The teachers evaluated the materials in a positive way and expressed their intent to use them again.
Postscript

What happened to the mirror lesson materials and to the researcher/developer after the thesis data had been collected?

By the end of the 2007/2008 school year the two rounds of piloting and revising of the mirror materials had been completed. Presentation in several workshops for primary teachers met with a positive response. Then the VTB Pro team of the Hogeschool van Amsterdam decided to include mirrors as one session in a 7-session in-service training course which was offered to about 400 teachers between 2008 and 2010. Feedback from teachers and evaluation research of Thomas van Eijck showed that the mirror materials were the most frequently used in the classrooms compared to other modules and materials presented in the course. Magic Mirrors indeed do have a low threshold for teachers and triggers enthusiastic participation of children. The perceived low threshold by teachers and therefore limited preparation can lead to missed opportunities in teaching as Welmoet points out in this thesis.

The teacher guide and the worksheets were also translated into English and distributed in the EU POLLEN project. An article was published in Science & Children, the science education journal for primary teachers in the USA with a circulation of 20,000 copies. Mirrors was presented at several international conferences and workshops. A list of publications has been provided below.

Meanwhile Welmoet Damsma has been working as a physics instructor and developer at the Hogeschool van Amsterdam. Amongst others she developed and taught the minor in science and technology for elementary education majors. This elective minor will run for the third year in 2011-12 with a stable enrollment. She also pioneered the internship scheme in which elementary education students carried out joint development projects with science and technology students in elementary schools. At present Welmoet is heavily involved in shaping the science and technology program for a new joint university-hogeschool program for elementary teacher education (UPvA).

Ed van den Berg, thesis supervisor

“Mirror” publications and presentations

Damsma, W., Berg, E. van den, Manneveld, G. (2008). Spiegels, een lessenserie voor de eerste vier jaar van de basisschool. NVOX, 33(6), 242-244.
Damsma, W., Berg, E. van den (2010). Magic Mirrors for Key Stage 1, ASE Annual Conference, University of Nottingham (workshop, 22 participants)
Preface

They say beginnings are seldom easy, but I find endings are no peanuts either. This thesis cost a lot of thinking and sorting and ordering and changing the whole thing around yet again. Luckily, people were patient. This project started as a way of really 'doing something'. It is not my wish to only do things in theory. And since I did not know what I would get myself into, I just jumped right in. Well, they also say: "When one teaches, two learn".

I would like to thank all people who listened to my stories about the lesson series and gave me good advice. I would especially like to thank my supervisor Ed van den Berg and my sometimes co-researcher and adviser Gerda Manneveld. Of course, a big thank you goes to all the teachers that participated in this project at De Nieuwe Kring: Machtelt van der Meer, Karin Fontijn, Frank Hoefnagels, Maartje Jongen, Ellen van Gullik and Anita Beerthuizen. For all their students: Thank you for being inquisitive and enthusiastic!
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1. Introduction

You cannot teach a man anything; you can only help him find it within himself - Galileo Galilei (1564-1642)

It is a miracle that curiosity survives formal education – Albert Einstein (1879-1955)

It is, in fact, nothing short of a miracle that the modern methods of instruction have not entirely strangled the holy curiosity of inquiry – Albert Einstein (1879-1955)

The whole art of teaching is only the art of awakening the natural curiosity of young minds for the purpose of satisfying it afterwards – Anatole France (1844-1924)

1.1 Motivation for this design study

In recent years the interest in science teaching in primary schools in The Netherlands has increased. Programs, guide lines and tests to stimulate schools and teachers to develop science activities were introduced and implemented. De Nieuwe Kring, a Jenaplan school in Diemen, was one of the schools looking for possibilities to introduce more science into their curriculum. Some of the teachers already participated in another science related research project, but they expressed a desire to do more.

In conversation with the school, it was decided that the participating teachers would like to have more inquiry-based science lessons. From the conversation with the school it was clear the teachers felt inexperienced and unprepared to develop science lessons themselves. Therefore, they asked me to do it for them. The materials would be developed in close cooperation with teachers and they were prepared to test and evaluate them during the developmental process. To choose a focus for this project, they requested that attention was given to kindergarten and grades 1&2 (age range 4 – 8), instead of the higher primary levels. According to the teachers it was hardest for them to envision what they could do with younger children, because you cannot pick lessons from books or the internet (they cannot, or hardly, read yet). The main objective that would be reached in teaching this younger age group is to create enthusiasm for and arouse interest in science in the children. The objective towards the teachers was to give them an easy-to-use, low-maintenance and inspiring science kit.

1.2 Aims and research questions

The purpose of this study is to report on the development of the lesson series about mirrors and the implementation of this lesson series. The aims are therefore:
1. To develop a lesson series based on inquiry-based learning, aimed at Kindergarten and grades 1&2;

2. To monitor the implementation of the developed lesson series.

These aims are made explicit in the research questions in chapter 3.

1.3 Structure of the thesis

To reach the aim of designing a science module, relevant background literature was studied to provide a theoretical framework. This is presented in chapter 2. The research questions are stated in chapter 3, as is the design framework and more specific design requirements. In chapter 4 the developed materials are described and discussed. Chapter 5 continues with the results from the first round of evaluations, in the form of observational reports and interviews with teachers and students. Some post-experimenting was done to explore what the effect of the learning materials was on the students, the set-up and results of this are in chapter 6. Chapter 7 contains the conclusions and discussion. The research questions are answered and limitations to and problems with the research are discussed.
2. Theoretical framework

In this chapter, I will look at the theoretical background of my design framework. It provides a background to the situation in which I develop my lesson series, and I explore what primary science entails and what kind of learning is suited to fulfill my design requirements. I focus on works written by Dutch authors, because they describe the subject in the framework of Dutch education, which is the most relevant for this design\(^1\).

2.1 What is primary science?

2.1.1 Definition and content of primary science

In The Netherlands primary science is called “wetenschap & techniek\(^2\)” (W&T), including not only biology, physics and a little chemistry, but also technology. Van Graft & Kemmers (2007) mention that generally speaking one can say that science (wetenschap) is about trying to understand the world, and technology (techniek) is about trying to manipulate the world. They caution that this view is oversimplified and explain that many aspects of these two are intertwined. The common thread can be found in more abstract notions that cover the whole of W&T (science & technology), such as the concepts “unity and diversity”. According to De Vaan & Marell (2006) primary science should cover recognizable subjects from the environment of the students. It is “knowledge of nature”, but also about how to investigate nature, care for nature and see patterns and structures between elements of nature.

According to Van Keulen (2010) W&T is first and foremost an attitude towards the world around you: curiosity, wanting to understand, wanting to improve, etc. Furthermore, he mentions that W&T is a search for answers, knowledge and knowledge building. He defines it more as a process than a body of knowledge one must learn or understand. He fills in what the content that is taught should be in a description of the field (domeinbeschrijving), in which context plays an important part. He shows that basically all W&T is present in the lives of the students. These are the contexts that give children meaningful experiences, which are also relevant to society as a whole. Themes he identifies in the

\(^1\) All translations from Dutch were made by the author of this study. Often the Dutch wording is also included to provide the opportunity to the reader to check the translation. There is always something lost in translation, but the core meaning of the words is hopefully still present.

\(^2\) In the past, this field was called “natuur & techniek”. The phrase is still in use. The content of “natuur & techniek” and “wetenschap & techniek” is the same.
contexts are for example “Living”, “Energy-use”, “Clothing”, “Sports”, “Music” and “Water and Water Management”.

Science is about trying to understand the world. In the context of primary science this means that students learn knowledge and skills that are useful to that purpose. In the past this field was also called “nature” in The Netherlands, but this brings the association of the biological sciences (plants, animals), while the field also contains physics, chemistry and earth sciences (this last field is not very prominent in Dutch primary science). De Vaan & Marell (2006) argue that the learning materials in W&T should give students an awareness of the influence of phenomena in and laws of nature on our existence. They define the central goal of primary science as: “Science is aimed at giving children insight into the relations within the material reality, with whom the lives of people are inextricably connected.” ("Natuuronderwijs is erop gericht kinderen zicht te geven op samenhangen in de materiële werkelijkheid, waarmee het leven van mensen onlosmakelijk is verbonden.") With this the students develop an attitude towards science. This ties in with Van Keulen (2010), who defines W&T as an attitude as well. De Vaan & Marell distinguish five areas of attention (aandachtsgebieden) within science:

- **Living organisms:**
  - **own body** composition, growth, functions, senses, organs, reproduction
  - **animals** species, food, behavior, way of living, movement, appearance, senses, etc.
  - **plants** composition, function of parts, growth, reproduction, function in environment, etc.
- **Environment** waste, occupations, constructions, sky, earth and use of the earth, change, etc.
- **Weather and seasons** seasonal phenomena, rain, wind, temperature, clouds, sun, climate, etc.
- **Materials and objects** characteristic features, shape and function, structure, etc.
- **Phenomena in science and technology** force, movement, electricity, magnetism, light, sound, warmth, etc.

They have derived this from the project group NatuurOnderwijs op de Basisschool (pgNOB) of the Stichting Leerplanontwikkeling (SLO). Technology is also more or less included.

The meaning of the word technology is dependent on the context in which it is used. In general, technology as it is used in the primary school curriculum is about controlling and manipulating nature. Bouwmeester et al. (2006) follows the description of De Vries (1986), in which this is specified in five elements:

a. “Technology is an activity of, for and by people. In technology needs and values of people play an important part.”

b. “Technology is a process of designing, producing and using products.”

c. “Technology works with materials, energy and information.”

d. “In technology natural science knowledge is used.”

e. “Technology influences society and is influenced by it.”

In the second element “designing” is mentioned, which has a role in inquiry-based learning (see
De Vaan & Marell (2006) agree mostly with the description of Bouwmeester. Their definition contains: a. Work of people (humans); b. Technology concerns materials, energy and information; c. Designing, making and using; d. Technology and science influence each other; and e. Technology and society influence each other. A subtle difference can be seen in argument d, where De Vaan & Marell say technology and science influence each other, while Bouwmeester defines the influence only in one direction, namely from science influencing technology. In Natuuronderwijs Inzichtelijk Haarhuis & Kersbergen say technology is often associated with difficult machines, like computers and rockets. But a book, scissors or a chair are also examples of technology. Making and exploring everyday objects brings technology closer to the world of the students.

The field of technology in primary school is often divided in four domains:

- Construction
- Transportation
- Information/communication
- Production

These are for example described in Bouwmeester et al. (2006), Slangen (2008) and Haarhuis & Kersbergen (2010). Below are very short descriptions of the domains, with some important associated concepts mentioned.

**Construction** is about making a spatial structure, for example for living, working or infrastructure. All constructions are a combination of shapes, materials and connections. There are static (fixed) constructions and dynamic constructions. Often one sees combinations of those two, for example, the walls of a house are static, but the windows and doors are dynamic. Strong, solid and stable connections are necessary for constructions. Examples of strong constructions are triangles, arches and profiles.

**Transportation** is aimed at moving people, goods and energy from one place to another. This can be over land, water or through the air and space. The transportation of information is part of the domain of communication. To transport something one needs energy of some form.

The domain of **information and/or communication** is about the exchange of thoughts and information. This can be done directly or indirectly. Indirectly is done for example with a communication between two pieces of equipment. Examples are security systems and traffic control systems. Sensors play an important role in this type of communication.

**Production** is about producing consumer goods and other goods. Material sources are converted into industrial half fabricates, which are converted into consumer goods. This can be done manually, with machines or automatically.

### 2.1.2 Kerndoelen or “core objectives”

The Dutch government has formulated 58 "Kerndoelen" (Core Objectives) for primary schools
(Herziene Kerndoelen, 2006). These are the minimal requirements students have to fulfill according to the Dutch government during their stay at primary school. There are seven Kerndoelen for the domain of Science & Technology (Natuur & Techniek), shown in Figure 1. There are two kerndoelen about biological concepts, three about physical concepts and two about technology. Earth sciences and chemistry are not mentioned, but in these are other kerndoelen that cover geography and some earth science is detectable there (volcanoes for example). There is also a kerndoel that says “students

Figure 1: Kerndoelen Natuur en Techniek or Core objectives science and technology, numbered 40 to 46. Above the Dutch version, below my translation in English. (Source: TULE, SLO)

<table>
<thead>
<tr>
<th>Kerndoelen</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-</td>
<td>De leerlingen leren in de eigen omgeving veel voorkomende planten en dieren onderscheiden en benoemen en leren hoe ze functioneren in hun leefomgeving.</td>
</tr>
<tr>
<td>41-</td>
<td>De leerlingen leren over de bouw van planten, dieren en mensen en over de vorm en functie van hun onderdelen.</td>
</tr>
<tr>
<td>42-</td>
<td>De leerlingen leren onderzoek doen aan materialen en natuurkundige verschijnselen, zoals licht, geluid, elektriciteit, kracht, magnetisme en temperatuur.</td>
</tr>
<tr>
<td>43-</td>
<td>De leerlingen leren hoe je weer en klimaat kunt beschrijven met behulp van temperatuur, neerslag en wind.</td>
</tr>
<tr>
<td>44-</td>
<td>De leerlingen leren bij producten uit hun eigen omgeving relaties te leggen tussen de werking, de vorm en het materiaalgebruik.</td>
</tr>
<tr>
<td>45-</td>
<td>De leerlingen leren oplossingen voor technische problemen te ontwerpen, deze uit te voeren en te evalueren.</td>
</tr>
<tr>
<td>46-</td>
<td>De leerlingen leren dat de positie van de aarde ten opzichte van de zon leidt tot natuurverschijnselen, zoals seizoenen en dag-/nachtritme.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kerndoelen</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-</td>
<td>The students learn to distinguish and identify common plants and animals and learn how they function in their environment.</td>
</tr>
<tr>
<td>41-</td>
<td>The students learn about the construction of plants, animals and people and about the shape and function of their parts.</td>
</tr>
<tr>
<td>42-</td>
<td>The students learn to investigate materials and physical phenomena, like light, sound, electricity, power, magnetism and temperature.</td>
</tr>
<tr>
<td>43-</td>
<td>The students learn how to describe weather and climate with the help of temperature, rain and wind.</td>
</tr>
<tr>
<td>44-</td>
<td>The students learn to make associations between the working, the shape and the materials of products from their environment</td>
</tr>
<tr>
<td>45-</td>
<td>The students learn to design, execute and evaluate solutions for technical problems.</td>
</tr>
<tr>
<td>46-</td>
<td>The students learn that the position of the earth in comparison to the sun leads to natural phenomena, like the seasons and day/night rhythm.</td>
</tr>
</tbody>
</table>
learn to take care of the environment” (“De leerlingen leren met zorg om te gaan met het milieu”), which is relevant for both biology and earth science.

Apart from these kerndoelen, there is no definitive curriculum for primary science in the Netherlands, which also means there are no curriculum goals, especially not for preschool. Bouwmeester (2006) indicates that there is no legal indication how much time is spent on the different domains. Every school has the freedom to make its own choices. The core objectives are criticized. For example, Van Keulen (2009) describes them as very broadly defined and formulated very generally. The teacher has little support and they are also hard to fit into a pupil tracking system (leerlingvolgsysteem1).

2.1.3 Learning trajectories or leerlijnen

To work with the kerndoelen (core objectives) schools have to design or implement a learning trajectory or leerlijn. In a learning trajectory objectives are formulated for various stages of the learning process (tussendoelen). For example, in the learning trajectory is formulated what the students should do and know for core objective 43 in Kindergarten, in grade 1, in grade 2 etc. This gives schools the support to fill in their lesson plans. As was stated in the last paragraph, schools have complete freedom in how they want to do this, but to give some support learning trajectories have been developed by institutions and publishers.

<table>
<thead>
<tr>
<th>groep 1 en 2</th>
<th>groep 3 en 4</th>
<th>groep 5 en 6</th>
<th>groep 7 en 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>- onderscheiden licht en donker</td>
<td>als groep 1/2 +</td>
<td>als groep 3/4 +</td>
<td>als groep 5/6 +</td>
</tr>
<tr>
<td>- onderscheiden donker en schaduw</td>
<td>licht is afkomstig van bronnen</td>
<td>licht wordt teruggeklaard en/of doorgelaten</td>
<td>licht plant zich rechtstreeks voort</td>
</tr>
<tr>
<td>- distinguish light and dark</td>
<td>- licht wordt teruggeklaard en/of doorgelaten</td>
<td>- licht wordt gebroken</td>
<td></td>
</tr>
<tr>
<td>as Kindergarten +</td>
<td>as grades 1&amp;2 +</td>
<td>as grades 3 &amp; 4 +</td>
<td></td>
</tr>
<tr>
<td>- distinguish darkness from shadow</td>
<td>- light comes from sources</td>
<td>- light propagates linearly</td>
<td></td>
</tr>
<tr>
<td>- light can be reflected and/or passed through</td>
<td>- light splits into colors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- light refracts</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: Learning trajectory for subdomain “light” in core objective (kerndoel) 42. In the top row it says “Kindergarten” (groep 1 en 2), “grades 1 and 2” (groep 3 en 4), “grades 3 and 4” (groep 5 en 6), “grades 5 and 6” (groep 7 en 8). In the bottom row the concepts that are suitable to cover in the different grades are described. Below the frame a translation is given.

1 In a leerlingvolgsysteem or pupil tracking system, the progress of students is monitored. For example, every six months, the results of the students are written down and analyzed. This also provides future teachers with a record of prior performance, making it possible to follow a(n) (individual) learning trajectory. It is also used to spot possible stagnation in progress and provide subsequent help. Tracking can be done in reading, writing, math etc., but also in emotional welfare and social development.
An example is the learning trajectory of Stichting Leerlingplan Ontwikkeling (SLO), which is called TULE. In Figure 2 a piece of this learning trajectory is shown. This is the part of the curriculum for the subject of light, which is present in kerndoel 42.

Another option for schools is to adopt a method from a publisher. The last couple of years many new methods for primary science have been developed by several publishers, for example Natuniek (ThiemeMeulenhoff, 2007-2008) and Naut (Malmberg, 2008).

Internationally, there have been curricula developed with more specific learning trajectories than the Dutch curricula. An example is the British National Curriculum (1999). General aims are formulated for the entire curriculum, very similar to the Dutch kerndoelen, but an additional curriculum is developed in which the aims are worked out for four key stages or age groups.

### 2.2 Situation of primary science in the Netherlands

#### 2.2.1 Overview

In the Netherlands there is little history of large investments for developing a national primary science program. Only in the last couple of years have efforts been made to implement W&T (science and technology) in the primary school curriculum. New ‘core objectives’ (kerndoelen) have been formulated for primary schools, including a few for W&T, as was just described. This does not necessarily mean that all schools and students achieve all core objectives. The multiple choice CITO exam (CITO toets), which all students take in the final grade of primary school only tests for language and math. There is an optional test for “world orientation” (wereldoriëntatie), which contains a little of the W&T field.

In Natuurwetenschappen en techniek basisonderwijs (Van den Berg, 2003) the following is mentioned:

<table>
<thead>
<tr>
<th>In Dutch education for 4-12 year olds there is relatively little attention for the aims and skills in the domain of science and technology. This is very well explainable if we look at:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The background and interest of most primary teachers;</td>
</tr>
<tr>
<td>• Which aims students are tested on at the end of primary education (testing of science and technology is not obligatory);</td>
</tr>
</tbody>
</table>
The lack of tradition and of infrastructure of schools in this domain;  
- The low priority of nature and technology at the pabo

The number of science graduates in The Netherlands is low compared to other European countries, as can be seen in Figure 3. To remedy this, new programs were set in motion. In 2004 the Dutch government gave the assignment to bring about 15% more science graduates by 2010 to the Platform Bèta Techniek. In 2010 a growth of 32% was realized (Platform Bèta Techniek, 2011). The total number is still low compared to the other European countries, but going up. In the years 2004-2010, investments were made in both primary education and in secondary and higher education. For 2011-2016 a new program is being developed. The status of this project is currently uncertain because the government has changed and due to the economic crisis budget cuts have to be made. The goal of the new program is presented in the document “Master plan: Room for Talent, Room for Science and Technology” (2009). The focus appears to have shifted from W&T to “talent development” (talentontwikkeling) in W&T and in particular “excellence” (excellentie). The vision for the next few years described in the Masterplan is that all children should develop their talents and that all children have talents. They are curious about the world around them and this should be used in their development. Mentioned is also that children are the future (“the capitol of the future”), so we should invest in them. What this means form the

![Number of Science & Technology graduates per 1000 population, aged 20-34 in 2000](image)

Figure 3: The number of Science & Technology graduates in The Netherlands is far below the European average.  
(Source: Education at a Glance, OECD Indicators, OESO)

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1 In The Netherlands, a pabo is a pedagogical institute where primary teachers are trained.

2 Masterplan: Ruimte voor Talent, Ruimte voor Wetenschap en Techniek
primary schools in The Netherlands is still unclear.

### 2.2.2 Present situation in schools

In 2002 the situation of primary physics and technology education in The Netherlands was studied by the Citogroep (Thijssen et al., 2002). They conclude that physics is taught by less than half the primary teachers in grades 4, 5 and 6. The authors think it likely it was unclear to the teachers what exactly the researchers meant when they asked for their teaching of “physics”, so the result might be inflated. Technology has an easier meaning for primary teachers to understand and Thijssen et al. conclude that only 12% of teachers in grade 6 and 4% of teacher in grades 4 and 5 teach technology with any regularity. Van Keulen (2009) says in 2007 it again was found that only half of primary school children received any W&T education. In 2008 the Onderwijsinspectie\(^1\) concluded that only 13% of the primary schools fulfills the government targets for sufficient technology education. Van Keulen (2009) mentions several reasons why it proves difficult to implement W&T. Firstly, schools are afraid there will not be enough attention left for the basic skills like spelling and math and they have the idea the government burdens them with this social problem in society. Schools also do not have the opportunities and capabilities to develop their W&T curriculum in a coherent and meaningful way. Apart from that are teachers not always automatically interested in W&T. Perhaps a cause for that last problem can also be found in the fact that the vast majority of primary school teachers is female (more than 82% of primary school teachers was female in 2005 and the number goes up every year (OESO report, 2003). Among kindergarten teachers less than 2% is male (NRC Handelsblad, 16-02-2008). It is not unreasonable to assume female teachers are less interested and less comfortable with science than male teachers, since there is a lack of women in the entire science field (Damsma, 2011).

In a study which compared schools involved in the VTB program, which means they got resources for primary science and technology (46-48 teachers), and non-VTB schools (32-49 teachers) it was found that in both types of schools there were a large amount of problems in teaching W&T (Van Weerden, Thijssen & Verhelst, 2003). 60% of VTB-school teachers and 80% of non-VTB school teachers said that materials were too expensive, 47% of VTB teachers and 69% of non-VTB teachers said their schools did not have enough materials available. Over half of the teachers also say that the school curriculum is too overloaded to find enough time for W&T and over half also mentions that their school does not have a suitable space to give the lessons. In this study, not many teachers mentioned that they do not have enough knowledge and expertise. Possibly this is because the study cohort is not representative of the whole population of primary teachers; however, the study does not give any further information on this. In Thijssen et al. (2002) teachers also mention the lack of materials, the cost of materials and the available space as large obstacles to teaching physics and technology. Too little time

\(^1\) The Onderwijsinspectie is the Dutch government institution that supervises and monitors the quality of Dutch education.
in the overloaded curriculum is seen as a problem as well. In this case, only about 10% say they often lack the knowledge and expertise to teach physics, with 40-50% saying this happens sometimes. (This is the same study though, where the authors doubt the teachers really know what physics is that was cited above.) In addition, 17-26% of the teachers say they often lack the knowledge and expertise to teach technology, with 40-50% saying this happens sometimes. This is surprisingly low, especially for physics, especially given that so few schools teach W&T and have W&T programs in the first place. It is also against the experiences of experts like Van Keulen, who indicates the lack of science background in teachers as a major reason for the lack of W&T in primary Dutch education. It would be interesting to study the real expertise of primary teachers in this area, instead of self-assessment and an estimation from experts.

2.3 Inquiry-based learning

2.3.1 General definition

In the last couple of years, efforts have been made to implement W&T in primary schools in The Netherlands. The didactical approach of inquiry-based learning (onderzoekend & ontwerpend leren) has become popular to model W&T lessons. Inquiry-based learning in essence uses the student-generated questions as a strategy for teaching. Students mimic the scientific process to better understand the content (Van Graft & Kemmers, 2007; De Vaan & Marell, 2006). The role of the teacher is to help students do an experiment based on students’ own questions. Children are usually curious and ask questions about the world around them, so this is a natural process. The National Science Foundation (2000) describes inquiry as:

“...an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding. Inquiry, as it relates to science education, should mirror as closely as possible the enterprise of doing real science. The inquiry process is driven by one’s own curiosity, wonder, interest, or passion to understand an observation or solve a problem.”

The idea of inquiry-based learning is not new. In the 1960’s many inquiry-based science programs were developed, for example Science - A process Approach (Gagne, 1966) in the USA and Nuffield Junior Science (Wastnedge, 1967) in the UK. These programs emphasized the nature and process of science. Students also learn to think for themselves and find their own solutions to problems. Skills like reasoning and critical thinking are important. The Dutch term for inquiry-based learning includes the word “onderzoeken”, but also “ontwerpen”. “Onderzoeken” is most directly related to “inquiry”, it means something like investigating or researching. This ties in with the “science” or “wetenschap” part of the curriculum. The addition of “ontwerpen” is linked to the “technology” or “techniek” part
of the curriculum. “Ontwerpen” means designing. In the design process, problems are solved by carefully studying the problem, designing a solution, testing that solution and (re-)evaluate your solution.

The inquiry-based way of working with students is not always easy for teachers. Often inquiry-based is interpreted as “hands-on” science, meaning working with concrete materials. Hands-on does not always mean inquiry. Rankin remarks: “All hands-on is not inquiry; not all inquiry is hands-on” (Rankin, 2000). Van Graft & Kemmers say that hands-on work is a condition for inquiry-based learning when it comes to science; they feel that the students have to work with concrete materials always. Huber (2001) also writes about this:

Unfortunately, hands-on activities recommended by many science textbooks and worksheets are typically presented as step-by-step instruction. As discussed in the National Science Education Standards (Standards; National Research Council, 1996), when science teachers move beyond worksheets and step-by-step procedures in order to engage student in inquiry, they must constantly struggle to guide student inquiry toward curriculum goals. As pointed out by Crawford (1999), this ongoing demand for improvisation during teaching can be expected to create a substantial stumbling block for novice science teachers.

Van Graft & Kemmers emphasize that “onderzoekend & ontwerpend leren” is not the same as learning to “onderzoeken & ontwerpen”. In the latter case students learn how to set up an experiment or design something, it is about the process. In inquiry-based learning or onderzoekend & ontwerpend leren the students learn about something through the process of inquiry or onderzoeken. Inquiry is the means to an end. Van Graft & Kemmers formulate the primary goal of inquiry-based learning as follows:

“The primary goal of inquiry-based learning is to stimulate and develop a scientific attitude. In comparison to nature and technology education as it is given at most primary schools at the moment working from methods, the added value of inquiry-based learning is that there are more possibilities for the broad development of children, including concept development in the nature and technology domain.”

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1 Original text in Dutch: “Het primaire doel van onderzoekend en ontwerpend leren (OOL) is om de wetenschappelijke houding van kinderen te stimuleren en te ontwikkelen. Ten opzichte van het natuur- en techniekonderwijs, zoals dat momenteel op de meeste basisscholen, werkend vanuit natuuronderwijsmethoden (met daarin opgenomen enkele technieklessen), is de meerwaarde van OOL dat er meer mogelijkheden zijn voor de brede ontwikkeling van kinderen, inclusief conceptontwikkeling op het gebied van natuur en techniek.”
Van Keulen (2009b) has listed the conditions in which “good” W&T education takes place. He mentions in that list a systematic attention to the development of skills from the empirical inquiry cycle and design cycle and a didactical approach which is not dependent on worksheets and direct instruction, but is based on questions, which are continued in specified goals and demands. The teacher is a coach; he or she monitors the progress and makes learning experiences explicit.

Especially in the US several projects have been carried out to develop inquiry-based materials. Examples are the FOSS materials, developed by the Lawrence Hall of Science in Berely, the STC materials from the National Science Resources Center and the INSIGHTS curriculum from the Education Development Center. INSIGHTS was the model for a French project ‘La main à la pâte’. STC was the model for a Swedish project called NTA (Van Graft & Kemmers, 2007). In the Netherlands there has also been a development project on inquiry-based learning, by the aforementioned Van Graft & Kemmers, but on a much smaller scale. Some methods developed by Dutch publishers claim to use the didactical approach of inquiry-based learning, like Natuniek (2007-2008), but they do not explain how they have done this.

![Figure 4: Overview of various inquiry cycles from the literature, gathered by Van Graft & Kemmers. The one on the right they developed themselves. It is explained further in Figure 5. The second one on the right is the model of De Vaan & Marell. Their steps translate as: 1. Introduction/confrontation; 2. free exploration; 3. experimental phase (doing research); 4. communicating the results; 5. broadening or deepening. (Source: Onderzoekend en Ontwerpend Leren bij Natuur en Techniek, 2007)]
2.3.2 Inquiry cycles

To implement inquiry-based learning, inquiry cycles have been developed. An inquiry cycle gives a model to facilitate the teacher in setting up inquiry in the classroom. Van Graft & Kemmers studied four inquiry cycles, shown in figure 4. As they explain, the left one is the Inquiry Training Model from the American educational psychologist Robert Suchman, developed in 1963; the second one on the left is the inquiry cycle from Douglas LLewelyn, developed in 2002; and the third one is developed by the people behind the American INSIGHTS program, in 2004. In *Praktische Didactiek voor Natuuronderwijs* (De Vaan & Marell, 2006) another possible structure for science lessons is suggested. This book does not use the word inquiry cycle or anything similar, but Van Graft & Kemmers have interpreted as one in their work. It is De Vaan & Marell’s model is the second cycle on the right in Figure 4.

An inquiry cycle can be used for different purposes. Some are worked through in one lesson (one activity), others in multiple lessons with different kinds of activities. The general idea is though, that you go through the same kind of cycle scientists go through when doing scientific research, so the learning cycle is repeated a number of times. The emphasis is on different steps in the process for different authors. The National Science Teachers Association (2004) from the US notes “that there is no fixed sequence of steps that all scientific investigations follow.”

Van Graft & Kemmers claim that the parts of the inquiry cycles seem chosen rather arbitrarily by the authors and designers and on this basis they made their own inquiry cycle, which consists of seven phases. It is further explained in Figure 5.
2.3.3 Observations of inquiry-based learning based on Van Graft & Kemmers

Van Graft & Kemmers developed several science modules based on their inquiry cycle. I observed approximately 15 lessons taught by 5 teachers from this project. In practice, the lesson materials developed by Van Graft & Kemmers put a very heavy emphasis on the setting up of the experiment: children have to formulate a research question and carefully construct a fair measurement set-up. Their target group was grades 1&2 and grades 3&4. For grades 3&4 the formulating of questions was hard, but after some encouragement they were able to come up with a good experiment.
The children in grades 1&2 already have trouble formulating a question in general, let alone to formulate one that is suitable for an experiment. Of course, some children were able to come up with good things and all experiments were great successes in the end, but it put a big strain on the teachers to get the children in the right frame of mind. Also, these children were very young to really record their data in a systematized way. It felt rather forced to ask the children to conduct a research project like a scientist, while at the same time they got little time for the exploration of the subject (Damsma, 2010).

Van Graft & Kemmers do mention that this approach with a full inquiry cycle is not possible in Kindergarten. Gagné (1963) also notes: “There is nothing wrong with practicing enquiry, and surely enquiry is the kind of capability we want students of science to attain in some terminal sense. But practicing enquiry too soon, and without a suitable background of knowledge, can have a narrowing and cramping effect on the individual’s development of independent thinking.” For the youngest primary students, it would be more suitable to emphasize free exploration, instead of the proper procedure of doing experiments. (See section 2.5 for more on science and young children.)

2.3.4 Design cycles

As was mentioned before, designing is the didactical approach for technology education. In the US, design is also a prominent feature in the K-12 technology program (International Technology Education Association, 2007). Long before that, it was already in the curriculum in the UK. It was added to Craft Design Technology (CDT) phase of the study program after 1975 (Wright, 1993). It is now in the new field of Design and Technology in the National Curriculum. The International Technology Education Association (2007) describes design as follows:

“The development of a technology begins as a desire to meet a need or want. These needs or wants could belong to a single inventor or be shared by millions of people. Once needs or wants have been identified, the designer must determine how to satisfy or solve them. The modern engineering profession has a number of well developed methods for discovering such solutions, all of which share common traits. First, the designers set out to meet certain design criteria, in essence, what the design is supposed to do. Second, the designers must work under certain constraints, such as time, money, and resources. Finally, the procedures or steps of the design process are iterative and can be performed in different sequences, depending upon the details of the design problem. Once designers develop a solution, they test it to discover its shortcomings, and then redesign it – over and over again.”

Design is also mentioned in the Dutch kerndoelen, namely in kerndoel 45: “The students learn to design, execute and evaluate solutions for technical problems.”
Van Graft & Kemmers (2007) have developed a design cycle, which has many similarities to their inquiry cycle. It also has seven phases:

1. Probleem constateren; 1. Indentifying problem;
2. Verkennen; 2. Exploring;
3. Ontwerpvoorstel maken; 3. Make design proposal;
4. Uitvoeren; 4. Executing;
5. Testen en evalueren; 5. Testing and evaluating;

The design cycle follows the description of the International Technology Education Association fairly well. It is also called a cycle, because you can start again at the beginning or hop in somewhere in the middle if your design has its shortcomings and you want to redesign it, just the ITEA mentions.

Another design cycle was developed by the state of Massachusetts (Massachusetts Department of Education, 2001) for their Science and Technology/Engineering Curriculum Framework. It consists of eight steps, which are:

1. Identify the need or problem.
2. Research the need or problem.
3. Develop possible solution(s).
4. Select the best possible solution(s).
5. Construct a prototype.
6. Test and evaluate the solution(s).
7. Communicate the solution(s).
8. Redesign.

This model is close to the design cycle of Van Graft & Kemmers. The Massachusetts cycle emphasizes the possibility of multiple solutions, from which the students have to pick the best one.

2.3.5 Inquiry skills

In the last section, an overview of the skills coming into play in the various stages of the inquiry cycle were discussed. To see what inquiry skills are relevant for the development of a specific science module, one would have to look at a learning trajectory for inquiry.

Inquiry is mentioned in the objectives for Dutch primary education, but it is not specified what it is. Kerndoel 42 says: “The students learn to investigate materials and physical phenomena, like light, sound, electricity, power, magnetism and temperature.” Kerndoel 45 is: “The students learn to design, execute and evaluate solutions for technical problems.” These clearly state that the students
should both investigate and design, so they refer to inquiry-based learning. There are no specific inquiry skills mentioned though. However, in the English curriculum, inquiry skills are prominent in both the aims and the learning trajectory. Figures 6 and 7 show the inquiry part of the curriculum for Key Stage 1 (5 to 6 years old, comparable to the Dutch groups 1 and 2) and Key Stage 2 (ages 7 to 11, comparable to the Dutch groups 3 to 6). These are the relevant for this study, because the target group is the same. It should also be noted that Van Graft & Kemmers later added to their learning cycle a learning trajectory for inquiry and designing. The trajectories can be found in the appendix of their LOOL Basisdocument. They also define the skills for Kindergarten, while in the document itself they mention that their inquiry cycle is not suitable for that age group. The relevant parts (Kindergarten and grades 1 & 2) are translated and shown in Figure 8.

There is no complete overlap between grades 1 and 2 in The Netherlands and Key Stage 2 in the UK, but it is comparable. The English standards are mostly practical and aimed at teaching the students to set up experiments, use tools and use methods. It can be closely related to an inquiry cycle. Van Graft & Kemmers have many of the same features (for example using the senses in Kindergarten, asking questions, comparing, pattern recognition), but they also identify a few more abstract notions, like “realize that something has intent instead of a cause” (“inzien dat iets bedoeling heeft i.p.v. oorzaak”), which can be related to the process of science, but needs to be translated by the teacher in what he or she should do with the children.

Additionally, the English National Curriculum comes with evaluation instruments for in-school assessment. With the instruments teachers can track their students’ progress. In science they have chosen only to assess scientific skills, not content (the content is described in the curriculum and the program of study though).

In the Assessing Pupils’ Progress: Science Assessment criteria (Department of Education, 2009) matrix, eight levels of student progress are defined within Key Stages 1 to 4. Every level consists of a number of criteria teachers can use to evaluate their students. These criteria are divided in five larger categories, which are:

a. Thinking scientifically;
b. Understanding the applications and implications of science;
c. Communicating and collaborating in science;
d. Using investigative approaches;
e. Working critically with evidence.

The criteria are very detailed and concrete. A possible problem could be that a teacher needs experience and expertise to use the criteria in a meaningful way, because it is not easy to judge a student’s level.
Figure 6: Inquiry skills in the English National Curriculum for Key Stage 2, ages 7-11 years old (Source: National Curriculum of England: Science, 1999)

Figure 7: Inquiry skills in the English National Curriculum for Key Stage 1, ages 5-6 years old (Source: National Curriculum of England: Science, 1999)

Figure 8: Inquiry learning trajectories for Kindergarten and grades 1 and 2 from Van Graft & Kemmers (2007). Left: the original wording; below: translation to English.
2.4 The Reggio Emilia Approach

Inquiry cycles do not seem to be suitable for the younger children to work with (Van Graft & Kemmers, 2007). To expect them to generate their own questions and set up an experiment based on those questions is too much. However, the teachers of the Nieuwe Kring that were involved in this study mentioned the Reggio Emilia Approach as something they were interested in and they thought it was close to inquiry-based learning in many ways.

After WWII the parents of the villages around the Italian city Reggio Emilia decided to set-up a new kind of school. After 40 years, their method of teaching is now called the Reggio Emilia Approach. The educators refuse to call it a model, because they say it is ever-changing and they are still learning. According to this approach, children must have direction over their learning. In classrooms teachers

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1 In overview E a list of art skills connected to science is given. The word “boetseren” is translated as “shape”, but the word “boetseren” is mostly used in the context of shaping clay.
see what the children are doing and talking about and adapt the program to what the children are fascinated by at that moment (real life problem solving). These are often long-term projects, in which the children get every opportunity to explore. In this, it has the same initial approach as inquiry-based learning, where student-generated questions are central. In Reggio Emilia, the learning environment is made with all senses in mind: touching, feeling, tasting, hearing etc. The children get different ways of expressing themselves (drawing, sculpting, writing etc.). The close relationship the children have with their environment is central to the method. The parents are also very important. The method was set up by parents and they still play an important role in the school. Usually, the Reggio Emilia approach is taken home and also incorporated in the home environment. In the United States this model has been adopted by many preschools and primary schools (Edwards, Gandini & Forman, 1998).

2.5 The young child

2.5.1 Development of young children

The materials to be developed for the Nieuwe Kring teachers are to be suitable for children aged four to seven years old. The French psychologist Jean Piaget has extensively studied the way young children view and interact with their environment. He concluded that younger children do not see the world as an adult would (Piaget, 1964; Piaget, 1969). According to Piaget, there are four stages in the cognitive development of children, which are occurring always in this order:

1. **Sensori-motor stage (approximately the first 18 months of life)**
   In this stage the structures for later representational thought are developed. The child learns to differentiate between himself and objects and it realizes it can act on them intentionally. The child does not have an idea of permanence yet. Piaget (1964): “When [an object] disappears from the perceptual field it no longer exists. No attempt is made to find it again.” It has achieved the idea of object permanence at the end of this stage.

2. **Pre-operational stage (approximately 18 months until 7 years old)**
   “The beginnings of language, of the symbolic function, and therefore of thought” are developed. The thinking is still egocentric, the child has difficulty placing himself in other viewpoints. It can classify objects based on one feature. The first fundamental operations of elementary mathematics, geometry and physics appear.

3. **Concrete operational stage (approximately 7 years until 11 years old)**
   The child achieves conservation of number (by age 6), mass (by age 7) and weight (by age 9). He
can classify objects based on several features and can put them in series, for example in size. He can think logically about objects and events.

4. **Formal operational stage (older than 11 years old)**

The child can now think logically about abstract propositions. He can test hypotheses systematically. He becomes concerned about the future and ideological problems.

Piaget bases his work on case studies, where he interviewed children and generalized the results of those interviews in a theory. In the past 50 years, others have found that there are some nuances to his findings. For example, Berthenthal (1996) and Wellman et al. (1986) showed that children that were three and four months old expect objects to continue to exist when they are out of view, much younger than Piaget thought. Gopnik, Sobel, Schulz & Glymour (2001) conclude that from their experiment it is clear that 3- and 4-year olds use causal relationships when reasoning. The relevance of Piaget’s theory for teaching lies more in the realization that children do not always think like adults and sometimes do not have the brain structure yet to understand a concept. The conservation of mass is central to a lot of science concepts, but is not present in most children younger than 6 years old. However, the concept does not have to be taught directly in the curriculum, because all children realize conservation of mass by the time they are 6 or 7 by themselves. Another example of a restriction in teaching is classifying. Classifying objects is something younger children can only do by using one feature; only later do they develop the ability to put them in several categories and put objects in series. Piaget points to four general factors in the mechanism of the development from one stage to the next: 1. Maturation; 2. Experience or exercise; 3. Social interaction and transmission; and 4. The need to construct in a certain order: it is a “gradual evolution in which each innovation is dependent upon the previous one” (Piaget, 1969).

A consequence of the developmental process for inquiry-based learning is that children cannot conduct research until they are in a certain stage. In Piaget’s theory, this is not until they are 11 years old, when they come into the formal operational stage. Before that, they do not have the mental structure to conduct research. They cannot control variables or manipulate them. They can also not draw conclusions on the variables’ effect. Children in lower stages, according to Piaget, can isolate some variables and manipulate several, but they draw conclusions about only one. Other researchers have shown though, that children are more capable of doing research than Piaget believed. Sodian, Zaitchik & Carey (1991) showed that children can differentiate between hypothetical beliefs and evidence. They found that first and second graders can correctly identify an experiment to choose between two hypotheses. The first and second graders also “spontaneously generated empirical procedures for gathering indirect evidence to decide between alternative hypotheses”. This means that with some guidance it does seem possible to let children conduct their own experiments from grade 1 and up.
Piaget has made statements about the role of the teacher, and then comes close to describing inquiry-based learning. He said: “In our view, the role of the teacher remains essential but very difficult to gauge: it consists essentially in arousing the child’s curiosity and in stimulating the child’s research. It accomplishes this by encouraging the child to set his or her own problems, and not by thrusting problems upon the child or dictating solutions. Above all, the adult must continually find fresh ways to stimulate the child’s activity and be prepared to vary his or her approach as the child raises new questions or imagines new solutions. In particular, when these solutions are false or incomplete, the role of the teacher will consist primarily in devising counter examples or control experiments so that the child will be able to correct his or her own errors and find fresh solutions through direct actions.” (in: Hohmann & Weikart, 1995)

Although recent research has resulted in some findings counter to a strict application of Piaget’s theory, nevertheless its continues to provide broad guidelines for structuring and designing curricula for younger aged pupils.

2.5.2 Young children and science

Eshach and Fried (2005) mention six reasons for teaching science to preschoolers:

1. Children naturally enjoy observing and thinking about nature. 2. Exposing students to science develops positive attitudes towards science. 3. Early exposure to scientific phenomena leads to better understanding of the scientific concepts studied later in a formal way. 4. The use of scientifically informed language at an early age influences the eventual development of scientific concepts. 5. Children can understand scientific concepts and reason scientifically. 6. Science is an efficient means for developing scientific thinking.


...it is essential that those who work with younger children provide them with direct science experiences; this point can hardly be overemphasized. Science experiences provide the conceptual basis on which later science competence can be built. […] It may be that depriving youngsters of such experiences will limit their subsequent intellectual growth.

Neuman further mentions that the "breadth, rather than depth should be stressed when carrying out sciencing activities with three to five year old children".
De Vaan & Marell (2006) devote a chapter to young children in their book *Praktische Didactiek voor Natuuronderwijs*. They also mention that concrete experiences are very important and enable young children to use all their senses. They advise teachers to be aware of their egocentric thinking and their large involvement in every process. Because they are egocentric, worksheets are less suitable, because children of younger ages are not interested in the questions of others, they want to explore the materials themselves, which gives them opportunity to do what they want. The materials should be designed or provided in such a way they invite exploration, but not too many materials at the same time. Suggesting actions to the children is key, encouraging them to try different things with the materials themselves, to get them to experiment more. The chosen subjects and materials should be relevant to their world. To create the right pedagogical climate, the classroom should be safe, well-organized, inviting action and give a feeling of freedom (provide choices). Characteristic for young children is their actively inquiring attitude. They are naturally curious and wondering about the world around them. Below six years old children grant lifeless objects with personality and do not distinguish between alive or dead.

Not all teaching methods are suitable for young children, De Vaan & Marell suggest the “observation circle” (observatiekring), “discovery corner” (ontdekhoek) and outside work (buitenwerk). These also provide a mix of half guided situations (discovery corner) and fully guided situations (observation circle).

### 2.6 Differentiation in the classroom

In Kindergarten the students are 4 to 6 years. They are in that group for 2 to 3 years and come in during the year, as soon as they turn 4 years old. In the Jenaplan education system, which is adopted by De Nieuwe Kring where this project takes place, in all other groups there are also multiple grade levels present. Grades 1 & 2 are in one group for example. In an ordinary classroom the need for differentiation is already great, but in a group that has different grade levels and ages, this need is even greater. Tomlinson (2000) describes differentiation as follows:

> At its most basic level, differentiation consists of the efforts of teachers to respond to variance among learners in the classroom.

She distinguishes four classroom elements in which can be differentiated (by the teacher):

1. content—what the student needs to learn or how the student will get access to the

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1 In Dutch education, children often sit in a big circle to share experiences or give presentations.
information; (2) process—activities in which the student engages in order to make sense of or master the content; (3) products—culminating projects that ask the student to rehearse, apply, and extend what he or she has learned in a unit; and (4) learning environment—the way the classroom works and feels.

Ideally, all these elements are addressed in the developed materials. This can result in for example extra material for interested students, information given by both auditory and visual means, working together to get struggling learners to catch up etc.

2.7 Light & mirrors

2.7.1 What do children know and think about light and mirrors?

When developing a lesson series about mirrors, it is useful to know which conceptions children can understand about this topic and what possible misconceptions they can have. In 1968 David Ausubel wrote in his book *Educational Psychology*: "If I had to reduce all of educational psychology to just one principle I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." People bring their experiences and mental models to learning situations. Piaget found that young children already have explanations for natural phenomena, which they base on their experiences in their lives until then. The concepts present in the mind of people are not always correct. In that case they are called ‘misconceptions’ or “alternative frameworks”. Ausubel claims that they are the most important influence on the learning process. During the learning process misconceptions can also form, if only by misinterpretation of a teacher’s words. The teacher’s misconceptions are also important and in the case of Dutch primary teachers they may be very prevalent, because the teachers lack a science background.

Another term for misconceptions that might be more appropriate in the case of young children is preconceptions or naive theories. Ausubel described preconceptions as “ideas expressed that do not have the status of generalized understandings that are characteristic of conceptual knowledge.” Di Sessa (1993) says that “naïve physics” knowledge is mostly based on everyday experiences with material substances. In Kindergarten children often have not received teaching in science, mental models, and possible explanations for natural phenomena probably come from their experience in life

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1 A small example: in a science lesson about sound I recently taught to pre-service primary teachers, I was explaining that there are hair cells inside the ear that pick up frequencies. One of the students asks: “Hairs, like hairs on your head?” Possibly I said ‘hairs’ instead of ‘hair cells’ at some point in the explanation, but also in the latter case it is possible to form a wrong picture in your head if you are a student that connects the ‘hair’ part to their own experience of hair. From then on, I am very careful to clarify it is not like hair on your head, but if the student would not have asked, I would not have realized this interpretation was possible.
until then. They have not misunderstood teaching, so these are preconceptions.

In the early days of this career, Piaget has talked with children about light. Andersson & Karrqvist (1983) say that he describes the interviews very briefly and concludes with:

> Despite the daily use of flashlights and the common idea of ‘rays’ of the sun or of sources of light, the understanding of the transmission of light is scarcely more precocious than that of heat. It is not until stage III [the formal operational stage reached by children at 11-12 years of age, according to Piaget] that the subject admits the existence of light ‘between the machine and the round spot... I don’t see it but I know it’s there’.” (Piaget, 1927 in: Andersson & Karrqvist, 1983)

Andersson & Karrqvist continue with a short review of some studies which show that children only obtain the view that light is something that exists and propagates in space, apart from sources and effects, after primary school age and they also show this with an experiment of their own with 14-year olds. The children in their study also still have the conception of “visual rays”, as they call them. “Visual rays” are the way the test subjects for example explained why a person could see a book: “Rays go from the eyes to the book so that we can see the book” and many variations upon that. Allen (2010) also reports this as a common misconception: “We see things because light travels from our eyes towards an object.” Another common misconception about light in Allen’s book is “Light is only found in bright areas.” This is also mentioned by Andersson & Karrqvist: Children often think that light is only present in for example the spots of light on the walls and in the light sources, and they do not believe light is in the whole room, or a shadowed room. Allen mentions other misconceptions about light concerning the moon and the sun (why the moon shines, why there is day and night, why there are seasons etc.), but they are not relevant to the subject of this research. Allen does not mention any misconception specifically about mirrors.

In Reiner et al. (2000) another list of misconceptions about light is given, they call them naive physics theories:

1. “Light flows and can be at rest.” This is basically the same as the shadowed room not containing light, because it comes from the belief that light is at rest in a spot of light. When asked whether there was light on a mirror, the test subjects confirmed this. Even when reminded that the mirror reflects, they insist that if light rests on the surface of the mirror, a small bright spot would appear.

2. “Light mixes as if it were a liquid.” Mixing all primary colours of paint would get you black, so people expect that this also happens with light, but mixing all primary colour of light makes white.

3. “Light creates friction upon contact.” This is used to explain why light cannot penetrate opaque objects and why light becomes fainter with distance (friction with the air).
4. “Light, colour, and shadows as something inherent of an object.” Shadows are only the absence of light, but many children think they are inherent to an object. They also often believe that light depends on the existence of its source, as was already explained before.

These four misconceptions are commonly still held by older children (over 11 years old). The literature seems to focus on this age group, also because these students begin their studies in optics and they still hold on to these alternative views even after education. For younger children, the literature is less clear. It is mentioned in that young children do not make the connection between the eye and an object, while older children have the view of vision as light coming to the eye, but they do not mention how old or young these children are exactly. When the object itself is not luminous, the older children adopt the aforementioned model of the eye sending rays towards the object. Also mentioned in the same article is that these views are not only held by children, by also by many adults and that there is no further development towards scientifically correct views when they grow up. Indeed, many primary teachers hold the same view. They also did an experiment with prospective primary teachers in the UK and found that these students, with some minimal training in optics, have misconceptions. They do know that light travels in straight lines, but they believe these lines to be individual rays, that all hold (some) information about the image. The students were aware of the reflection of a plane mirror, but struggles to explain how exactly it works. When for example asked what happens to the mirror image of three object next to each other when the observer moved (when the mirror images of the objects also appear to move), the predictions varied wildly: colours reversing and the ordering of the images in the mirror changing. Also, some students held the belief that the mirror image was on the mirror surface, instead of the same distance behind the mirror as the object itself was in front of it.

Another interesting misconception about mirrors, is that people believe that they can see an object in the mirror in totality if they move further away from the mirror. This is in fact untrue. When you stand in front of the mirror and only see your face, you can walk backwards endlessly and still only see your face. You have to make the mirror bigger, or tilt the mirror surface, to make more of yourself visible. This concept can be shown fairly easily to anyone, including young children (you can just try it out and see it yourself), but is still unclear to even American college students who had a course in optics. “Virtually all students who had not thought about this question specifically said they would see more of themselves by moving backward.” (Goldberg & McDermott, 1986)

Misconceptions are “highly robust” and are hard to change, even with extensive teaching (Posner et al., 1982). To find under which conditions actual concept change occurs, Posner et al. (1982) proposed a theory consisting of four factors necessary for this process to occur:

1. “There must be dissatisfaction with existing conceptions.” Students do not like to change their views, so they do not feel the need if their old mental model suffices to explain the presented phenomena. Only when they meet a conflict with their beliefs, new mental models will be
introduced. This has recently been shown to work with preschoolers in a study about the concept of balance by Bonawitz, Lim & Schulz (2007). The pupils were asked about their ideas about balance (centre of mass) and then presented with something that contradicted their expectations. The preschoolers played longer with toys that contradicted their conceptions, than with toys that confirmed them.

2. “A new conception must be intelligible.” If a student is not able to structure the new information in a meaningful way, then no learning takes place. New concepts must be presented in a way that has meaning to the student.

3. “A new conception must appear initially plausible.” If the new conception does not seem to solve the presented problems with the old conception and must be consistent with other knowledge. To accept a new theory, it must not bring too many additional problems and have too many holes in the structure.

4. “A new concept should suggest the possibility of a fruitful research program.” If students see the use of the new concept for their own life or the lives of others, they are more willing to learn it. The willingness is also greater if the concept opens up new avenues of inquiry.

Posner et al. (1982) mention implications for education and they point to two strategies in particular to guide the change from one conception to another. Firstly, providing an anomaly to students. The student then goes to a state of crisis and will be more willing to learn, to solve the conflict. Secondly, teaching the basic assumptions necessary for the new conflict. Posner et al. use the example of teaching special relativity. If the students are not yet committed to the “parsimony and symmetry of physical theories”, they will accept the new theory.

To get the students to see there is an anomaly, takes an understanding of the theory behind an experiment. A lot of experiments are not very transparent to students, especially younger students (they appear to be either “magic” or “just the way it is”). Posner et al. say that it is difficult to teach the fundamentals necessary to make judgements on theories in limited physics courses, especially when the time is short. They ask the question: “Is it realistic to expect science instruction to produce accommodation in students, rather than merely to help students make sense of new theories? And secondarily, should this be an expectation for all students, or only of certain groups, such as science majors?” They suggest that curriculum objectives should be to make students aware of their fundamental assumptions and demand consistency in their beliefs about the world. Apart from that, an awareness of the process of science and the foundation of modern science and some sense of the fruitfulness of new conceptions. Inquiry-based learning might be a good fit to achieve these objectives, because opportunities are given to students to explore subjects, make errors, ask questions about things that surprise them (conflict their beliefs) and learn about the process of science and what makes something plausible in science.
2.7.2 Key concepts for the lesson series

Given the age range of the children, the lesson series that was developed in this research study does not need to use such sophisticated concepts of light and mirrors. The presence of light can just be taken for granted and the nature of this phenomenon does not have to be discussed. The focus lies on the properties of the mirror, but the physical concepts behind the mirror image are also complicated and, as just shown, even difficult for older students. Many lesson materials have been developed about light and mirrors, also for children. Usually they are aimed at an older age group. An example is *A Sourcebook for Elementary Science* (Hone & Hone, 1971), of which chapter 15 is called “Light and Color”. The writers summarize briefly activities you can do (no worksheets), with some illustrations of the workings of the experiments. For mirrors, it mentions:

- the angle of incidence of a mirror (reflection);
- the periscope, the parallel mirrors;
- water and glass as a mirror,
- multiple images;
- the kaleidoscope;
- reversion of the image in mirrors (left-right, back-front);
- distortion in a convex of concave mirror.

In *De Grabbelton* Frederik wrote about a science lesson she carried out in a Kindergarten group. In this lesson she explored mirrors with the children by finding more mirrors in the classroom, looking at the distortion of the image in some mirrors and looking at symmetric images. From these sources and experimentation with materials, properties of the mirror that were understandable for young children were collected:

- Mirrors reflect yourself and your environment;
- All kinds of surfaces reflect mirror images; for this to happen the surface has to be extremely smooth and usually shiny; Water, glass and plastic act as a mirror under certain circumstances;
- When you have a convex or a concave mirror, the image appears distorted, depending on the shape of the mirror the image can appear larger, smaller and otherwise distorted;
- When you have multiple mirrors, multiple mirror images appear; and those multiple mirror images can also be mirror images of mirror images.
- An image that has two exactly the same sides, can be made with a mirror: the mirror reflects exactly the same image back (the concept of symmetry); there are many symmetric images and objects in the world to find;
- Letters appear differently in the mirror;
- Rays of light are reflected off a mirror; when the ray of light falls in almost horizontally, it also comes out almost horizontally; if the ray of light falls in almost vertically, it comes out almost vertically (the angle of incidence is the angle of reflection, but only qualitatively).

These concepts were the foundation of the developed lesson series, even though they are not mentioned as learning goals, as is explained in the materials themselves.

2.7.2 What do primary teachers know about light and mirrors?

It is important to note that not only the children can hold misconceptions about light and mirrors, but adults hold many alternative beliefs. Primary teachers are not exempts, as was just shown. In The Netherlands, primary teachers are not well versed in science (see section 2.2), but some attention is given to the subject at most pabo’s, the training colleges for future primary school teachers. The book most often used as a reference book at the pabo is Natuuronderwijs Inzichtelijk (Kersbergen & Haarhuis, 2002). It has information about plants, animals, the human body, environmental issues, physical phenomena, constructions, energy, the weather and some astrophysics. It is a source book, so not everything is taught directly, but all information is accessible.

There is a short chapter on light in Natuuronderwijs Inzichtelijk. It covers the basic principles, namely:

“1. You can see objects when they give light themselves or when a light source shines upon them and they reflect the light.
2. Light propagates in straight lines. Unlike sound can light also move through vacuum.
3. Light rays that find an object in their way can either be reflected, absorbed or let through. This depends in the surface the light falls upon and the material the object is made of.
4. Smooth and white surfaces reflective more light relatively, while dark, rough surfaces absorb more light.
5. When light goes from one transparent material to another, the light rays change direction. This phenomenon is called refraction.
The workings of lenses are based upon this phenomenon: a lens can refract the light rays in a certain way, which results in enlarged or shrunken images, depending on the shape of the lens.
6. White (sun)light consist of many colors (the colors of the rainbow). The color an object had for our eye, is determined by the reflected colors.”

These are the main insights, but there is a small paragraph about mirrors, where the law of incidence
is shown in an image (the book does not use formulas or symbols). In the teacher manual of the learning materials that were to be developed, it was clear that a short background on the scientific principles of mirrors should be included, to make sure that the teachers had the pertinent information at hand. For the lesson it should also be assumed, that the teachers would not be very knowledgeable about these concepts.

2.8 Summary

From the literature, it is clear that the situation of primary science in The Netherlands is improving, but the majority of schools are still not reaching the goals specified by the Dutch government. The main reasons for this lack of science teaching are a lack of time and opportunity in the schools (no learning materials available) and the lack of science expertise of the primary teachers.

The didactical approach of inquiry-based learning is central to science teaching all over the world. In inquiry-based learning, the lessons are set up around student-generated questions. The students usually go through an inquiry cycle, where they follow the steps that mimic the work of scientist. They first explore a subject, then formulate a research question and set up an experiment around them. The teacher supports this process. The most widely used inquiry cycle in The Netherlands is the seven step model by Van Graft & Kemmers (2007). For the Kindergarten group, the inquiry cycle is not yet appropriate, the emphasis for that age group should lie more with free exploration.

Young children think about the world differently than older children or adults. An inviting learning environment should be created to facilitate their naturally curious and inquiring attitude. Both students and teachers hold misconceptions and preconceptions about scientific subjects, including light and mirrors. The concepts that are suitable for the age group 4-8 years old were selected. For the developing of the lesson plans, it should be assumed the teachers have no prior knowledge of light and mirrors, but a short piece of background information should be included to make them aware of the important principles.

“[The educator’s] problem is to protect the spirit of inquiry, to keep it from becoming blasé from overexcitement, wooden from routine, fossilized through dogmatic instruction, or dissipated by random exercise upon trivial things.”

*John Dewey (1933)*
3. Design framework

In this chapter, I will formulate my research questions and look back at the developmental process and show how the project came from idea to design rules.

3.1 Research questions

The main reason for developing this lesson series is to arouse interest in science in the students. The acquisition of scientific knowledge about the subject matter is secondary. There is room for this in the curriculum, because the target group is not subject to exams or tests about this subject. Not only the aims for the students are important to this design, but also the way the teachers are able to use the developed materials. As was explained in the last chapter, primary teachers in The Netherlands are not very experienced or comfortable with teaching science and the additional requirement to teach inquiry-based asks even more from the teachers.

It is therefore of great interest to me whether the materials are teacher-friendly and in what ways the teachers use them. To this aim, the following research question has been formulated:

**Question 1: How do the teachers use the lesson materials?**

Since this is rather broad questions, this is more specifically split in:

**Question 1a: How do the teachers interpret the lesson plans? Do the teachers follow them exactly or do they take the freedom to structure and fill the lessons as they think is best?**

**Question 1b: Do the teachers have enough science knowledge to implement this module?**

**Question 1c: Are the teachers able to implement the inquiry-based learning of the method? Do they have the skills to effectively lead the group discussions? Do they adapt to ideas and questions of the children (use 'teachable moments' productively)?**

If and when the teachers are using the materials, the students work on the learning goals and objectives of the lesson series. To find whether the materials are sufficient to reach the learning objectives, I evaluate the children’s experience with the lessons. This leads to a second research question:

**Question 2: Are the objectives of the lesson series achieved?**

This is again a very broad question. Furthermore, I need to formulate measurable quantities. The
target group is very young, so interviewing and testing the students is limited by their verbal en
mental capabilities. Observations are important as data. From this, the interest in the lessons can be
shown. In interviews it can be determined how much the students remember of the lesson series
after some times has gone by. The understanding of the scientific phenomena might be learned from
their handling of the scientific equipment and the way they talk about them. The lesson series is set
up as an exploration, which means the learning is not always the same for each student and also what
they learn is not always measurable. To specific question 2, the following questions were formulated:

- **Question 2a: How much do the children remember of the lessons?**
- **Question 2b: Do the children use science specific language appropriately and with apparent
understanding?**
- **Question 2c: Are the children comfortable with the scientific equipment and use it
appropriately?**
- **Question 2d: Do the children evaluate, interpret and share their (scientific) findings?**
- **Question 2e: Has the children's interest in science been aroused?**

### 3.2 Method

The presented research employed qualitative approaches for collecting and analyzing data. The
qualitative method suits the exploratory nature of the developmental process and provides more
detailed descriptions of the activities of the lesson series. The study was done in several phases:

I. A development phase during which lessons were developed and tried out in a Kindergarten
group and a grades 1&2 group (Cycle 1).

II. A revision phase during which the lessons were revised based on results of the try-out and
were described in the form of a teacher guide with lesson plans and extra information (Cycle
2).

III. An evaluation phase during which the revised lessons were implemented in two other
Kindergarten groups and another combined grades 1&2 group.

IV. An analysis phase, in which children and teachers were interviewed to provide more data to
answer the research questions.

The sources of data are: 1. direct observations in the class room from various observers; 2.
videotaped lessons; 3. audio taped lessons; 4. videotaped children interviews; and 5. audio taped teacher interviews. The role of the observer was that of a spectator. There was no direct involvement of the researcher/developer in the lessons. One kindergarten teacher and one grades 1&2 (mixed class) teacher were observed during phase I, which took place during the developmental process. Two kindergarten teachers and one grades 1&2 (mixed class) teacher were observed during phase II, which took place after the development process was finished and the materials were revised. Approximately 50 children were interviewed post teaching, as were all of the teachers involved. See Table 1 for an overview of where what method was used. More detailed information about the developmental process and the method employed

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*Table 1: Overview of methods of data collection during study*

### 3.3 Chronological overview of research project

Below a short overview of the timeline I have followed for my this research project. The individual points are explained in subsequent chapters.

**September 2006:** Request from the school to develop materials

**Autumn 2006:** Discussion with school about planning and content

**November 2006-February 2007:** Development and test-run of lessons in one kindergarten group and one grade 1&2 (first cycle)

**February 2007:** Post-interview kindergarten group (video) and evaluation with teachers

**February 2007:** Revision lessons and writing teacher manuals

**March-April 2007:** Teachers of two kindergarten groups use teaching materials;
3.4 The request of the school

The learning materials were developed in close cooperation with primary school "De Nieuwe Kring" in Diemen. This primary school is a so-called “Brede School”, which means that it also includes a nursery school and a day care institute. The philosophy of the school is Jenaplan, which means for example that they have two grade levels mixed in one class, that children work on their own level in all things (which means they join other classes during the day) and the school works with ‘themes’, around which many lessons are arranged (themes like 'me' or 'buildings'). The population of the school is mixed, leaning towards “autochtoon”. The school had the explicit request to make something for the lower grades of the school (Kindergarten and grades 1&2), because there is not much Science & Technology material available for K-2. After meetings with the teachers involved (three in total) I got a more clear view of what they wanted.

It was very clear that the school wanted the materials inquiry-based. Some teachers have experience with inquiry-based learning from the LOOL project, also conducted by the AMSTEL Institute (Van Graft & Kemmers, 2007). Furthermore, it is already in some form incorporated in their lesson plans, with the children working independently often.

The teachers named the following possible subjects for the lesson materials:

- the rainbow
- light & shadow
- light & dark
- hovering & flying
- floating & sinking
- magnets

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1 This means the children were born from originally Dutch parents, usually Caucasian.
The weather

building & constructions

After careful consideration of the target group, the requirement for certain basic materials, the literature and the ideas that came up during the meetings, I decided that I liked light & shadow the best. But during my search I came upon the subject of mirrors, which appealed to me especially because it such a simple and clear subject, but with many possibilities in all directions (mathematics, art, language, crafting etc.). The teachers were also enthusiastic and we decided to do that subject.

The school indicated that it does not develop materials themselves is that they lack the background knowledge in science. As the teachers explained to me, they can see that there are certain possibilities in what children say every day, but it is hard for them to make the step to an actual lesson. If they were to get into the subject of mirrors, they would be able to follow the instructions to let children discover the mirror, but could not do anything with the specific comments and questions of the children. It became clear that the teachers wanted the material to come 'from the children', so to speak. This is, according to the teachers at least, the Reggio Emilia approach (Edwards, Gandini, Forman, 1998). In the philosophy of Reggio Emilia, children have some control over the direction of their learning. The summary of what I gathered they wanted is in Figure 9. This ties closely with inquiry-based learning, where student-generated questions are central to the learning process.

What they ultimately want is an ongoing lesson plan for K-6. This was beyond the scope if this project, so we decided it should be a compact 'leskist' (module kit) with materials and lesson ideas.

Finally, they wanted to incorporate the after school day care in the learning process, for example with extra materials the children could explore after having the lessons at school. This proved to be a bridge too far for this project, although there are ideas for the implementation of this idea in the final teacher guides of this project.

3.5 Design rules

The teachers involved were enthusiastic about the project. They feel the need for more attention for technical and scientific subjects in their lesson program, but they do not have the time and scientific background and experience to make something themselves. Too much lesson preparation time or the need to acquire (in their eyes) complicated materials are likely to result in not executing the lesson. Therefore this needed to be a lesson series as ‘basic’ as possible. Luckily, this agrees well with the inquiry based objective of the lesson series. I set up the series as an exploration for the teacher as well. The teacher invites the children to share their discoveries with the group and needs only discussion leading skills and little knowledge of the subject matter. Of course, background knowledge is a pre, but not necessary.
Figure 9: The development of the lesson series as considered ideal by the teachers from De Nieuwe Kring. The first step is the messing round with a certain subject. This exploring phase is very free: the children can do whatever they like. There is a group discussion about the discoveries, guided by the teacher. The discoveries should bring up new questions and ideas for exploration. These ideas can be worked out as lessons further (the clouds coming from the discussion). The problem here is that the teachers can do the exploring phase and the discussion, but have insufficient background in physics to change the ideas from the discussion into workable lessons. The whole idea of the mirror series is to anticipate the questions of the children and make lessons about possible discoveries. It turns out that all groups more or less discover the same things, so it is possible to make a number of lessons that follow-up on the initial exploration phase. This means unexpected ideas will not be covered, but there is always the possibility for the teacher to do something with ideas from the classroom. In practice though, the experience learns that teachers already find coping with the mirror series like this is quite difficult, so they do not get to the ideas for further exploration (added to every lesson plan). But maybe if they do it more often, they will get more comfortable and start varying.
Since the children are in Kindergarten or grades 1&2, they cannot read yet (or only just). Therefore, all worksheets had to be word-free. No written instructions were possible for the children. This makes it the task of the teacher to explain the assignment and to limit preparation time for the lessons again, the assignments had to be simple and self explanatory.

In this school two grade levels are put together in a class room. Already the difference in development is fairly large between children of the same age (some children in kindergarten are still very much like toddlers, often lost in their own world, while others already exhibit independent and driven behaviour), but there are also different ages present. This means the material needs to provide possibilities for the teacher to differentiate within the group and the material has to be such that all children can get something out of it. The assignments have to be simple enough for the young ones to understand or just tinker with, but interesting enough to hold the attention of the more developed ones. Also, there should of course be extra assignments with all lessons, in case the teachers or the children want to do more.

Since the children are very young, their attention span is quite short. I was advised by the Kindergarten teachers to not make an activity last more than 30 minutes, because that was already a very long time for that age group. Even better would be to have a switch of environment or way of working every 10-15 minutes or so. This generally means that the children explore for a while, then discuss their findings, explore again or work on a more focused assignment. Every lesson lasts between 30 and 60 minutes, depending on the enthusiasm of the children and the time available.

There is also another reason to change between teaching styles during the lessons. Some children are more capable of expressing their thinking in words. Others are very creative and can make beautiful things. Some are more comfortable when they can actually do something, that like to be active and touch their learning materials. All these kinds of learning should be addressed; every child should be able to get something out if it. The teachers referred to the theory of multiple intelligences in our conversations (Gardner, 1999).

To summarize, the materials had to fulfill the following design rules (see also chapter 2):

- easy-to-get and inexpensive materials
- hardly any preparation time for the teacher
- no words or instructions in words on the worksheet
- possibilities for differentiation in the group
- variation in teaching methods during the lessons
- inquiry-based
3.6 Process of lesson development

To start of the lesson series, a lesson where the children just explore a mirror themselves was planned. From the literature I already had an idea what kind of activities might be suitable for the lessons, but to stay close to the inquiry-based learning, I would like to do something with discoveries and ideas that children brought in from the first lesson. Observing during the first lesson would show whether my ideas aligned with possible ideas of the students.

During the first cycle I developed the lessons a couple of days before the next lesson, e-mailed them to the teacher and brought in the materials for the lesson myself half an hour before the scheduled time. Afterwards, I would discuss the lesson very brieﬂy with the teacher and consider what revisions should be made. When the first cycle was finished, I made the teacher manuals with background knowledge and worked out lesson plans etc (appendix A, B and C). Figure 10 gives a schematic overview of the procedure followed to develop the lesson series.

Figure 10: Flow chart development lesson series.
4. Overview lesson series

This chapter gives an overview of all lessons in the mirror series. The complete lesson plans are in the teacher manuals (in Dutch), see appendices A, B and C. A few examples of lesson plans are translated in English, see appendix D. A complete set of English materials can be found on: http://www.pollen-europa.net/?page=lvhjR0Y6nE%3D&element=3Bh9HuJf8As%3D

For every lesson, summarized teacher instructions are given. Following that is the general idea behind the lesson, with examples of discoveries the children made, lesson situations that arose, pictures from the lessons and other impressions and commentary on the lesson. The teacher instructions come in two versions, one for Kindergarten and one for grades 1 & 2. The general outline of the lesson is the same. There are some extra assignments for grades 1&2 and there are more options mentioned for extending the lesson. See the teacher manuals, appendices A and B. Also, there usually is some sort of assignment at the end of the lesson for grades 1&2 to write the experiences down. This can be seen in the (number of) worksheets in the manual, see appendix C. Grades 1&2 make a mirror booklet, with all lessons documented by the children themselves in some way, although one of the kindergarten teachers also preferred to do that with her children.

4.1 Overview

Level: Version A: Kindergarten, age 4-6
Version B: Grades 1&2, age 6-8

Number of lessons: 7, each lesson takes about 45 minutes but most lessons can be made to last anywhere between 35 – 60 minutes

The module consists of a science kit with a teacher manual. There are two manuals, one for kindergarten and one for grades 1&2.

Materials in the science kit per class:

- 1 big mirror for teacher demo
- 25 mirror tiles
- 25 double mirror tiles
Christmas balls
Glittering stars
Example magic mirror (students make their own)
Templates for magic mirrors
Example disco ball (students make their own)
Mini disco balls
Flashlight
glittering stuff
coloured beads
spoons and other mirroring or non-mirroring materials (to be used in lesson 2)

Large worksheets (with drawings only, no text):
  - Double mirror: line and dot
  - Double mirror: triangle
  - Double mirror: square
  - Double mirror: pentagon
  - Symmetry: complete tree
  - Symmetry: half a tree (1)
  - Symmetry: half a tree (2)
  - Symmetry: half a tree (3)
  - Symmetry: half a tree (4)

**Lessons**

1. Explore the mirror
2. Discovering more mirrors
3. The magic mirror
4. The double mirror
5. Reflection
6. Symmetry
7. A. The line game (for kindergarten)
   B. Symmetry in letters (for grades 1&2)
Figure 11: Example Lesson plan

- **The double mirror**
  - You can experiment with two mirrors connected to each other in a stand of SEND. You will see two nice images, one of which is a mirror image of the other.

- **Lesson description**
  - **Activity** (mirrors arranged in a V-shape):
    1. Each child gets a double mirror and a postcard (5.5 x 4.5 inches) to "wish".
    2. Pass the postcard to the student next to the child.
    3. Place the mirror on a table with your own mirror.
    4. What do you see if you put something between the mirrors?
    5. What can you do with those mirror images you cannot do with a single mirror?
    6. How many times is the image multiplied?
    7. What happens when you move the angles between the mirror lines at an angle?

- **Discussion**
  - The students cut out identical triangles out of the cardboard, and copy them to the other side.
  - The child is able to see the reflection in the mirror, the cardboard can see an entity.

- **Assignment**
  - The students cut out identical triangles out of the cardboard and write on the back.
  - The mirror mirror has a different picture of the cardboard, the child can produce the picture which can be seen as the teaching should in the mirror.

Figure 12: Example Worksheet (for Lesson 6: Symmetry):

- **Activity** (mirrors arranged in a V-shape):
  - Each student gets a double mirror and a postcard (5.5 x 4.5 inches) to "wish".
  - What do you see if you put something between the mirrors?
  - What can you do with those mirror images you cannot do with a single mirror?
  - How many times is the image multiplied?
  - What happens when you move the angles between the mirror lines at an angle?

- **Discussion**
  - The students cut out identical triangles out of the cardboard, and copy them to the other side.
  - The child is able to see the reflection in the mirror, the cardboard can see an entity.

- **Assignment**
  - The students cut out identical triangles out of the cardboard and write on the back.
  - The mirror mirror has a different picture of the cardboard, the child can produce the picture which can be seen as the teaching should in the mirror.
4.2 Lesson 1: Explore the mirror

Summarized Teacher Instructions

This first lesson is dedicated to exploring ordinary mirrors. What can you do with just an ordinary mirror?

1. Spread the mirror tiles across a table. When the students enter, they will be interested right away.
2. Plenary: The class starts with all the kids sitting in a big circle as is custom in the lower grades in the Netherlands.
3. Plenary: Take the big mirror. What is this? What can you see? Later the kids will get their own mirror. Alternatively (and better): start with a story about a mirror.
4. All students get their own mirror tile and are allowed to walk around for a few minutes to discover things.
5. Plenary: Students tell what they discovered.
   We suggest that you let other kids “copy” the discovery by trying it with their own mirror.
6. Individual: It is possible to do another round of walking around and discovering. They often get more ideas the second time around. They also like to walk around.
7. Plenary: another round of communicating and imitating the discoveries of others.
8. Extension: We let kids put the mirror above their heads and look into the mirror

Figure 13: A kindergarten group is exploring the mirror for the first time.

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1 Plenary usually means putting the chairs in a circle, called the ‘kring’, but it is up to the teacher whether to do that or not. The kring is a common occurrence in Dutch primary schools. The children share experiences and discuss things with each other and the teacher.
while walking around.

9. More: Let the students make drawings and texts about their discoveries (there is possible worksheet for this in the teacher guide).

**Discussion lesson**

This first lesson is meant as an exploration of the subject in the broadest sense. Anything goes. There are two cycles of exploration and discussion to focus the attention of the students better and to give them new ideas halfway through. Movie 1 shows first how the children start exploring with the mirror (they have just gotten them for the first time) and then switches to the group discussion later, during which a girl tells about her discovery that you can see behind you in the mirror.

The advice in the teacher manual is to put all the mirrors on a big table in the centre of the circle of children, preferably when the children are away, so they see them lying there when they come in. This is more than enough to catch their attention. It looks very beautiful, the table with mirrors. The children start touching them, organizing them immediately. One child remarked: “It looks like a big puzzle.”

When the big mirror is brought out and the teacher asks what it is and what you can do with it, the answers are always “You can see yourself”, “You can comb you hair”, “You can do your make-up” or other self centered things. When they start exploring they find wholly different things, for example (see for some real live action Movie 1):

- When you hold the mirror above your eyes and look into it, you see the world upside down. This is the absolute favorite of all classes and fascinated the children every time.
- When you look into the mirror when you hold it flat in front of you (or it lies on the table), you see the ceiling.
- When you hold mirror on your stomach and look into it while walking, it seems like you are walking on the ceiling.

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1 There is a disc enclosed with this thesis with movies from lessons in a kindergarten group.
- When you hold the mirror in front of you (a little to the side), you can see behind you. This is sometimes too difficult for the children in kindergarten, especially the younger ones in the group, but in Movie 1 you see a girl explaining this.
- One girl found that if you put the mirror straight on the 4 of a big plush dice, you see the same thing (she discovers symmetry).
- If it is sunny they see the lights reflected by the mirror.

**Grades 1&2:**

In grades 1&2 they discover all the things the kindergarten group does, but they find more, for example:
- One girl finds that if you look at a book in the mirror, the letters are ‘wrong’.
- In all groups the children put mirrors together and make kaleidoscopes and boxes of mirrors (one time referred to as a ‘maze’).
- When you breath over the mirror, it fogs.

All teachers are surprised at how many things the children find. The children are also very eager to share their experiences; all children have their fingers in the air to tell their discoveries. Usually the teacher copies the discovery of the child and makes all the other children do it as well. In grades 1&2 the discoveries are written on the blackboard and later the children write them down in their mirror booklet as well.

![Figure 15: The teacher of a grades 1&2 group during cycle 1 has made a worksheet for the children to fill out, because the children were starting to write things down spontaneously. The texts are discoveries the children made, which were written down on the blackboard first. The first discovery reads for example: “Block with 5 mirrors (cube)” The room to the right is left blank for a drawing. In the revision this was made into a worksheet, almost exactly like this (see appendix C, worksheet 2).](image-url)
4.3 Lesson 2: Discovering more mirrors

Summarized Teacher Instructions

In this lesson other mirrors than ordinary ones are explored, such as spoons, windows etc.

1. Preparation: Collect various objects that mirror (like spoons, pans, Christmas balls etc.), objects that mirror a little bit (like plastic cups, compact discs etc.) and also things that do not mirror (wood, paper, etc.). Make boxes with collections, one box for every group of students (student group for example 4 children).
   It is also a good idea to leave some mirroring things around the class room for step 3, for example a stapler or a mirroring garbage bin.

2. Plenary: Start in the big circle (see lesson 1). Ask what we did last time. We experimented with mirrors. But there are more mirrors to discover, right here in the class room. Does someone see something that maybe mirrors a little bit? Usually someone notices the window, or something, but if not, point something out and discuss.

3. The students get the instruction to walk around and find things that mirror.

4. Plenary: Students tell what they discovered.

5. Introduce the boxes. You can let the children sort the things in the boxes in piles (things that mirror, things that mirror a little, things that do not mirror at all).

6. Groups: The students look at the objects in the boxes.

7. Plenary: Students tell what they discovered. Do all things mirror the same? What do the Christmas balls do? And the spoons? Why is that? This can be followed by a discussion about why something mirrors. What characteristics do all mirroring things have in common?

8. Extension: Let one or two of the boxes stand somewhere accessible in the class room for a few days more, so the students can look at them again.

9. More: Ask the children to bring something from home that mirrors, but isn’t a mirror. They can record their discoveries again on a worksheet.

Discussion lesson

The idea behind this lesson is to look a little closer at things than in the first lesson. The lesson is set up
in such a way that the children go into a funnel: first they explore widely, then they are forced to approach the subject differently and focus more on details. First the children are invited to find more mirrors, which usually results in many things (water, window, stapler, scissors, little buttons on clothes, belts, glasses, eyes etc.). They are allowed to walk around again and then discuss in the group. After that there is a more focused assignment again, with the children getting boxes with all kinds of things. Some objects mirror to some degree, others don’t. They have to sort them in piles: mirrors well, mirrors a little, mirrors not at all. According to Piaget, children in the preoperational stage should hardly be able to sort things, but the kindergarten groups managed the assignment quite well. It is hard for the youngest children to distinguish between 'a bit' and 'very', but they are able to sort. They also confuse sparkling and mirroring, as mentioned before, so some things end up in the wrong pile, but there is discussion again at the end, so some things are corrected. The assignment is not about them making perfect piles, it is about them looking more closely at the phenomenon of mirroring and discussing things with the teachers and each other.

They have to work together in groups, which is usually not a problem (due to experience with working in groups because of the Jenaplan philosophy of the school), but some groups are dominated by one member, who takes everything, sorts it and does not let the other children get their hands on anything. There are also groups that study the materials together, although there is a certain greed from the children towards the more desirable objects (nice, shiny ones), which they sometimes claim for themselves. This is probably a more general problem in kindergarten groups.

This lesson is the most work intensive for the teacher. Some materials are in the lesson kit, but many have to be gathered beforehand. It is hard to keep the attention of the children at the task, since there are so many distracting, new things in their hands. The concept of why something mirrors, which is the scientific goal of the lesson, is usually not comprehended. It is already quite a discovery that eyes mirror for example, so why that is so is too hard. Also, convex and concave mirrors are found
wondrous things by the children, but the comprehension that it is the curving of the materials that causes the effects is hard. The children do like the lesson though. They like all the shiny things and they make discoveries at their own level.

*Examples of lesson situations:*

**Kindergarten groups:**
- Child finds that eyes mirror too. The children like this very much and spend some time staring in each others’ eyes.
- There is some fluid spilled on the floor (accidentally). The children notice this mirrors as well and find it pretty. Some notice that it mirrors differently under different angles.
- A 4-year old boy is looking at the spoon. He notices his image is upside down. He turns the spoon around (not turning the other side, but making the bottom the top and vice versa) and says: *“Hey, I’m still upside down!”*
- In one group it is very sunny during the lesson, so lights appear on the walls as reflections of the mirrors. The children notice this. The teacher does not go into it in this lesson, but mentions it after the lesson to me, because it comes back in the lesson about reflection later on.
- A girl mentions in the group that if her finger comes very close to the Christmas ball, it becomes very big. The teacher asks how that is possible and the children agree that it is because the mirror is convex (‘bol’). They cannot really explain any further.

**Grades 1&2**
- One child remarks that the transparent sheet does not mirror, but if she holds it in front of something, it does. This is exactly the concept central to the next lesson, where the children make a magic mirror with transparent sheets and colored paper.

One of the teachers lets the children walk past the work of the other children (the piles created during the final assignment). She wanted to share the experiences, but this does not work out well. It becomes a bit chaotic, with children walking everywhere and picking up materials, which is not the intention. Later, the teacher says she will not do it next time.
4.4 Lesson 3: The magic mirror

Summarized teacher instructions:

This lesson consists of making a craft, namely the mirror from the story of Snow White. Before making the craft the best material has to be selected, to make the best magic mirror.

1. Plenary: Start with the big circle. Read the fairytale of Snow White and the magic mirror. Do they think a mirror like that can really exist? From this you have to get to the ‘magic mirror’ we are going to make, how this is done is very personal.

2. Take the example and ask whether it mirrors. A little bit it does. The mirror is a little magic too, because it is made from something that does not mirror at all. Show the plastic overhead sheet. Does it mirror? No, but why does it mirror in the example then? Because it has paper behind it. Show different colours of paper. Which paper works best? You can already establish this more or less in the circle, or let the children work it out themselves later. (The darker the paper, the better the mirror.)

3. Individual: Make the ‘magic mirror’, but find the best colour of paper first. Usually this step is only done with a smaller part of the group in the case of the classes of 4 to 6 year olds. The craft consists of the constructions of a paper hand mirror, strengthened by card board or wooden sticks. The overhead sheet is glued over the part where the mirror usually goes. After that, the mirror is decorated.

Discussion lesson

The idea behind this lesson was to let the children make a craft with a scientific background, for which they first had to do some research. To get from the reading of the fairytale to doing the experiment, the teacher has a discussion with the children. In kindergarten the teachers usually choose to do the experiment/discussion plenary in the circle and then continue to do the assignment with a smaller group. The scientific idea behind the lesson is that a mirror is basically a sheet of glass with silver foil behind it. But a mirror also works when you have a dark color behind a glass sheet. You can see this in a window: if the room you look into is dark, the window mirrors very well. Also, a clear pond with a dark bottom is a good mirror. A clear pond with a white bottom is not a very good mirror. In this case
the overhead sheet serves as the glass/water and the colored papers as the background color. The lighter colors do work, but not as well as black. Usually, this results in the children picking darker colors, as you can see in Figure 17. In kindergarten most children choose dark blue, although black is also chosen. The dark blue is a compromise between the black they don’t particularly like and a nice color. This table has only one black mirror, usually the percentage is higher. In grades 1&2 the children choose black more often. Those children already want to do it ‘right’. One girl in kindergarten insisted on making a violet mirror, because it was her favorite color. The example in the lesson kit is red, to not give away the outcome already. See Movie 3 for a (subtitled) discussion in the circle where the children reach the conclusion black works best. A transcript can be found in Appendix G. The children are allowed to experiment themselves after that, resulting in all children choosing dark colors.
4.5 Lesson 4: The double mirror

Summarized teacher instructions:

Two mirror tiles have been taped together like a book. When opening and closing the mirror one can see multiplication and patterns.

1. All kids get a double mirror and walk around for a few minutes to “discover”.
2. Plenary in circle: What did you discover? Students tell their discoveries while other students imitate to try to see it also with their own mirrors. This imitation is not trivial, for example, students sitting across from each other have to “mirror” the mirror set up.
3. Teacher questions could be:
4. What do you see if you put something between the mirrors?
5. What can you do with these mirrors which you cannot do with a single mirror?
6. How many times is it multiplied?
7. What happens when you make the angle between the mirrors greater or smaller?
8. So what do you do if you want to see something many times in the mirror? (mirrors close together, small angle).
9. The students will come with many more discoveries, when imitating the position of the mirror, the teacher can see and verify.
10. The students receive a worksheet with a line and a dot. Just show them how to put the mirror.
    On the sheet is a line and a dot. You can make the angle between the mirrors greater and smaller and that way you can make a triangle out of the line and see 3 dots,
11. Individual: students now work with their lines and dots. They can also make a square and 4 dots (see photo below). If you almost close the mirror, then you can see many lines and dots.
12. Individual: the teacher distributes coloured beads and students can make patterns with the beads. Some students will make full use of the multiplier effect of the mirrors and create all kinds of symmetries. Some other students may not.
13. Students get a blank sheet where they can make a drawing with colours. Again some will make beautiful patterns with the mirrors and a few will not. See results on the photographs.
14. More: You can try to explain what happens with two mirrors. If you wink to yourself in the mirror, your mirror image winks with the other eye. But if you have double mirror, and you see
yourself multiple times, not all mirror images wink with the same eye. From this you can deduct that some mirror images, are actually mirror images of mirror images.

![Image of child drawings](image)

**Figure 18:** Results of drawing for 6-year old girl (left) and a 4-year old boy (right). Even the left-side drawing does not look very nice now, but with a mirror it gives a very beautiful pattern. This drawing was made by trial and error. The right-side drawing does not look like much at all, but this was done by a very small boy while he was looking in the mirror. He was making little lines, while concentrating very hard on the mirror image of his hand in the mirror. It looked like he was exploring the effect the movement of his hand had in the mirror more than that he was aware of patterns he was making. He spent ten minutes on this.

**Discussion lesson**

First, there is time for free exploration. Again, discoveries are shared and copied. Then there is a more focused assignment, which is also about exploring, but in a different way; to let the children take another approach. The level on which the children work varies greatly. Some children are just making a drawing and look in the mirror every now and then. Others really use the mirror in constructing their drawing. Some children like the beads very much and spend a lot of time making different patterns, some even continue working on this after the lesson ends.

In Movie 4 you see the group exploring the double mirror first. After that there is some footage of the children working with the beads. You see a boy discovering you can make a triangle (which is an
assignment for grades 1&2, but he discovers it on his own in kindergarten) and two girls working with the double mirror for a long time, experimenting with it and sharing their discoveries.

*Examples of lesson situations:*

**Kindergarten**
- One teacher gave the coloring materials and the beads at the same time. This resulted in some children making whole drawings and holding the mirror close to them. Others started to make patterns with the beads. Others were just simply drawing a couple of lines. The teacher walked around, gave positive feedback and made pictures.
- After the exploration phase the children were asked to come back in the circle. One girl walks towards the table in the centre of the circle and places the mirror next to the plants that are on the table. She is amazed by the fact you see more plants “all of a sudden”. She asks the teacher to come and see. Many children watch too and place their mirror next to the mirror of the first child. They create a large arrangement with the whole group (see Figure 20).

**Grades 1&2**
- The children are sharing their discoveries in the circle. A few children explain they made a box. The teacher asks to demonstrate and three children come forward to hold three double mirrors together such that they make a cube, with the mirrors on the inside. The children tell you can put things inside and then you see everything “many, many times”.
- One child holds the mirror very close together and puts it against his face, such that you see the mouth if you look between the two mirrors. The child holding the mirror bares his or her teeth and the person looking sees many teeth. In one class this was the favourite
game of the children. They like to scare each other with it.

Figure 21: Examples of drawings with double mirror from grades 1&2. On the upper left a student has drawn a caleidoscopie pattern. The upper right shows a start made of a few lines. The lower left is the start of a nice pattern and the lower right has some experimentation with symmetry and faces. These drawings are all made by one group.
4.6 Lesson 5: Reflection

Summarized teacher instructions:

In this lesson a flashlight or the sun is used to demonstrate how light reflects on a mirror. Children make a craft based on this principle, namely a disco ball.

There are two ways to approach this. If it is very sunny, getting a light to shine on your mirror is easy, they can all do it. If it is winter, darken the room as much as you can and use a good flashlight.

1. Plenary, big circle: Place a mirror on the ground or on the table. Show the flashlight. What will happen if we shine on the mirror? It reflects. But where does the light reflect to? Make a prediction. What happens if we shake the flashlight?
2. Do this several times with different positions of the mirror and the flashlight. Ask different students to help you.
3. What we learn here can be illustrated by a picture on the board of the mirror and the light beams. Let students come forward and draw the correct lines.
4. What happens if we add a second mirror? Can we catch the light coming from the first mirror and guide it towards the second mirror? Let a few students try.
5. Make it into a game. Choose a mark on the wall and try to let the light hit that spot via two mirrors. Let different students try this.
6. Show the small disco ball. Let the light shine on it. What happens here? Little lights all over the place! Why is that? Because the disco ball consists of many little mirrors.
7. Introduce the craft.
8. Individually: Make their own disco ball, by gluing small pieces of reflecting paper on a foam ball. You can hang the balls in the class room to make very many little lights.
9. More: Make a dark hut and put some flashlights and mirrors there. Students can experiment themselves. You can also make it into a game. How many mirrors can you set up for the beam to bounce of?

Discussion lesson

If it is sunny, the mirror reflects the sun. Otherwise, you can take the flashlight. The fact that there is
light coming from the mirror is already an interesting observation for the children. They like to follow the light and experiment with it. They are always very enthusiastic about the lights of the disco ball.

Examples of lesson situations:
- The teacher asks: "How is it possible a light comes out of the mirror?" and a child answers: "The sun falls on the mirror." (Kindergarten)

  - The group is in the circle. The teacher has the disco ball (the professional one) and gives it to a child. She makes it spin and you see all the little lights moving on the floor and the walls. The children react very enthusiastically to this and follow the lights. The teacher asks: "How is it possible we see all these lights?" And a child answers: "There are many little lights". The teacher asks: "Are we able to make this ourselves do you think?" The class is divided between yes and no. The teacher then picks up the example ball and gives it to a child. This ball is made from foam with pieces of silver foil glued to it. The child spins it and tries to make lights on the floor. When this happens, he reacts: "It makes bigger lights!" The teacher asks: "How is that possible?" Another child says: "Because you cut it yourself." This child thinks that the bigger the pieces of silver foil, the bigger the lights. Another child says: "What if you cut it smaller?" The teacher answers: "I don't know, let's find out!" (It is true bigger pieces of silver foil make bigger lights, but the spreading out of the lights is mainly due to the fact that the image is less sharp, because the silver foil is not a perfect mirror. The teacher probably does not know this. She handles the situation very well though, by making the craft into an experiment.) (Grades 1&2)

- They children are in the circle with the disco ball. A boy (5 years old) gets his turn to say something and he points to the ceiling. There you see the reflection of the sun on the water outside the school building (the reflection also moves with the ripples of the water). The boy says: “Look over there [points to ceiling], there is a light. The sun shines on the water on the ceiling.” The teacher repeats his words to the rest of the group (see movie 5). The boy notices the phenomenon spontaneously (which is not directly part of the lesson) and also gives the correct explanation. (Kindergarten)

In grades 1&2 you can go a bit further, by making the light beam go via several mirrors. In one class
the mirror game is quite extensive. A target is picked (the clock), two children both have a mirror and another child has the flashlight. When they work together they can hit the target. The whole group works with them. The teacher draws on the blackboard what happened and the children seem to understand. In the post-interviews most children used the word reflection (‘weerkaatsing’ or ‘weerspiegeling’) and say the light goes to the mirror and reflects back to (for example) the ceiling. They are also able to manipulate the light beam to a certain spot, partly by trial and error, but usually with a clear idea in mind of what is supposed to happen with the beam. In this grade they can anticipate the results of their experiments.
4.7 Lesson 6: Symmetry

Summarized teacher instructions:

This lesson introduces the concept of symmetry. Some objects and illustrations are the same on two or more sides.

1. Plenary, big circle: The picture of the tree is on the blackboard. The big mirror is placed vertically in the middle. What do we see? What happens when we place the mirror horizontally?

2. We have seen that the left side is the same as the right side. Explain that this is called symmetry. But the bottom half is not the same as the top half of the tree, so it is not symmetrical in that sense. There is a line on which you have to place the mirror to do it right. This we call the mirror line.

3. Can we find more things in the classroom that are symmetrical? What if we place the mirror on the ... (clock, picture of butterfly, table...).

4. Individually: Students get a worksheet with pictures of symmetrical things and a mirror. They have to find the mirror line (possibly let them indicate it on the worksheet).

5. Plenary: Discuss briefly what they have found. What about their own faces? Are they symmetrical? Try on your neighbour.

6. The pictures of half the trees (four in total) are put up on the blackboard. Let a student place the mirror on the ‘mirror line’. Which pictures make a whole tree with the mirror and which ones don’t? Explain the way they have to indicate later on their worksheets which ones are ‘correct’ and which ones are not (this is done with smilies, to prevent having to use words).

7. Individually: Students get the worksheets and a mirror and have to find out how the pictures are symmetrical. They indicate their results with smilies (happy or sad smilies).

8. For ages 6 to 8 there are more worksheets with more complicated assignments.

9. If there is time you can discuss the results. What did they find with the circle? Is it always symmetrical? What about the snowflake? Etc.

10. More: Make butterflies, snowflakes etc by folding paper and cutting them out. Where you fold is the ‘mirror line’. Put paint on paper and fold the paper together and open again, this gives a symmetrical figure. Mandala’s are colouring pages with large symmetrical figures. Can the students also colour them symmetrical?
Discussion lesson

The children first have to identify things that are symmetrical. Then they have to fill out worksheets which have half figures on them. They have to work out whether they become the asked for picture with the help of the mirror. See Movie 6 to see the children filling out the worksheets. There is much more possible with this subject and a lot of suggestions are added to the lesson plan, but sadly no teacher took the time to do more.

Lesson examples

Kindergarten
- The teacher lets only a small group work on the worksheets and lets the other (younger) children explore. One boy who is exploring finds several things that are symmetrical. See Movie 2, where you see the boy presenting his discoveries to the group (second part of the movie).
- All groups like the fact that your face is symmetrical too. They place the mirror on the faces of their neighbours.

Grades 1&2
- In one of the grades 1&2 groups, a child comes with the idea himself to put the mirror straight on the paper to make a whole tree in the plenary discussion in the beginning of the lesson. All children step forward to see the whole tree in the mirror.
- The worksheets are self explanatory for this group. The teacher does not really explain what they are supposed to do, they figure it out themselves. The extra worksheets are hard, but these are also figured out by a lot of children.
- A child starts filling out the worksheets without the help of the mirror. She has the insight to (successfully) decide whether a picture will be whole in the mirror or not.
- One child starts writing down things that are symmetrical on the back of one of the worksheet. After encouragement by the teacher, more children start doing this. In grades 1&2 the need (and ability) of the children to document things is greater.
4.8 Lesson 7

Lesson 7 is not the same for kindergarten and grades 1&2. The kindergarten groups play a game and the grades 1&2 dive deeper into the concept of symmetry.

The line game (Kindergarten)

Summarized teacher instructions

For the ages 4 to 6 there is an extra ‘lesson’, which is not really a lesson, but a game to stimulate the students to play some more with the mirrors.

A path is set out on the ground which the children have to follow. But they are not allowed to look at the line while they follow it, they have to look in the mirror. They can hold the mirror over their eyes, so they see the world upside down. The can walk backwards and watch the line in the mirror in front of them. They can hold the mirror against their stomach and bend over it to see the line. Maybe they can come up with another variation themselves.

Discussion lesson

This is the favourite lesson of most children. The idea behind it is to make the children more comfortable with the mirror, to make them aware of the fact that you can see something else in the mirror you cannot see elsewhere (for example behind you, which is a concept a lot of them did not grasp in the first lesson). They manage to walk the line, but the youngest cheat often and glance at their feet and do not look only in the mirror. Some children already find it very exciting to follow the line, let alone with the mirror. They do find other ways to hold the mirror while walking the line, to the surprise of some teachers. The scientific goal may not be as pronounced as in other lessons, but it certainly makes an impression on the children. Also, the children get practice in spatial operations in their head. They have to do left-right conversions and act against their intuition based on ‘evidence’ from their mirrors.
Symmetry in letters (grades 1&2)

Summarized teacher instructions

For the ages 6 and 7 there is one more lesson about symmetry. These children have already learned letters and letters can be symmetric or not.

1. Plenary: What is symmetry again?
2. Write a big $a$ and a big A on the board. Are these letters symmetrical? Where is the mirror line? One is horizontally symmetrical, the other vertically. How is this for the other letters of the alphabet?
3. Draw the following figure on the board:

   ![Figure](image)

4. These make three boxes: one box for horizontally symmetrical things, one box for vertically symmetrical things and the overlapping part for things that are both. Where do the $a$ and the A go?
5. Individually: Students get a worksheet with all the letters of the alphabet and the figure, plus of course a mirror.
6. Plenary: It takes too long to go through all the letters with everyone. Discuss a few and fill out the boxes on the board with the rest, so they can check their answer.
7. You now have a collection of letters that are horizontally symmetrical. These are fun, because of you make a word of them, the whole word is horizontally symmetrical. For example, I D E E (idea in Dutch).
8. Individually: Write words on the next worksheet that are horizontally symmetrical. After that, try the vertical symmetrical letters. Why are they less fun?
9. More: Introduce mirror writing. For this you can use carbon paper, but it is not necessary. Discuss what you see in the mirror if you have words on your shirt. What about the ambulance that has a weird word written on the front?
Discussion lesson

This is a difficult lesson for the youngest children in the group, because they have learnt the letters only recently. This creates a vast difference in tempo. This is neutralized by letting the youngest only do the horizontal letters and the older ones everything. They make a lot of mistakes, because they sometimes think they know, but don’t look too closely. This makes it necessary to insert a plenary discussion, but it takes too long to discuss all letters. This lesson is better broken in two, with the children continuing working on making words at a later time. Some children really enjoy the game of finding letters and words and others don’t care too much. In one group the teacher let children that were interested continue working on it and the rest did something else. There were 6 children (of 24) that continued.
4.9 Inquiry stages and process skills in mirror series

In the lessons developed for this Master’s research, inquiry cycles and process skills were taken into account. The inquiry stages mentioned below in Table 2 are from the inquiry cycle as developed by Van Graft & Kemmers (2007), in which the inquiry stages are: Confrontation, Exploration, Setting-up of experiment, Execution of experiment, Conclusion, Presentation/communication of results and Deepening/Broadening of subject. Not one lesson completes the whole cycle, because the “setting-up of the experiment” is not done by the children themselves. They explore and find a question, but the teacher guides them towards the experiment, in contrast with the lessons designed by Van Graft & Kemmers based on their cycle, in which the children first have to formulate a question themselves and then figure out an experiment to find an answer to this question. The inquiry cycle by Van Graft&Kemmers is meant for grades 1 and up, but to lighten the load for the teacher and children the decision was made to not include this step in the lessons. The inquiry cycle is not meant for Kindergarten, as expressively mentioned by Van Graft & Kemmers in their work, and is used here for reference and to show that this lessons series is a good preparation for working with the full inquiry cycle at a later stage in the education of these children. The children and teachers of grades 1&2 also do not have any experience yet with inquiry based learning, so this should also be seen as the preparation for more in depth inquiry in other lessons.

The process skills mentioned in Table 2 are from Holt, Rinehart & Winston (this is a publishing company with resources on the internet). They describe process skills as: “… a means for learning and […] essential to the conduct of science.”
<table>
<thead>
<tr>
<th>Lesson 1: Discover the mirror</th>
<th>All groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inquiry stages</td>
<td>confrontation, exploration</td>
</tr>
<tr>
<td>Process skills</td>
<td>observing, describing, communicating</td>
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</tbody>
</table>

<table>
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<tr>
<th>Lesson 2: Discovering more mirrors</th>
<th>All groups</th>
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</thead>
<tbody>
<tr>
<td>Inquiry stages</td>
<td>confrontation, exploration, execution of experiment</td>
</tr>
<tr>
<td>Process skills</td>
<td>observing, describing, communicating, classifying, comparing</td>
</tr>
</tbody>
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<tr>
<th>Lesson 3: The magic mirror</th>
<th>All groups</th>
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</thead>
<tbody>
<tr>
<td>Inquiry stages</td>
<td>confrontation, exploration, execution of experiment, conclusion, presentation/communication of results</td>
</tr>
<tr>
<td>Process skills</td>
<td>observing, describing, communicating, hypothesizing</td>
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</tbody>
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<table>
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<tr>
<th>Lesson 4: The double mirror</th>
<th>All groups</th>
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</thead>
<tbody>
<tr>
<td>Inquiry stages</td>
<td>confrontation, exploration</td>
</tr>
<tr>
<td>Process skills</td>
<td>observing, describing, communicating, spatial reasoning, predicting</td>
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<tr>
<th>Lesson 5: Reflection</th>
<th>All groups</th>
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<tbody>
<tr>
<td>Inquiry stages</td>
<td>confrontation, exploration, execution of experiment, conclusion</td>
</tr>
<tr>
<td>Process skills</td>
<td>observing, describing, communicating, predicting, inferring</td>
</tr>
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<table>
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<tr>
<th>Lesson 6: Symmetry</th>
<th>All groups</th>
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</thead>
<tbody>
<tr>
<td>Inquiry stages</td>
<td>confrontation, exploration</td>
</tr>
<tr>
<td>Process skills</td>
<td>observing, describing, communicating, spatial reasoning, comparing</td>
</tr>
</tbody>
</table>
Lesson 7: Symmetry in letters

<table>
<thead>
<tr>
<th>Inquiry stages</th>
<th>Grade 1&amp;2</th>
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</thead>
<tbody>
<tr>
<td>confrontation, exploration, execution of experiment, conclusion, presentation/communication of results</td>
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</tr>
<tr>
<td>Process skills</td>
<td>observing, describing, communicating, comparing, reading, classifying</td>
</tr>
</tbody>
</table>

Lesson 7: The line game

<table>
<thead>
<tr>
<th>Inquiry stages</th>
<th>Kindergarten</th>
</tr>
</thead>
<tbody>
<tr>
<td>confrontation, exploration</td>
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Process skills | spatial reasoning, inferring

Table 2: Overview of the inquiry stages and process skills that are present in the mirror series. For lesson descriptions, see chapter 4.
5. Results

In this chapter, the results of observations and interviews are presented. The first cycle, with one Kindergarten group and one grades 1 and 2 group testing the materials, was done during the developmental process, with the teachers also giving feedback during the series (in section 5.1). The second cycle was done with the revised and finalized lessen series (in section 5.2). When both cycles were completed, a few post-experiments were done with students, to evaluate the learning process. This is reported on in section 5.3.

5.1 Results of cycle 1

In this cycle, the materials were in development. All lessons were observed by the developer, but given by the teacher of the group. After the lesson series was finished, teachers and students were interviewed. In this section a report on the observations and interviews is given.

5.1.1 Cycle 1 in Kindergarten

The first cycle was the pilot run. The developing was done during the course of the lesson series, to incorporate ideas picked up during the previous lessons. Two groups, one kindergarten group and one grade 1/2 group (mixed class age 6-8), entered the project at this point. A few days before the lesson the teacher would get a lesson plan. The material would be provided half an hour before the lesson started (brought in by the developer). After every lesson the lesson was evaluated, usually also very shortly with the teacher. For the definitive lesson descriptions see chapter 4.

To get a preliminary answer to the research questions, observations were made during the lessons by the developer. The observation of these lessons were aimed at:

1. observing what works well, what can be improved and what does not work in the developed (developing) materials
2. observing what the teachers do with the materials, in other words: do they strictly follow the given procedure or do they invent their own lesson around the given suggestions?
3. observing whether the children are capable of doing the assignments, how long they can stay focused, and whether they are enthusiastic about the lessons.

This should result in preliminary answers to the research questions. The goal of cycle 1 though, was to evaluate the lessons for a revision, resulting in definitive teaching materials.

The kindergarten group started first. The first lesson was just handing out mirrors (mirror tiles from the hardware store) and letting the children discover the mirrors themselves. This went excellent. The
teacher was instructed to just give the children time to freely explore their (individually given) mirrors and walk around with them and just see how that went. If it would be interesting for the children for only ten minutes, so be it. But it turned out the children discovered dozens of things and were also very well able to talk about that in the group (in the 'kring'). In Dutch primary schools students are collected in a circle (the 'kring') for a group discussion quite frequently. The teacher asks a question and the children react with their experiences and answers and react to each other as well. In this case, the teacher would give every child the opportunity to tell his or her discovery and then proceed to copy that discovery with the whole group. Please see chapter 4 for a more detailed description of the lessons and the discoveries the children made.

After the first success with this very simple lesson, the lessons became a little more complicated (more structured, more materials). But all lessons went very well. The teacher of this group was a very experienced woman. She had no trouble with any of the subject matter. She was also able to improvise quickly, for example when the lesson with the beads came up (the double mirror). Her class was also very enthusiastic. All children participated actively, even the very young ones (there was one boy who did not speak Dutch yet - his parents do not speak Dutch - but he also contributed to the group discussion in his own 'language'). The youngest children (4 years old) are often still in their own little world. They walk around dreaming and do not actively seek contact with others. When they become older they are more inclined to work together and to look at what others do for ideas. The mirrors were still wondrous things for the young ones. For them, it was already a pleasure to just look in the mirror and make funny faces, but they also discovered the world upside down and look at the ceiling and your feet etc. What they cannot do is look behind themselves or look via two mirrors. The oldest ones sometimes were able to grasp these concepts, but often enough they only understood up to a certain level (for example that they see something via two mirrors), but in another situation they could not (for example if they were asked what it is they saw later on), so there was apparently no real comprehension.

5.1.2 Evaluation after interview children after cycle 1 in Kindergarten

After the last lesson the children were interviewed very shortly about their experiences in groups of three. There were groups of three, because the children are more uncomfortable when it is just an interviewer and themselves and there was supposed to be an atmosphere of openness and discovery. It was hoped there would be some interaction between the children. Also, it would have taken too much time to interview everyone separately. This has the downside that it is very noisy and animated, with children talking through each other and some children not getting the chance to express themselves fully. It is sometimes hard to establish what exactly is their own idea and what is their neighbour's. Please see the full interviews on video in appendix E..

The questions central to the interview were:
How much do the children remember of the lessons?

Do the children use science specific language appropriately and with understanding?

Are the children comfortable with the scientific equipment and use them appropriately?

Do the children evaluate, interpret and share their (scientific) findings?

Is there evidence that children have made progress in their scientific knowledge and skills?

Is the children's interest in science been aroused?

(adapted from "Mentoring in Primary Science", SCI centre, 1998)

Not one of the questions was directly asked. The aim of the interview was to find out how much the children remember of the lesson series and sometimes try to get them as far as giving an explanation for certain phenomena. From observing the children’s behaviour and attitude during the interview and analysis of their answers, the answers to the abovementioned questions were inferred.

18 children were interviewed (and videotaped).

*How much do the children remember of the lessons?*

The children clearly remember a lot about the mirror series. The interviews were done a week after the last lesson. The last lesson was after Christmas, the earlier lessons were before the Christmas break. So the first lesson was 2 months ago for the children at that time. For a child of four years old, this is a long time. You can even see the development some children have gone through in that time (for example, the progress in language skills). As one of the kindergarten teachers said during an interview, "the children usually don't remember what we did yesterday, so it is quite special they remember this much".

The line game (lesson 7) got the most spontaneous mentions when the children are asked to tell about the mirror series. This was also one of the last activities. They were allowed to go outside the classroom for this and they had to go in line to do it. This probably has something to do with the impression it all made. But most of the other lessons are also spontaneously mentioned, such as the double mirror and the disco ball. After reminding the children of a few elements of the lessons, they were almost always able to reproduce the lesson quite accurately. They also enthusiastically show findings and discoveries they did during the lessons again, often unbidden.

The children remember the mirror lessons long afterwards, because when I would run into one of the children months later they still asked whether I would come to do mirror lessons again. See movie 8.
for an example of an interview, in which the children tell what they did. One girl explains very detailed how the magic mirror was made, one boy knows you have to add a color to the plastic to make a mirror and another girl is still fascinated by the double mirror.

Do the children use science specific language appropriately and with understanding?
The language the children use is still very basic. They do not use words like reflecting or light rays or multiplication. It's all about 'little lights', 'seeing myself more times', 'if you do it like this...'. Many children have a hard time distinguishing between 'spiegelen' and 'glimmen' (mirroring and sparkling). These are often used interchangeably. The teachers also did not put any emphasize on this during the lessons, but they did not pick it up spontaneously.

Are the children comfortable with the scientific equipment and use them appropriately?
The children are very comfortable with the mirrors. They pick them up and hold them in various positions easily. Many children start experimenting immediately. Some even suggest new experiments spontaneously.

Is there evidence that children have made progress in their scientific knowledge and skills?
During the lessons, the children would share their discoveries with the group. All children then copy the position of the mirror as shown by the explaining child. This takes a certain insight, because often the children would sit on the other side of the circle and would have to mirror the child sitting opposite. The children also observe very carefully. For example, a 4-year old girl found a little button on a dress that mirrored. The teacher first did not believe her, but she proved it to her by holding it very close to her eye.

During the interview, most children were able to show and tell that the closer the mirrors of the double mirror are together, the more images you see. They could manipulate the mirror in such a way it showed exactly five images, or ten or whatever. A lot of children were able to reproduce the procedure of the making of the magic mirror and a couple of them were able to explain that there has to be a color (or better, a dark) color behind the plastic to make a mirror. I have the feeling more children know this, but they had difficulty with the question ("why does it work?" is a difficult question). With a more focused approach ("Which one of these colors would work best?") I think most children would have gotten the right answer, but I did not think of it at the time and it would also have been very time consuming. One boy said: “I looked with the black en then it worked. But only sometimes, just like yours” (“Ik keek met zwart en toen deed ie het wel. Maar soms, net als de jouwe”). “Yours” is the example I made, with red paper. In any case, all children but one chose a dark color for their magic mirror in the lessons, a lot of them even black (while the example was red, I did that on purpose of course), so they all saw it then. One girl insisted on violet, it being her favorite color.
How reflection works was not clear to most of the children when speaking to them in the interviews. In the movie of one of the lessons you see a boy explaining it (“Because the disco ball has little mirrors”) and continue with pointing out that the ditch in front of the window reflects the sunlight towards the ceiling of the room. He obviously got it, and during the interviews some children were able to explain that the disco ball is (has) small mirrors and they sparkle or make little lights. It must be said that the children that were interviewed had a very short lesson about this. This concept should be repeated and not mentioned only once. The disco ball with the little lights did make an impression though, they all remembered during the interview.

Do the children evaluate, interpret and share their (scientific) findings?

During the interview, the kindergarten children do not share their findings or work together. In the lessons I have seen it, but only in the older children. They look at their neighbours to see what they are doing. For example, while making the drawing with the double mirror and before that, putting down the beads in patterns, several of the older girls shared their findings and also drew the same things (one girl made the most beautiful things, which the rest copied). They also very rarely put their mirrors together to get more reflections. (For grades 1&2 the situation is completely different. At 6-8 years old, they enjoy it very much when they are allowed to work together and they start doing it immediately when the opportunity presents itself.)

Is the children's interest in science been aroused?

The children were all very enthusiastic and focused during the lessons. They are able to reproduce in words and acts many aspects of the lessons. When asked they all claim they liked the lessons a lot. Months later, they would still ask whether there would be more mirror lessons soon. The teachers confirm that the children liked the lessons and referred to mirrors at other moments as well:

> [...] mirroring and reflecting... They were having it at the back of their head all the time. At one point they would see that the picture books gave little lights and that same thing came back everywhere. They would walk past something with mirroring effects and they would say: Oh yes! At the viering [a weekly ceremony during which children show their work, usually in the form of theatrical or musical work] the children would look into a window... [and would spontaneously mention that it mirrors] That was very funny. It really stuck with them. They knew the exact order of the lessons and what we did in them.
> (Kindergarten teacher)

5.1.3 Cycle 1 in grades 1&2

Parallel with the Kindergarten group, the lesson series was adapted for grades 1 and 2 and tried out in
a group of students by another teacher, while being observed by the researcher. The teacher of that group has some experience with inquiry-based science learning due to her involvement in the "Leren Ontdekkend en Onderzoeken Leren" project the year before. She followed a two day training course at that time.

**The start**
The teacher started very originally. She took a little pocket mirror from home and now brings it out, saying it is a magic mirror. She does not allow anyone to look at it very closely. The mirror is magic, because it can remember faces. The teacher orders her class assistant (who is present during some lessons and also gives one of the lessons) to go outside the room. She then picks one child and tells her to look intensely in the little mirror. The mirror will remember her face. After the mirror has had enough time to remember, the class assistant is called back. All children are very quiet when the class assistant returns and start looking in the mirror to see the face there. Her guess is correct in one try (she has guessed by very cleverly looking at the body language of the children. The chosen girl starts tugging her hair, when the class assistant mentions something about hair etc.). The teacher pockets the mirror again and does not bring it out anymore. She then starts the real lesson. A girl later asks whether she can see the magic mirror, halfway believing and not believing.

Maybe this is not a very scientific way to start a science lesson (the magic mirror does not come back in this form during the lesson series and it is never questioned whether what happened is real or not). But it certainly is entertaining and it caught the attention. It also shows initiative from the side of the teacher. She has thought about it and brought her own things to implement it. It was also very well executed. The whole thing was not discussed in advance by the teacher and class assistant, it was pure improvisation. It is of course a pity the teacher does not do anything with it later, but it is an attention grabbing way to start.

**The lessons**
The lessons were all characterized by the intensive attention of the children and the extensively sharing of experiences during the group discussions. The teacher was able to lead the discussion in such a way that all children got their turn, while still keeping it brief and businesslike. She was very emphatic. For her everything was new too, and she considered this a bonus, saw everything as a surprise for her too. All discoveries were put down on the board in a long list.

**Differences between kindergarten and grade 1&2**
The children in grade 1&2 were able to do more with the material. The are eager to work together, with the children spontaneously building structures with five or six mirrors at the same time (from five or six children) and they are better able to remember what they have done or discovered (in the kindergarten group you sometimes saw children do something interesting, but if you would ask later, they already forgot) and are better able to express that. They also have the natural inclination to write things down (or make drawings). Some girls would spontaneously get paper and pen to write
down what they did in the lesson. The teacher facilitated this further, by making sheets where she already wrote down the discoveries (taken from the list on the board), with room for a drawing of the situation (which is a good idea, because in words often it is not clear what position the mirror exactly is in). This led me to make more worksheets with room for comments and drawings to add to the teacher manual and to just make a general worksheet booklet with all the work done in the mirror lessons.

**Teacher science knowledge**

The teacher is sometimes lacking in background knowledge. For example, she was in the middle of the lesson about reflection and a boy was trying to test whether his 'disco ball' reflected light. The teacher was trying to help him by pointing the flash light at the ball, but she did it from above. The reflection of the mirrors then will bounce back into the room. She should have pointed it from below, then the reflection would have fallen onto the table. It must be said that most children were capable of doing this themselves, so the lack of knowledge did not affect the quality of the lessons much. Also, she is a very good watcher and listener, so in the group discussions she was able to grasp exactly what the children meant, even though she had never seen it before or could explain the phenomena.

5.1.4 General evaluation of cycle 1

**Teacher preparation**

The teachers got very little time to prepare for the lessons, because the lessons were developed during the series. Often I got the impression they only spent maybe 5 minutes to read through the instructions on the lesson plan, so they apparently did not feel the need to do a lot of preparation. Often the lesson plan was kept at hand during the lesson, to read the instructions on the spot and implementing them at the same time. Of course, the developer was present during all lessons, so in case something was not clear or went wrong, there was possible backup, so this may have influenced the teachers light hearted way of preparing. But the backup proved unnecessary for the most part. There was of course some talking during the lesson between the teacher and the developer in moments of peace, to evaluate the situation or just to say something encouraging, but there was no input of the developer directly in the lesson. This proves that the lesson plans are virtually preparation free.

The materials are collected in a box. Not everything needed for the lessons is present in the box though, because some things are used in the lessons. This will take preparation time. The second cycle should prove how much of a burden this is. This first time everything was brought in before the lesson by the developer.

**Teacher input in design and revision process**

The teachers provided useful feedback on the lesson in the sense of saying 'split this up' or 'maybe
some suggestions in your lesson plan about this or that'. They did not have any influence on the content of the lesson series. One of the teachers said afterwards that this lesson series was not something they could have thought of by themselves. In the very first meeting with the teachers of this school this was already one of the main reasons to ask an outsider to make this lesson series. The teachers would like to do more with science in their curriculum, but they lack the science background to do so. During the developmental process it became clear to the developer that the teachers were indeed right that it would be very hard for the school to develop lesson materials like this by themselves.

**Children's interest in lessons**

The teachers reported that the children liked the lessons very much. This was also the impression during the observed lessons. Some children sometimes had a little trouble with the assignments, but never all children in the class. Of course, some things that are suitable for a 6-year old are not suitable for a 4-year old. All in all the impression was that all children were focused on the content of the lesson, even in the cases where they did not really understand the assignment at a level that was needed to really advance in the subject matter. In every lesson all children were concentrated on the lesson for at least 45 minutes. Usually they got a little rowdier at the end of the lesson, but this did not lead to shift of attention to other things. This also indicates that the children like the lessons and the lessons are on a suitable level.

Interestingly enough there were lessons that the kindergarten group actually performed at a higher level than the grades 1&2 group. For example, the lesson where they make a 'magic mirror', the kindergarten children understood the assignment quicker and were able to deliver better looking mirrors than grades 1&2. The teachers explained this by saying that the kindergarten children are always busy crafting, so it is an easier assignment for them. The children of grades 1&2 experienced more anxiety and insecurity for the unfamiliar assignment. This does not mean they were not able to do the assignment, just that the expectation would be that grades 1&2 have less problems with any assignment than Kindergarten, which is not always the case.

To get back at the aims for the observation mentioned at the beginning of this section:

1. **observing what works well, what can be improved and what does not work in the developed materials**
   All lessons worked, although some could be improved. The lesson plans and worksheets are revised.

2. **observing what the teachers do with the materials, in other words: do they strictly follow the given procedure or do they invent their own around the given suggestions?**
   The teachers did follow the lesson plans rather strictly, but this was to be expected, because this is what we were testing out. They did improvise in small ways during the lesson and were able to convert the minimal directions in the lesson plans (just some suggestions of what kind of questions they could ask to get the discussion going) to a real group discussion.
3. observing whether the children are capable of doing the assignments, how long they can stay focused, and whether they are enthusiastic about the lessons

As already mentioned, the children were definitely capable of doing the assignments. The lessons generally took 45-60 minutes, during which all children participated actively in some way. The teachers report the children like it and when asked the children confirm this. Please see above for more details on the interviews with the children.

5.2 Results of cycle 2

5.2.1 Overview

In the second cycle the teachers got a manual with lesson plans, background material and work sheets (see appendices A, B and C) and the box of materials. The idea was to test whether the material was sufficient to teach the lesson series independently (without any outside help, although they could confer with their colleague teachers) and what exactly they would do with it. The lesson plans are rather strict, but the introduction in the manual explicitly says that the teacher can change anything he or she likes. Furthermore, there are suggestions at the end of each lesson plan to do more with the material. About 75% of all lessons taught were observed by the developer and/or outside observers.

Questions central to the observations were:

*About the teachers:*

- Are the lesson plans strictly followed or is there improvisation and contributions by the teacher?
- Are children's responses to questions evaluated, explored and developed?
- Are children's alternate views or misconceptions noticed and responded to?
- Are suitable resources and equipment prepared, well organized and efficiently presented?
- Are children encouraged to bring their own scientific experiences to the lesson?
- Does the teacher show a clear understanding of the science covered?
- Are productive questions used to move children on in their scientific thinking throughout the lessons?
About the children:

- How much do the children remember of the lessons?
- Do the children use science specific language appropriately and with understanding?
- Are the children comfortable with the scientific equipment and use them appropriately?
- Do the children evaluate, interpret and share their (scientific) findings?
- Is there evidence that children have made progress in their scientific knowledge and skills?
- Is the children's interest in science been aroused?

About the materials:

- Are all materials needed for the lessons present in the case?
- What improvements can be made to the lesson plans, work sheet and other parts of the manual?

5.2.2 Cycle 2 in Kindergarten group 1

The lesson series manual and materials were given to a Kindergarten teacher, who tried it out in her group. Below is the general impression from this evaluation round.

Method

- Two lessons were videotaped.
- Four lessons were observed
- Three different observers were present during different lessons
- Post-interview with teacher

General impression

There are a lot of girls in this group and only one child that is really very young. This group discovered fairly quickly that they could look behind themselves with the mirror, the only kindergarten group in which it was a common discovery. The group discussions were less lively, perhaps because of the teacher (see below), but the children worked very focused and also at other times during the week, when they would make drawings and play with the materials that were put out in a special corner of the room. The teacher did not like the idea of cameras in her group, so most lessons were done
unobserved, some were done with observer and two were done with cameras present.

The teacher

A. is an experienced teacher, but still sometimes unsure of her teaching. Her class has a lot of girls and possibly therefore have a more quiet nature. A. herself is also very calm. She remains seated often during the exploration. She always holds a mirror herself, sitting or standing up, and 'mirrors back' at the children. She does not say much during these phases, but encourages the children quietly. She mentions in her interview that she likes it that the children are encouraged to investigate and do not give up when it does not work immediately.

Are the lesson plans strictly followed or is there improvisation and contributions by the teacher?
The teacher prepares well for the lessons, always making sure she has all the materials at hand. She does stray from the lesson plans though, especially in the sense that she lets smaller groups work on the assignments. Sometimes she only lets the older children in the group do the assignment (and does the introduction and/or exploration with the whole group) and sometimes she lets the children take turns. She contributes materials for lesson 2 to the lesson kit permanently. In the interview she suggests more scientific subjects she would like to explore with her group (namely floating & sinking and magnets - having magnetized strips on the wall and do something with that).

Are children's responses to questions evaluated, explored and developed?
This can be improved. The teacher manages to create a very safe environment for the children, but she sometimes does not continue on things the children bring into the discussion.

Are children's alternate views or misconceptions noticed and responded to?
The children confuse sparkling and mirroring often. There is no discussion about this, although the teacher sometimes asks: does it really mirror? There is also confusion about shadows. One says at one point: "The sun mirrors too." The teacher asks what he means and he says: "My shadow". (It's a very sunny that day.) A lot of children start looking at their own shadow and a girl says: "You can see yourself too." The teacher does not continue this conversation. It might very well be some children get the impression your shadow is the same as a mirror image.

Are suitable resources and equipment prepared, well organized and efficiently presented?
Yes, all lessons are prepared very well. This is probably an effect of the insecurity of the teacher. She thinks about the organization of the lesson in advance and rarely has to improvise. She also prepares extra worksheets for the children to work with during the week, besides the lesson materials for the mirror lessons.

Are children encouraged to bring their own scientific experiences to the lesson?
All children get the opportunity to tell their discoveries, but the teacher does not encourage some children to tell things she has seen them do. She does not notice when children do something special.
But she does create a very safe environment, in which all children feel secure to say something in the discussion.

*Does the teacher show a clear understanding of the science covered?*
This is hard to establish. She sometimes does not correct misconceptions (see above), but also does not seem to be having a hard time with the concepts of the lessons. The lesson about reflection, the one that leans most on the knowledge of the teacher, was not observed.

*Are productive questions used to move children on in their scientific thinking throughout the lessons?*
Sometimes she does, and other times she doesn't. She does not ask many second-round questions in the circle. She sometimes asks: "Why is that?" or "How does it work?", but does not continue after a child has answered that. She also does not make it into a real discussion. But when the children were working with the double mirrors and the beads, she walked around and gave positive feedback, suggested things etc.

**The children**
The teacher reports that the children are very enthusiastic. One girl painted the line game spontaneously later. The children were not interviewed after the lesson series and only a couple of lessons were observed. The children seemed involved, explored and were capable of doing the assignments. They came with original things, like putting the double mirrors around a plant and finding symmetry in a dice in the first lesson.

Children of this group were involved in the experiments described in section 5.3.

**5.2.3 Cycle 2 in Kindergarten group 2**

Another teacher tested out the same materials in her Kindergarten group. In this section are the results of this test round.

**Method**

- All lessons were videotaped
- Four different observers were present during different lessons
- Post-interview with teacher

**General impression**
The lesson series was extremely successful. The teacher is excellent and the group of students enthusiastic.
The teacher

M. is very young, but not insecure. She is very good at getting the children to pay attention by asking lots of questions and teasing them a little bit. She often says things like: “That’s impossible, to see behind you when you are looking in front of you...”, at which a child then react: “Yes, with a mirror you can!” or she says “I think this one is the best!”, when using the yellow sheet in lesson 3 (where it is in fact the worst color to use), to get a reaction out of the children as well.

Are the lesson plans strictly followed or is there improvisation and contributions by the teacher?
There are no actual contributions to the materials, but she takes the freedom to do things differently. For example, she lets only a smaller group of children work on the disco ball and the worksheets of the symmetry lesson. The whole group participates in the exploring and discussing. One boy of the younger group who is not included in the worksheet group is allowed to explore more since he expressed a lot of interest. The teacher later lets him tell the whole group about his discoveries and later tells me she was very impressed with his work, since he usually is a bit unfocused.

Are children’s responses to questions evaluated, explored and developed?
This teacher is very good in getting the children to think about their discoveries and questions. (like the example above, where the teacher says: “That’s impossible! You cannot look behind you if you look in front of you.” And a child answers: “Yes it is. With the mirror you can.”) She pushes the children to take a stance. She poses questions and reacts spontaneously to their remarks. The only criticism would be that she does not use scientific language a lot. She stays with ‘sparkling’ (glitteren) and “little lights” (lichtjes), but perhaps this is on purpose, since it is only Kindergarten and she does not feel it necessary to do this now.

Are children’s alternate views or misconceptions noticed and responded to?
The teacher does not correct the children’s language (see above), but she discusses many concepts in the lessons quite thoroughly (for example the discussion of the magic mirror at the start of lesson 3, see movie 3 and the discussion of the disco ball in lesson 5, see movie 5).

Are suitable resources and equipment prepared, well organized and efficiently presented?
Lesson 2 (more mirrors) is prepared with help of a colleague who is also doing the mirror series. For lesson 6 (symmetry) a nice booklet is made for the children. Sometimes she does not spend much time in preparation, but this does not seem to hinder her, because she can implement the lessons as we speak. She also mentions that she did not have a lot of time to prepare and she would have liked to spend more time on it, but is did not diminish the quality of her lessons.

Are children encouraged to bring their own scientific experiences to the lesson?
The teacher said in the post-interview that during the week children would tell her about mirroring phenomena they had seen in their environment. She gives room to all children to tell what they discover during the lessons. In lesson 6 (symmetry), she lets a boy explore and find more symmetric
things in the class room and show them to the whole group later. In lesson 5 (reflection) a boy tells about the light he sees on the ceiling (which he correctly explains as coming from the reflection of the sun on the water outside the school building).

**Does the teacher show a clear understanding of the science covered?**

Not specifically, but no mistakes are made. She mentions in the post-interview that she would not have had sufficient scientific background to make a lesson series like this.

**Are productive questions used to move children on in their scientific thinking throughout the lessons?**

Yes, the teacher is very good at asking questions and getting student to think. For example, in lesson 3 she is leading the group discussion towards the insight that dark colors work better for the magic mirror. When showing the plastic sheet:

Teacher: “Do you see that?”
A child: “I don’t see anything.”
Teacher: “What do you see?”
Another child: “You.”
Teacher: “Me?? Is that because you see me or because you can see through it?”
Another child: “Because you can look through it.”
Teacher: “Because you can look through it. How can we make it into a mirror?”
Another child:: “By adding a color.”
* (excerpt Movie 3)*

**The children**

The children were very enthusiastic through all lessons and very involved and focused. The teacher reports they were talking about mirroring phenomena during the rest of the week. The group was very mixed, about equal boys and girls and large differences in development and interest. Because this lesson series was videotaped we were present and this signaled a new ‘mirroring lesson’ for the children and we were always welcomed with great enthusiasm. The teacher would sometimes ask what they did in other lessons and they could also reproduce this quite easily.

Children of this group were involved in the experiments described in section 5.3.

**5.2.4 Cycle 2 Grades 1&2**

To further evaluate the materials developed for grades 1 and 2, another teacher was given the manual and the materials. She tried it out in her grades 1&2 group (a mixed group). The results of this test round are described in this section.
**Method**

- All lessons were videotaped
- Post-interview with teacher
- Post-interviews with about half of the children in the group

**General impression**

The timing of the lesson series was a bit unfortunate, because the group had just been moved to a new location, with a smaller classroom and just a lot of hassle because of the movement in general. It was also very warm (over 30 degrees Celsius), so the teaching environment was not optimal. Furthermore, this is a much smaller classroom (a temporary place), so there is less room for the ‘kring’ and the walking around. The sounds are also quite hollow and oppressive. The group is sometimes permitted to use the hallway for their work, but they have to be rather quiet, because other class rooms are very close.

Apart from this, the lesson series went very well. All the children were very much involved and motivated. Only five lessons were given, the children would have liked more. The teacher was happy with the materials and fully capable of using them with the teacher manuals. She did not have time to prepare very well, which was usually no problem, but she missed the fact that she needed to provide the foam balls for the reflection lesson herself. The making of the mirror balls then had to be done at another time and was not finished even then.

**The teacher**

The teacher of this group has some experience from a prior project in inquiry science teaching. She is young and enthusiastic. The teacher mentions that she was not at her best due to the warm weather and that she did not have enough time to prepare the lessons and develop other activities. She would have liked to have done more with the materials. In the interview she mentions for example the making of poster presentations and a more permanent corner in the class room devoted to the mirrors. This would also have resulted in more involvement of the parents, who would have noticed it while picking up their child.

Are the lesson plans strictly followed or is there improvisation and contributions by the teacher?
The teacher decides to skip two lessons, namely lesson 3 and lesson 7. This is also suggested in the teacher materials as a way to save time if that is a problem.

Are children’s responses to questions evaluated, explored and developed?
Sometimes. For example, in lesson 6 about symmetry: The teacher allows children to speak about their discoveries, but she does not invite discussion. She is rather strict when the children are in the ‘kring’ and only lets each child tell a little. But at the start, when the big half tree is on the blackboard, she invites a boy to come to the board and do ‘something’ with the mirror and the picture. She does
not say what or even what the goal is. He gets the idea to put the mirror on the picture and after a little thinking he does so ‘correctly’, thus making a ‘whole tree’. All the children of the class are then invited by the teacher to come and have a look. She also suggests that all the children write down their discoveries in that lesson, after she sees a girl do that out of her own volition. At the end, there is some discussion between the children about which answer is correct on the worksheets. She solves this by letting them do it again with their mirrors.

*Are children’s alternate views or misconceptions noticed and responded to?*

The discussions during the lessons are usually a little superficial. The children get the chance to share their discoveries, but she keeps it quite strict and there is not real discussion. She also does not come back to discoveries she has seen the children do in the exploratory phase, but which they do not mention spontaneously in the group discussion.

*Are suitable resources and equipment prepared, well organized and efficiently presented?*

In the post-interview the teacher mentioned that she did not have much time to prepare and sometimes also felt unprepared a little. In lesson 5 (reflection) she did not see they would need foam balls for all children, thus making that assignment at that moment impossible. This was also due to the fact that they just moved to another building and that it was the end of the year, plus extremely hot (over 30 degrees in the classroom).

*Are children encouraged to bring their own scientific experiences to the lesson?*

The children are encouraged to tell about their discoveries, but possibly because of the shorter time span of the lessons and the general lack of time during the lessons there is not much.

*Does the teacher show a clear understanding of the science covered?*

This is hard to establish, since there were few lessons and there was not a lot of discussion during these. There were no obvious mistakes made, but the discussions were short and not very many.

*Are productive questions used to move children on in their scientific thinking throughout the lessons?*

The discussions are usually short, but she lets the children think for themselves, as is shown in the example above of lesson 6 (symmetry lesson).

**Interviews with students**

About half the children in the group were interviewed afterwards about their experiences in the lesson (15 children total). They were also asked to hit a target with a flashlight, via one mirror.

*How much do the children remember of the lessons?*

They all remember the lessons very clearly. They spontaneously demonstrate various positions of the mirror and can recall the various assignments in the lessons. It varies a lot what they come up with in the first instance. Some mention the symmetry assignments, others the double mirror, others the
kaleidoscoop, others the reflection and the disco ball.

_Do the children use science specific language appropriately and with understanding?_
They use the word reflection ('weerkaatsing' and 'weerspiegelings') frequently and sometimes mirror image ('spiegelbeeld'). The word symmetry did not stick, although they do remember the assignment clearly.

_Are the children comfortable with the scientific equipment and use them appropriately?_
The children immediately start positioning the mirrors (usually more than one) in specific arrangements. They are all able to hit a target on the wall or ceiling with the flashlight via the mirror.

_Do the children evaluate, interpret and share their (scientific) findings?_
They like working together, they explain what they are doing during the experiments and name what it is they see exactly. They come up with other arrangements, so this means they interpret the results in some way (they are able to predict that something could be interesting).

_Is there evidence that children have made progress in their scientific knowledge and skills?_
They are able to make a start with explaining certain phenomena. During the interviews they are asked to explain the multiple images in the double mirror, and one girl says: "That mirror mirrors that edge, that mirror mirrors it like that [points back at the first mirror] and that mirror mirrors there again [points to the second mirror] and they go opposite each other." Another girl says: "Well, the mirror mirrors on that mirror, and mirror mirrors on that mirror, and that mirror mirrors on that mirror, and that mirror on that mirror and makes a lot of mirrors!" A boy says: "Because it reflects." Others show instantly that if you put several mirrors together and you put you hands between them you see a lot of hands, put after asked why that is, they don't know. One boy says he 'does not have a clue'.

During the interview the Christmas ball was presented to the children again and they enjoy very much that they see themselves distorted. They like the effect the double images have (they find the patterns very beautiful). They understand this is because the ball is spherical. After being pointed out they see the whole environment differently; they notice for example that the hallway is very long in the mirror, but not in reality and they also explain this by saying the mirror is rounded. Most children are not able to get any further. One girl adds that this sort of stretches the image. Another girls says: "Then it goes more apart." In the lessons there is also no explanation given, only observations were made, so the children are speculating here, based on their observations of course.

They are able to manipulate the light beam coming from the flashlight via the mirror. One girl explains it: "The light goes to the mirror and then to there." A boy says: "Because it casts back." ("Omdat het terugkaatst") The disco ball is explained as: "That are all very small mirrors." and one boy mentions: "It looks like you are sawed in pieces."
Is the children's interest in science been aroused?
A lot of them start experimenting during the interview and they usually work together for this (for example, they make a kaleidoscoop and put the flashlight in it; they shine from two sides on the disco ball; they ask for equipment they remember from the lessons to redo a certain position of mirrors they especially liked; they wonder what happens if you use two mirrors when reflecting the flashlight and want to try this immediately etc.). In fact, they are far more interested in the materials than in the interview. One boy shows a certain position with the mirrors and flashlight and says: "If you do it like that, you see a light over there. How is that possible??" They are reluctant to leave the mirrors and show that they are not finished experimenting with them. They sometimes spontaneously mention they liked it very much and no-one is negative about the lessons. One girl asks whether there will be more lessons, a boy asks whether they will have more lessons in grades 3&4.

5.2.5 Evaluation by teachers all cycles

All teachers report great enthusiasm from the children. All kindergarten teachers report the symmetry lesson fits in the writing method they use as preparation for the next grade (Novoscript this method is called). They all say the mirror series gives enough opportunity for all children in the group to discover and learn (differentiation possible). They suggest a few small changes and additions to the manual and the lesson kit. The lesson plans are clear and the preparation time is minimal.
5.3 Post-experimenting with students

After the first cycle, interviews with students were conducted (see section 5.1). These interviews consisted of asking what the students had done and whether they liked that. It appears difficult for children to answer questions like “How does it work?” because they are (too) abstract. Another unwanted effect is that the reaction of the children starts from a teacher-to-student relationship, instead of them freely answering the questions. The students are looking for the “right” answer, while what you actually want is for them to freely explore, show what they experience and communicate with you about that experience. A new set-up was therefore developed, to try and understand whether for example the concept of reflection is understood, without asking directly. Several set-ups were developed and tried out. The most successful set-up was a game, during which the children have to hit targets on the wall with their flashlight, but with the help of mirrors.

Below is the set-up of the experiments done with the children. The results of task 3, which is the game that was just mentioned, are subsequently discussed. Drawings made by individual children during the task are analyzed.

5.3.1 Set-up experiments

The tasks are done with two children at the time. This was done because if the children are alone, they sometimes feel uncomfortable. Some children are from groups that did do the mirror series in class, others are from groups that did not. The three tasks that were developed are described below. All experiments were videotaped.

Task 1: Mirror image

Central questions:
Where is the mirror image? 
How is it possible that the mirror switches front and back and left and right?

Situation:
Two objects in front of a mirror. One object (a box) has one yellow side and the rest is pink.

Questions/assignments:
- You see the object not only on the table, but also in the mirror. But where are these objects then?
- If you look at the box on the table in front of you, it is pink, but if you look in the mirror you see it as yellow. Why is that?
- What if I would put the box down like this, what would you see in the mirror then?
**Task 2: Around the corner**

*Central question:*
Is it possible to look around the corner with the help of a mirror?
If you see someone, does that person see you as well?

*Situation:*
The interviewer is sitting at the table with the children. Another person is sitting behind a case or a wall ‘reading’.

*Questions/assignments:*
- The interviewer says there is someone behind the case, reading something in secret and she would like to know what that is. We are going to spy on her. We cannot just go looking of course, she would see us immediately. Maybe we can use a mirror? -> the mirror has to be held in a certain position to look around the corner of the case or wall.
- Now we can see her, but can she see us? Why? Is this always the case?
- The experiment can be extended by looking through two mirrors and by taking a periscope and analyze that machine.

**Task 3: Reflecting light beam**

*Central question:*
How does light beam reflect on a mirror?

*Situation:*
A table with two mirrors, two flashlights and targets that are put upon the walls and ceiling.

*Questions/assignments:*
- First they can play with the flashlight a little bit.
- There are targets on the wall and ceiling. Hit the target with your light through the mirror.
- Make a drawing of how the light beam goes when the flashlight is in a certain position (mirror and flashlight are drawn by interviewer).

**5.3.2 Results Experiment “Reflecting light beam”**

Task 3 (Reflecting the light beam) was conducted with 12 children (6 groups of two). The results of some drawings are shown below, with an analysis.
**Group 1: Boy 1 & Girl 1**

These two children (for children's ages see Figures 24-31 following) are from a group that did the mirror series recently. The boy is the one who made the remark about the reflecting of the water outside on the roof inside (see the end of Movie 5). He understands the concept of reflection very well, which already was apparent in the lesson, but in the interview he can also accurately predict where the light will end up if you put the flashlight and mirror in a certain position. He points at the right spot at the ceiling. But his drawing is far of the mark. He lets the light beam bounce around and make circles (Figure 24).

The girl is better able to draw the light beam. In the beginning, after the interviewer has drawn a flashlight and a mirror, she more or less accurately draws the light beam. After that she draws the marks which were set up in the room (the squares with circles in them in the drawing) and were used for the light game just before and she draws beams to that, more or less randomly. She is obviously just wants to draw the game she just played and is not really taking into account the position of the mirror and the flashlight (Figure 25).

**Group 2: Boy 2 & Girl 2**

The girl is one of the oldest in the group (see Figure 26). This group has done the mirror series 5 months ago. During the lessons she was very active and made the impression she understood a lot. At first, she does not understand the assignment. She points to the ceiling when the interviewer asks where the light beam will go. She can predict accurately where the light beam will go. When she understands better, she also draws the correct line (the yellow and the lines in the picture). She has difficulty manipulating the flashlight and the mirror, although she tries concentrated. So she knows where the light will go (points to the right spot on the ceiling when a position of the flashlight is shown), is able to draw it after some encouragement, but is not able to manipulate the flashlight and mirror towards a target (Figure 26).

**Group 3: Girl 3 & Girl 4**

Girl 3 says when they see the light on the ceiling coming from their flashlight and mirror: “I know why that is! It’s because the light shines to the mirror [points] and then goes there [points to ceiling].” She leaves the mirror lying on the table and has a hard time manipulating the light beam. When she is asked to draw, she repeats her explanation of the light beam reflecting of the mirror and points it out, but does not understand how it relates to the drawing. She does draw it in the end. The first line is correct (the yellow one), but the second one ends up at the same place on the ceiling according to her (the pink line), while it is very clear she does understand it in real life (Figure 27).

**Group 4: Girl 5 & Girl 6**

These children are from a group that did not do the mirror lessons. Girl 5 joined the activities with
mirrors in the after school daycare (where I made periscope with the children and showed them reflections too). The girl remembers immediately and says: “I have seen this before!” She is also able to tell that the light beam reflects and uses the word reflects (‘weerkaatst). Girl 6 has not experience with mirrors, but immediately understands the light goes to the mirror and then to the ceiling. They are able to hit the targets after some practice. The drawing assignment is difficult for them, because they don’t understand the flat configuration. They keep pointing at the ceiling as to where the light beam is going. Girl 6 does understand very well in the end though (blue line. Although the line does not seem to hit the mirror). She even initiates another experiment with the mirror under the table, while the flashlight shines on it from below (the mirror reflects to the floor). She is capable of drawing this too (the purple flashlight and the red beam) (Figure 29). Girl 5 draws her first light beam correct (the green flashlight), but has trouble with others. She just lets them reflect back to the ceiling, with no direction in them (Figure 28).

**Group 5: Girl 7 & Girl 8**

Girl 7 and 8 are from a group that recently did the mirror series. They find very quickly that the mirror reflects to the ceiling and explain this as: “The light goes like this and then there.” They both pick up the mirrors as well and manipulate the mirror and the flashlight together. This makes it a lot easier to hit the targets, but also shows initiative. They hit the targets fairly easy. They have some difficulty with the concept of drawing the light beam, insisting that the light goes to the ceiling. After some encouragement Girl 7 draws the light spot (the yellow dot in the right corner; the dotted line was later added by the interviewer for clarification). The other two light beams are also more or less correct (Figure 30). Girl 8 lets the light beam reflect directly back from the light blue flashlight. They both understand that if you want to see the light directly above the mirror, you have to hold the mirror straight above the mirror (this is a question from the interviewer). In the drawing of Girl 7 the reflection from the green flashlight is drawn on the left. She draws them more or less correctly, although the paths of the beams are curved (Figure 31).
Figures 24 till 31: Drawings made by the children during experiment with reflecting beam. For analysis, see section 5.3.2.
30: Group 5
Girl 7 (5 years old)

29: Group 4
Girl 6 (5 years old)

31: Group 5
Girl 8 (5 years old)

28: Group 4
Girl 5 (6 years old)
5.3.3 Conclusions of post-experimenting with students

Because of the variety in abilities in the children, it is hard to conclude something from these experiments. See the individual analysis of the drawings. Some interesting points from the experiments are:

- The children that did the mirror series in the group were more comfortable with the mirrors, but the other children caught on quickly.
- The girl that uses the word ‘reflect’ (‘weerkaatsen’) did a special mirroring activity in the after school daycare (given by me, the developer of the series) and did not do the mirror lessons.
- Some children did not do the mirror series and did the assignments very well; others did the mirror series and were not able to come up with much.
- Some children were not able to manipulate the mirror very well, but did draw the light beam correctly and vice versa.
- All children first point to the ceiling when asked where the light ends up in the drawing. They have difficulty with the transferring the 3D situation to the 2D of the paper. Most children understand in the end though, although they seem more concerned with where the light beam ends up then with the path of light beam itself. The light is of course not visible in real life, only the light spot, so this seems logical enough.

The overall conclusion seems to be that children do not seem to connect the real experiments and the drawings. Some did well in the experiments, others in the drawings. There seems to be no correlation. This probably is probably due to their age: they still need to develop their abstract thinking.

Improvement of interview techniques

The interviews went well, but there are some things that were done wrong, because of the inexperience of the interviewers. Points of improvement are:

- The children need more time to explore the materials first. It might be better to just let them play with the equipment, before starting with the questions.
- The children sometimes need more time to answer something. Do not jump too quickly to the next question.
- The formulating of the questions is very important. A question like: “If you do it like this...” (and pointing something out) is sometimes too abstract, as is “How is that possible?”
- Making a drawing is a good way of talking about things, because it gives them something to do and you have a real thing to talk about. But the children see a drawing different from a researcher, namely like something creative, while you want it to be something scientific. Still, it is good to have something which you can analyze later.
- The children were with two at the time. That relaxes them a little more than being alone, but since they do not yet work together, it may be better to try with one child at the time as well. That makes it more focused. Quiet and uncertain children also get the chance to talk more.
6. Discussion and Conclusion

With the evaluations of five lesson series and the results of observations, videos and interviews, I will now answer my research questions. The research questions of this study were aimed at the teachers (Question 1) and the children (Question 2). The developed materials are the overarching subject and I will evaluate them at the end.

6.1 Research Question 1: How do the teachers use the lesson materials?

*Question 1a: How do the teachers interpret the lesson plans? Do the teachers follow them exactly or do they take the freedom to structure and fill the lessons as they think is best?*

Five teachers have worked with the lesson series so far and they all declared to be very happy with the materials and would like to use them again in the future. Part of the design requirements was that the materials would be easy to use and would not take a lot of preliminary (science) knowledge. The first thing was achieved, as the teachers said they sometimes prepared only five minutes for the lessons and found the lesson plans clear and helpful. The only minor complaint they had was that the actual case with mirrors and other materials for the lessons was very heavy (there are 75 mirrors in it), but I don’t believe it was an obstacle for using it. The teachers follow the lesson plans very closely for the most part. They go through the steps and keep the lesson plan at hand during the lesson for consultation of what to do next. What they do change is the group size. Especially the Kindergarten teachers sometimes prefer (for example in the lesson about symmetry) to split the class in smaller groups. At that point, not all students follow the same program, the teachers save certain assignments they deem too difficult (for example the worksheets for the symmetry lesson) for the oldest students. Another way a teacher changed the set-up was by providing a “discovery corner” during the week, where the children could work with the materials on their own initiative. The content the teachers do not change, nor the order within the lessons or between lessons.

In the second cycle there were suggestions for more activities at the end of each lesson plan. Those were universally ignored. In fact, teaching seven lessons was already a bit too much. In cycle 2 the grades 1&2 teacher shortened it to five lessons (which is also suggested in the teacher manual). One of the teachers also said that she found it helpful the researchers were coming for observation, so she would be forced to do the lessons. She wanted to do them, but found it difficult to plan them in because of other demands and in this way she had no choice but to fit them in. Finding time for lessons is a general problem of primary science education in The Netherlands, so it remains to be seen whether the lesson materials are going to be used in the future, even when the teachers want to, when there is no pressure to do so. The teachers also mention in the post-interviews they would have liked to do more with the materials, for example set up a permanent corner in the class room for the
children to explore (which one teacher already did). Perhaps if they would do the lesson series for a second time, they would have a better idea how to structure the series and build in more moments to do other things with the lessons.

**Question 1b: Do the teachers have enough science knowledge to implement this module?**

The lesson series was designed to be taught without any science knowledge or knowledge of the outcome of experiments by the teachers. One teacher mentions that she likes it very much that she basically “explores with the children” and that “it is all a surprise for [her] too”), but the lack of background knowledge is noticeable in the sense that the teachers sometimes miss ‘teachable moments’. For example, from observations it is clear that the difference between ‘mirroring’ and ‘glimmering/sparkling’ is unclear to many children in Kindergarten, but none of the teachers addressed this. It would speculate that this is at least partly because they don’t know the difference exactly either (or at not the cause of it). Another reason could be that they deem it too difficult for the children to understand, or a combination of these two (when the teacher finds it difficult to understand, she might assume that the children would be too young to understand).

Teachers were also observed doing things like pointing the flash light in the wrong angle towards a mirror when demonstrating how to let a light from the mirror shine on the table. In that situation, it is immediately apparent that it is wrong and the students have enough time to explore to find the answer to this particular problem themselves, but one cannot help but think that the guidance and the questioning of the children could be massively improved if the teachers would know better where the science is going. This is also illustrated by the fact that one teacher said in the post-interview that she would never have come up with the ideas for the lessons herself, because she has “no content knowledge whatsoever”.

**Question 1c: Are the teachers able to implement the inquiry-based learning of the method? Do they have the skills to effectively lead the group discussions? Do they adapt to ideas and questions of the children (use ‘teachable moments’ productively)?**

On the one hand, I would say the answer is positive. Teachers lead interesting group discussions and were able to foster the exploring and inquiring nature of the lessons by sharing the discoveries of the children and encouraging them to explore more. On the other hand, most of the discussions stayed on the surface: The discoveries of the students were acknowledged and copied by the whole group, but if some child came with a very interesting observation, there usually was no follow-up on this. For these groups of children it was not a big problem because they were so young and it was all exploratory in nature, but when the children would have gotten to the next stage in the inquiry cycle (coming up with their own research questions and designing an experiment), there would be a problem with the guidance that was possible from the teachers. This also ties in with the result that the teacher miss a fair amount of background knowledge. This did not stand in the way of an engaging
science module, but leaves the question open how much the quality could be improved and what problems might surface when materials demand more from teachers – which would already be the case when the children become older and would be more capable of setting up experiments.

6.2 Research question 2: Are the objectives of the lesson series achieved?

Question 2a: How much do the children remember of the lessons?

Question 2b: Do the children use science specific language appropriately and with apparent understanding?

Question 2c: Are the children comfortable with the scientific equipment and use it appropriately?

Question 2d: Do the children evaluate, interpret and share their (scientific) findings?

Question 2e: Has the children's interest in science been aroused?

Research questions 2a-e were analyzed for all executed lesson series in chapter 5. From this it can be concluded that the students at the very least do remember the lessons (question 2a). Even a year later when I was at the school again (for something completely different) children would still come up to me to ask whether there would be more lessons. Also, they could describe very well what they did in all lessons weeks or months after they took place (see for example Movie 7). One of the Kindergarten teachers said in an interview: “They often do not remember what they have eaten only a couple of hours ago, so this is quite an achievement.” The students were also very enthusiastic about the lessons and were still ‘playing’ with the equipment during the interviews, so they were not finished exploring. The teachers remarked in conversations and interviews that the students would notice other ‘mirroring things’ during the rest of the week, for example when they walked past a window, when a student would point out they could see themselves and connect that to their mirror lessons. The interest in scientific phenomena (with respect to the subject matter) has been aroused and awakened. Combining the facts that they notice new things in their environment, that they are still interested in the lesson materials weeks after their intensive course and that all students agree they ‘liked the lessons very much’, I believe the question “Has the children's interest in science been aroused?” can also be answered affirmative. Also, the children were very focused during the lessons and stayed on task sometimes even after the lesson ended.

Whether the children actually have learned something about mirrors is a more difficult question to answer. The children are more open to mirroring phenomena in their environment and they shared their scientific findings extensively (both asked for and not asked for, during both the lessons and the
post-interviews). It is hard to determine what the children have learned, because they are so young and they cannot be asked directly. It was attempted to establish what they picked up with some post-experiments (see chapter 5.3), but the results of this remain inconclusive. It was again noticed during the post-experiments that the children were very comfortable with the scientific equipment and also still fascinated by them, as they were during the lessons and the interviews.

The set-up of the lesson series was not to teach the children specifically something about mirrors. It would have been a bonus if that would happen and the lessons were set up in a way that is was very well possible. To develop scientific skills on the other hand, was one of the goals of the lessons series. The lessons are too few to really develop inquiry skills and it also remains to be seen what happens with the skills that were developed (there needs to be some follow-up for them to become real skills), but during the lessons it was clear from observations the children were exploring, comparing, sorting, experimenting, thinking, asking questions, presenting etc, all the inquiry skills mentioned in chapters 2 and 4. Furthermore, they were introduced to new words (like mirror image/spiegelbeeld) and were practicing their visualization skills and spatial abilities (when finding symmetries, when positioning the double mirror etc.).

Although the children were introduced to new words, the teachers were not encouraging them to use the science specific language appropriately and during the post-interviews it turned out they did not pick them up naturally. For example, the word ‘glitteren’ (sparkling) was used often for mirroring, this was not corrected by the teachers (they used it themselves, echoing the wrong word back at the children) and in their explanations of the mirroring phenomena the children use words like these (“you see a lot sparkles because there are a lot of mirrors”, which is a correct explanation, but not very scientifically worded). It is also worthwhile to have the children explain in their own words what is happening and they were probably very young to use difficult words, but the teachers could be more alert during the lessons by using the correct words more often.

### 6.3 The developed lesson materials

#### 6.3.1 Evaluation

The original design requirements were:

- easy-to-get and inexpensive materials
- hardly any preparation time for the teacher
- no words or instructions in words on the worksheet
- possibilities for differentiation in the group
- variation in teaching methods during the lessons
Easy-to-get and inexpensive materials

The most important materials for this lessons series were the mirrors, which were mirror tiles purchased at the hardware store (used for bathrooms for example). They are not that expensive, but the initial cost is not nothing. They can be reused though. All other materials are very inexpensive and mostly already in the classroom.

Hardly any preparation time
This second requirement was evaluated positively by the teachers (see section 5.1). All materials are in the module kit, so available when needed. The only materials that are not in the module kit are the ones that are used up during the construction part of the lessons (for example the foam balls in lesson 5). This might be a small hurdle for teachers to do the lessons. They also mention it in the post-interviews, as something that they need to pay attention to and that it sometimes caught them unaware. This is not avoidable though, there is as much in the module kit as possible.

Worksheets
The worksheets were easy for the students to use. The teachers in cycle 1 had the inclination to make more worksheets, so they were not too difficult for the younger age group. After the first cycle, some worksheets were added to the manual. In the post-interviews the teachers were positive about the worksheets and the manual in general.

Differentiation
The materials were used in Kindergarten and in grades 1&2. These were already mixed groups, and the difference in development between the children was large. This was not a problem during the lessons. The Kindergarten teachers often took a smaller group of children to do some extra assignment with, while they did the plenary and exploratory part of the lessons with the whole group. All the assignments were designed so that they were easily understood and could be done by all students, while still being interesting for the more advanced students. An example is lesson 4 (the double mirror), which lets the children play with beads between the two mirrors. First of all, this assignment is always a success, because the results are always pretty. Even if you just throw a few beads on the paper there will be a nice pattern. The beads can also be arranged carefully and the mirrors can be moved to explore patterns, symmetry and multiplication. This was also done by the more advanced students of the Kindergarten group. (For example: two girls were working on this assignment quietly, every now and then calling each other’s attention to what they had made. They move the mirrors in different positions, arranged the beads and copied each other’s work sometimes. They worked on this with concentration for 15 minutes, when the teacher announced the next assignment – see movie 4 for this scene.) There are lots of moments when the students share their experiences with the group, during these times the less advanced students also copy the more
advanced positions of the mirrors and share in the experience.

At the end of each lesson plan, more lesson and activity suggestions were included, but the teachers did not use those to differentiate. It seems that the lesson series already took quite some time of the teaching hours, so this might be a reason for this. In the post-interviews the teachers mentioned that they would have liked to make a special corner in their classroom with the materials for the students to explore during the week, at their own volition (this is a regular activity form at this school) or make posters of discoveries. In this way the more interested students would be able to explore more and the less interested could do something else. This method was already implemented by some teachers in the lesson (for example in lesson 7 (symmetry in letters) in grades 1&2, where the lesson took a bit too long and the teacher let the students who wanted to continue with making symmetric words do that, and the rest continued with something else), but not often in the sense that the materials stayed available all week. One Kindergarten teacher made a corner with the materials of lesson 2 (see Figure 10, page 43.).

Variation in teaching methods
The lessons were also set up to not do one thing for a long time and to approach the subject in different ways. Most lessons took between 30-60 minutes, which is a long time in Kindergarten, according to the teachers. By letting the students explore for 10 minutes, then share their experiences, then maybe explore more or do an assignment some variation was created. Also, this speaks to the different talents of children. Some children are very verbally advanced and easily talk about their experiences, while others are more creative and make beautiful drawings, but are not really able to explain how they did it (they must have some understanding, but apparently it is more intuitive). By switching between language-oriented, spatial-reasoning oriented, creatively oriented and technical skills-oriented, the talents of more children were appealed to.

Inquiry-based
The requirement of using inquiry-based learning was the fundamental idea of the lesson series and while the full inquiry cycle was not executed by the students in a very apparent way (the students do not set up their own experiment), parts of the cycle and inquiry skills were present in all lessons (see Table 2, pages 57-59). The teachers were very well capable of leading the group discussions and creating an encouraging environment, although the discussions were sometimes superficial (see section 5.1).

6.3.2 Conclusion

As was mentioned in chapter 4, this lesson series should be part of an entire inquiry based curriculum. Children 4-7 years old have difficulties with formulating research questions and setting up their own experiments. It also gives a lot of stress to the teachers, because the success of the lesson series
depends on whether they are capable of coaching the children in setting up a good experiment. They are not experienced themselves in conducting research and they often lack the sufficient scientific background. The younger children are very curious and are natural explorers, so by providing them with attractive materials and letting them explore gives very good results. Some small experiments can be carried out (like the experiment in lesson 3, the magic mirror) and questions can be raised. When they are older this can evolve in setting up their own experiments naturally. The impact of this lesson series will in the end be larger if it is part of a bigger whole.

In all lessons, the students were focused and on task for the entire lesson (which took from 30-60 minutes). The students expressed their enthusiasm for the lessons and were not even finished exploring after seven lessons. They were more aware of mirroring phenomena in their environment. The teachers were happy with the materials and found them easy to use. They are now being used for teacher trainings and almost all people are attracted to the mirroring materials, especially the double mirror with the beads. From this, it can be concluded that the developed materials were successful in achieving its goal of being accessible and engaging.
Afterword

I have now spent several years working and studying in primary science in various ways. I have seen a lot of children, teachers and lessons. Even if I limit myself to this project, it is hard to describe and discuss all that in the 100 pages of my thesis, let alone in one afterword. My conclusion probably would be that although primary science is great fun and I am as enthusiastic about it as always, it is also hard. I regret that I have to say this, because in workshops and lessons I teach I always maintain that it is not that difficult, but to do it well it is a challenge. Teachers and schools want to do it, or at least they say they want to do it, but in reality it comes about only in bits and pieces. Even working with the school in this project, which approached me to do something, I encountered many problems. First of all there were the expectations of the school. The overall aim of the school is to have a science curriculum from 4-12 years old. In the end I only made one lesson series, which was a lot of work for me, but also for the teachers involved, for which I am very grateful to them. The expectation that they could create and implement an entire science curriculum in one year is unrealistic, especially since they want it catered to their teaching philosophy. Also, when I asked about some funding to acquire the most basic of materials that was not possible at all. There were other problems which I will not even go into because I also left them out of my thesis (not enough space!), but suffice it to say that although the teachers were willing, we were also presented with the various problems that come from working with so many people in such a new and challenging way.

I believe that if a school wants to do something with science, the first step would be to put it in the curriculum. That sounds rather straightforward if you put it like that, but there aren’t many schools that actually program hours for science in their week plans. The teachers are probably supposed to squeeze it in somewhere, next to language, math, gymnastics, music, art etc. ‘No time’ is the most used excuse to not do science and quite frankly a very good excuse too. If you want to do it, then something has to be sacrificed. If there are hours designated to science, then there also has to be attention for the preparation for it. Many schools in The Netherlands work with themes or other flexible programmes: in the preparation for that there also has to be attention for science. Usually teachers don’t look in the science direction for inspiration for their lessons, because it is unknown to them, but science links to a lot of other school subjects and to a lot of current events and society problems as well. Teachers should be made aware of the existence of science and to say it quite bluntly: forced to implement. Teachers are somewhat afraid of science and given the choice will almost always leave it be. They have to be provided with all support from the school board, in time and in materials. In my experience teachers are enthusiastic about new things, but they are passive; they will not make the change happen themselves. In the case of primary science this is for the large part lack of science knowledge and experience, but it is also because they already have a heavy workload.
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Appendices

A. Teacher Manual kindergarten

Please see attached. In Dutch. File name: SpiegelsGr12Leraren.pdf

B. Teacher Manual grades 1&2

Please see attached. In Dutch. File name: SpiegelsGr34Leraren.pdf

C. Worksheets

Please see attached. In Dutch. File name: SpiegelsGr34Werkbladen.pdf

D. Interviews teachers

Post interview teacher Kindergarten cycle 2

Teacher: Het is heel fijn dat je lessen krijgt aangereikt over iets waar je normaal niks mee zou doen. Ik zou eigenlijk niks bedenken met spiegels. En door die lessen kom je erachter wat je er allemaal mee kan en het zijn eigenlijk allemaal hele leuke dingen om te doen.

Is er materiaal of een methode voor techniek?

We doen te weinig met natuur en techniek. Wel veel natuur, met seizoenen enzo, dat je dingen van buiten haalt. Plantjes. Maar techniek enzo, veel te weinig.

Er zijn wel een paar kisten, maar die zijn vooral voor hogere klassen en die staan ergens stoffig boven op een kast.

Die worden niet gebruikt?

Nee

Waardoor komt dat?

Ik denk toch dat wij veel doen... Je bent altijd met thema's bezig. Dan heb je weer de lente met de kleuters en dan ben je meer daar mee bezig en zoek je daar dingen van op internet en dan vergeet je gewoon vaak dat dit soort dingen ook kunnen. Zoals met magneten bijvoorbeeld. Dan denk je, o ja, daar kan ik ook wel eens wat mee doen. Af en toe dat je denkt van 'deze les is wel leuk', maar nooit
echt standaard ingevoerd [iets met techniek dus].

_Maar je vindt het wel leuk om te doen?_

Ja, ik vond het gewoon leuk en ik heb ook ideeën gekregen. In het nieuwe gebouw [verhuizing gaande] wil ik een ontdekhoek maken echt, zodat je die lessen die jullie hebben gemaakt op kaarten doet met symbooltjes zodat ze gewoon weten wat ze moeten doen en dan zelf gewoon gaan ontdekken. Dat is een beetje…. Je krijgt er ook weer andere ideeën door, waarvan je denkt ‘o dit kan nog’, dat het wat meer een plekje krijgt, standaard wordt.

Want dat was wel lekker, dat jullie kwamen [filmen tijdens de les] op maandag en donderdag, want dan moet je gewoon en omdat je het moet ga je het gewoon doen en dan zit je er op een gegeven moment in en die kinderen hadden laatst zo iets van ‘he gaan we niet...’. En dat vind ik heel erg mooi eraan.

_Ga je het weer doen, over twee jaar ofzo?_  

Ja.

_Als je terugkijkt, had je dan iets anders willen doen dan je hebt gedaan? Zou je het anders aanpakken volgende keer?_

Sommige lessen waren, ja die gingen niet helemaal zoals ik wilde. Maar dat ligt niet aan de lessen, maar gewoon aan mij en inderdaad, kleuters. Maar de laatste lessen waren gewoon goed, gewoon zo te doen.

_Welke lessen dan bijvoorbeeld?_

Die les met dat lampje, met die zaklamp schijnen, die zou ik dan wel doen, dat is hartstikke leuk, maar dat zou ik dan niet in de zomer doen of in de lente, want we hebben allemaal lokalen die je niet kan verduisteren. Maar het zou kunnen dat we in het noodlokaal [waar ze naar toe verhuizen] wel zonnewatering hebben en dan zou ik het leuk vinden om nog een keer te doen.

_Daar zou je ook nog iets van kunnen maken, zaklampen..._

Ja, ik denk dat ik al die dingen, zoals een spiegeltje en een zaklamp en een glittertje kun je ook goed in een ontdekhoek leggen en dan gaan ze _zelf_ kijken zo van o ja, want dat heb ik nu ook wel geprobeerd, zo van ‘wat zouden we hiermee moeten doen’, dat ze _zelf_ met dingen komen.

_In principe lukte dat ook. Toen zag je die kinderen die hier bezig waren, die waren bezig met hun taak, maar de rest was toch ook nog... Dat was leuk om te zien. Het is geen nadeel dat de spiegels breekbaar zijn? Je kunt ze wel laten liggen voor ze [in een ontdekhoek]?_

Als er eentje een beetje stuk is is het handig die aan de kant te doen, want dan komen er van die scherpe randjes aan, maar nee... En kijk, als je een ontdekhoek hebt, dan pak je ook een rustig plekje in de klas, met een tafeltje en een kastje... Dat gaat wel goed.
En de handleiding?

Die was duidelijk. Ook leuk dat je wat algemeens vooraf had. Dat heb ik nog doorgenomen. Ik zag alleen dat ze achterin ook een 'spiegelboekje' hadden en dat had ik niet gezien, maar daar had ik zelf een beetje zo van 'o ja, een spiegelboekje' [had ze zelf al gemaakt van een deel van de werkbladen, alleen zonder kleurplaat als voorkant] Dat is ook wel erg leuk.

Karin had gemerkt dat die kinderen vanzelf al dingen op gaan schrijven en ermee bezig gaan.

Dat is het ook, ze vinden het gewoon leuk. En als kinderen het leuk vinden dan zijn ze ook enthousiast. Met die kraaltjes, daar zijn ze een uur mee bezig geweest. Dat vond ik echt de leukste les.

Ook leuk voor de ontdekhoek.

Ja, dat kunnen ze ook blijven doen en dat kun je ook anders doen. Je kunt ook met tekenen en figuurtjes tekenen... En ik had bedacht dat het ook heel goed onder Novoscript past, dat is onze schrijfmethode en dan moet je kringeltjes maken en het is hardstikke leuk om te zien dat je dan dat in die spiegels ook krijgt. Er zijn een aantal dingen waarvan ik denk, die kunnen heel goed in een vaste hoek en dan kan je bijvoorbeeld zeggen, dan doe ik nu twee maanden spiegels en daarna doe ik magneten of weet je wel? Zodat je zelf ook een beetje gaat zoeken naar wat zou je dan nog meer kunnen doen op dit gebied.

En de handleiding, de lesopzetten waren goed?

Was duidelijk. Alleen, er was er eentje waarvan ik het niet helemaal zeker wist... Toen heb ik het aan Anita [collega] gevraagd en die zei, dat moet je zo doen... Ik ben nu even aan het denken... Het was met al die voorwerpen... Die vond ik vrij lastig. Ik wist niet of ik nou elk kind, of elke groepje een doos moest geven met glimmende spullen en niet glimmende spullen of... Dat was niet helemaal duidelijk. Maar dat maakt het ook wel weer grappig, want dan gaan ze gewoon zelf... Het is leuk als ze bij elkaar kijken, maar dat ging een beetje mis [chaos]. Maar ze waren wel leuk bezig.

Ze hebben veel dingen gezien. Het is wel leuk om te doen, hoewel het niet heel duidelijk is wat ze er uit halen, maar ik vind het toch....

Over spiegelen... Ze halen spiegelen en schaduwen altijd door elkaar. Glimmen, spiegelt ook. Maar dat was de enige les waarvan ik van tevoren dacht, wat moet ik nou precies doen? En daar had ik ook geen spullen voor... Dus ik heb bij Anita zo'n doos gehaald.

Dat is natuurlijk lastig. Maar als ik alles in de leskist stop...

Ja die kist is wel heel zwaar... Maar ik heb gewoon van Anita geleend. En verder vond ik het allemaal duidelijk lessen. Soms net wat anders gedaan dan wat er staat, omdat je het gewoon het moment...

Het is ook niet een strikte methode.

Nee. Het is niet dat van begin tot eind wordt gezegd, dit en dit en dit moet je doen en dit moet je
zeggen en dat is wel fijn. Daar zou ik niet zo...

Ik zou er nog meer suggesties tussen kunnen voegen, van 'als een kind dit zegt, dan...', maar dan wordt het weer zo'n lange lap tekst. Ik weet niet wat jij ervan denkt?

Ik vind dit prima. Als ik veel meer tekst zou zien, dan zou ik denken hm. Ik zou absoluut niet heel veel meer tekst erbij zetten.

Nog meer advies voor de leskist, om ze te verbeteren?

Er was een stencil die verkeerd genummerd was. Het is wel belangrijk dat alles erin zit [bij Anita was dit niet zo].

Maar hij is nu compleet?

Ja.

De individuele lessen gingen heel goed vond ik. Je hebt een stel pientere kinderen.

Ja dat zie je ook... Zo'n Finn en Sador, die doen dan iets wat ze heel leuk vinden en soms kijk je er toch overheen. Dan vergeet je toch... Je probeert wel heel ontdekkend bezig te zijn, maar vaak vergeet je het ook. Dan zitten ze gewoon in die hoeken, maar dat is elke keer wel standaard. Dus het is goed dat daar een keer nieuwe impuls aan wordt gegeven. Zodat je dan meteen de kinderen eruit kunt halen waarvan je denkt, o ja... Zoals Sador, die heeft me echt verrast.

Die snapte het ook meteen...

Terwijl hij geen oudste kleuter is... Zo zie je van o, dat had ik van tevoren niet gedacht.

Dat had ik ook zo bedacht, sommige dingen zijn met ruimtelijk inzicht en andere wat creatiever, zodat ook verschillende kinderen...

Dat is een beetje die verschillende intelligenties waar je toch niet altijd helemaal aan toe komt, ook al weet je dat het moet.

Wat denk je dat de kinderen geleerd hebben?

Ik denk dat ze wel veel geleerd hebben eigenlijk. Zoals die begrippen die terugkwamen, zoals dat spiegelen, reflecteren... Daar zijn ze gewoon de hele tijd mee bezig.... Op een gegeven moment gingen ze ook zien dat de prentboeken zo'n lampje gaven en bij alles kwam dat steeds terug... En dan liepen ze ergens langs en dan o ja... Ook met de viering, dat in een raam keken... Dat vond ik grappig. Het is ze ook heel erg bijgebleven. Ze wisten ook nog de volgorde van de lessen en wat we precies gedaan hebben en dat is echt... Meestal als je vraagt 'wat hebben we gister gedaan', dan geen idee. En nu wisten ze gewoon al die lessen nog. Ik denk dat ze wat er in stond, wat de bedoeling was van de lessen, dat hebben ze er telkens wel uitgepikt. En dat zag je ook, dan kwamen jullie binnen [onderbreking door andere juf]... Ze vonden het ook leuk. Het was iets vasts, en jullie kwamen binnen en oh spiegelles.
Het is lastig te achterhalen wat ze nu echt snappen. Gerda en ik willen graag nog wat testjes doen...

Je merkt dat er enorm verschil is tussen de oudste en jongste kleuters. Ik had er ook een paar die elke keer zoiets hadden van 'het zal wel'. Dan kun je zelf als leerkracht... Dat is met alles wat je doet. Daar moet je zelf een beetje flexibel in zijn. Zoals de vorige keer, met die boekjes, voor de jongsten zei ik, ja loop maar rond en als je klaar bent...

*Dat ging eigenlijk best wel goed he.*

Ja. Als je die hele kleintjes aan een werkblad zet, die hebben nog geen idee, dat op papier is echt heel moeilijk voor de kleintjes.

*We willen ook kijken of ze dingen kunnen tekenen bij de taken, of ze het kunnen overbrengen op papier...*

Dan moet je echt aan de oudste kleuters denken... Die kleintjes kunnen amper een potlood of pen... Die krassen nog echt. Met die kinderen die naar groep 3, daar zou je het mee kunnen proberen. Zoals Finn, die kan wel dingen natekenen. Die zou je ook kunnen vragen, teken wat je gevonden hebt. Maar dat is echt alleen maar voor de oudste.

*Op het bord, met die reflectie tekenen, dat lukte toch nog wel.*

Ja, maar dat waren oudsten. Ik denk dat oudsten dat kunnen. Die van 5 of 6, maar die van 4... Ik denk dat deze lessen heel leuk zijn met kleuters, maar ik denk dat je in de middenbouw nog meer resultaat eruit haalt. Wat jij eigenlijk wil. Dat ontdekken, dat doen ze in de middenbouw nog meer. Ik kan me ook vergissen.

*Toen ik bij Machtelt [kleuterklas] en Karin [groep 3/4] was, merkte ik dat bij Karin de kinderen meer samenwerkten en op een bepaalde manier verder kwamen, maar dat bij de creatieve opdrachten ze het minder deden dan kleuters. Zoals bij het maken van die toverspiegel, dat vonden ze moeilijker dan de kleuters.*

Ze zijn banger om het niet mooi te doen.

*Dus het is gewoon te doen, deze leskist met een klas?*

Ja, zeker, alleen dat knutselen niet, maar daar hebben we het al over gehad [ze wil liever in een klein groepje knutselen, ook vooral voor oudste kleuters].

Ik vond het leuk om te doen, bedankt voor het ontwikkelen.

**Post interview teacher grades 1&2 cycle 2**

Hoe vond je het gaan?

Ik vond de lessen heel leuk, maar de uitvoering soms wat lastig. Dat kwam ook door het geluid in dit
gebouw en het gebrek aan ruimte [ze zijn net verhuisd naar een noodlokatie met kleine klaslokalen die nogal hol klinken]. Eerst in de kring en dan weer weg en dan weer erin, dat heb ik soms niet gedaan. En de warmte ook. [Het was bij tijd en wijle 33 graden binnen.] Dat waren factoren die belemmerden, waardoor ik eerder mopperig was en waardoor de kinderen hangeriger waren enzovoorts, waardoor je er toch minder uit laat komen dan zou kunnen.

En de lessen zelf?
Leuk. Super.
Ze waren te doen?
Ja. Behalve toen ik de ballen niet had [voor het maken van de discobal], maar dat was een stukje eigen inbreng die ik gemist had. Misschien zou je kunnen opschrijven dat je het nodig hebt, hoewel ik het ook gemist kan hebben.

Wat zou je anders hebben gedaan?
In veel gevallen de terugkoppeling naar de kinderen. Er zijn meer vormen om dat te doen. Er werd nu wel regelmatig iets op het bord gedaan, maar je zou iets met postertjes kunnen doen. Ik denk dat ik meer zou kiezen voor iets blijvends in de klas. We zijn er nu wel veel mee bezig geweest en het zat dicht bij de ervaringen van de kinderen en dat is natuurlijk goed, dichtbij de belevingswereld van de kinderen, maar ik zou ook meer voor de ouders die binnen komen, dat het meer zichtbaar is zodat ze ook aan de kinderen gaan vragen: wat heb je nou gedaan.

Hebben ze het er gedurende de week nog over?
Nee, niet heel veel. Ze vinden het wel leuk als ze horen dat je weer komt, want dan weten ze dat ze die lessen weer gaan doen. We hebben ook spiegeltjes neergelegd in de klas, maar daar zijn ze niet verder mee gaan onderzoeken. De ballen hebben ze nog wel aan gewerkt.

Dat is iets wat ik zelf leuk vind. Dat als ouders ’s ochtend meegaan, dat ze er dan naar vragen en kinderen erover hoort vertellen. Op dat moment is de leerervaring nog een stukje groter.

Nou moet ik zeggen dat ik ook niet heel veel tijd heb genomen om dingen voor te bereiden, door de verhuizing ook.

Meestal las ik het de dag ervoor door in een kwartiertje, halfuurtje en dan ’s ochtends nog wat kopien maken en dat was het wel.

Wat denk je dat de kinderen ervan geleerd hebben, eruit hebben gehaald?
Vooral dat gevoel van: ik mag gewoon rondlopen, ik mag gewoon naar anderen kijken en vertellen wat ik leuk vond. Dat vrije wat meer, hoewel ik ze nog vrij strak hou altijd. Dat weet ik van mezelf. Dat vind ik wel heel belangrijk. De verbeelding werd erg geprikkeld, van goh wat kun je er nou mee. Er
wordt verder gekeken en verder gedacht en dat vond ik toch wel heel leuk. Dat sommige kinderen komen met weerkaatsing, dat je begrippen hoort waarvan je denkt, dat is toch wel goed. Ook dingen die ze zelf verzinnen en die helemaal niet klopten, dat is ook leuk. Ik zie het als een stukje voorkennis activeren, voor als ze straks natuuronderwijs krijgen. Dat ze alvast wat meer interesse hebben. Ze vonden het ook leuk?
Ja, wat ik heb gezien wel. Ze waren altijd erg blij als je kwam.
Ik durf ook niet zo te zeggen wat ze geleerd hebben.
Zou je het weer gebruiken?
Ja, over twee jaar, als ik weer een nieuwe klas heb. Symmetrie, die dubbele spiegel, dat zijn toch dingen die erg leuk waren.
Heb je nog iets gemist?
Ik weet niet of ik zo iets weten. Wat ik wel moet zeggen is dat ik het veel papierwerk vond. De werkbladen waren heel goed, maar de kinderen gingen er soms heel snel doorheen en dat is toch niet echt je doel, dat produceren. Zo’n soort van competitiegevoel. Ik weet niet hoe het anders kan.
Misschien zou je ze zelf kunnen laten tekenen bij symmetrie.
Dit was meer vrij onderzoeken en dat andere was meer een proces, van wat wil je weten, hoe ga je erachter komen. Dat is natuurlijk een andere kant. Dit was meer ervaringen krijgen met bepaalde dingen.
Heb je dat nog gemist hier?
Er was veel tijd voor de aanrommelfase en er waren ook gerichtere opdrachten, maar nu je dit zegt denk ik dat het toch wel leuk was geweest als je had gezegd van ‘wat wil je nu ontdekken?’ en dan weet ik niet waar ze mee zullen komen met spiegels.
Vorig jaar hadden toch wel veel leraren moeite met het krijgen van die vragen uit de kinderen.
Nou, je bent wel gerichter aan de slag met de vragen van de kinderen, want ik had nu wel eens het idee en ik had nu wel eens het idee, hoewel ze het heel leuk vonden, maar dat ik daar stond en zei je moet nu dit doen en dat doen, weet je wel. Soms voelde het een beetje te statisch. Maar dat is dan mijn eigen gevoel. Dat komt ook door hoe ik er zelf in sta en door die andere factoren die ik net al aangaf. Ik voelde me af en toe stijfjes, dat ik het in de hand ging houden. Terwijl ik het meer los zou willen laten.
Doe je vaker van dit soort dingen, natuur&techniek?
Maar wel biologisch dus meestal.
Ja, vaak wel.
Jullie hebben geen methode?
We hebben een methode voor wereldoriëntatie en daar zitten wel een paar kleine dingetjes in. Grote reis. Maar dat is maar kleine dingetjes.
Nog aanmerkingen op de lerarenhandleiding? De achtergrondinformatie?
Niet echt. Je wordt natuurlijk wel geacht dat je zelf nog wat weet. Het is prettig. Het is wel leerzaam om een keer weer te doen. Zo was het ook al weer.
E. Videotaped lessons

The first six movies are short bits from one lesson series, taught in a kindergarten group. A few are subtitled in English. They are not included with this thesis to preserve the privacy of the children in the movies. If you would like to see them, contact Ed van den Berg or Welmoet Damsma.

Movie 1

From lesson 1: Exploring the mirror
The children explore the mirror for the very first time (the children walk around) and the group discussion afterwards (a girl explains you can see behind you in the mirror).

Movie 2

From lesson 2: Discovering more mirrors
The children show each other objects they found that mirror in the group.

Movie 3 (subtitled)

From lesson 3: The magic mirror
The teacher has read the fairytale of Snow White and is now discussing the magic mirror example. She gets the children to see that the black background works best. After this, the children will continue experimenting themselves and make the magic mirror.

Movie 4

From lesson 4: The double mirror
The children explore the double mirror for the first time. After that, they start working with the beads. You see one group working and later another group, in which two girls are extensively exploring the double mirror and share their experiences.

Movie 5 (subtitled)

From lesson 5: Reflection
The teacher is explaining about the reflecting light beam on the mirror and the children are asked to come forward and draw the beam on the board. One girl who correctly draws it is shown. After that
they discuss the disco ball in the group. One boy notices that the water running outside the building is casting a reflection on the roof.

**Movie 6**

From lesson 6: Symmetry
The children are working on the worksheets.

**Movie 7**

Interview with Kindergarten students after cycle 1. The children tell something about the lessons and clearly remember a lot.
F. Reports lesson observations

Following below are several lesson observations, made by different observers of different lessons in different cycles.
Opmerkingen

1. Dit verslag is zo geschreven dat het als een observatierapport in de appendix van een scriptie kan passen (als data).

2. De hoofdstukjes in het verslag zijn observaties, analyse, en commentaar en follow-up.

Donderdag 7 december 2007

Les van 11.00 – 12.15

Onderwerp: spiegels en in deze les vooral dubbele spiegels, dat zijn 2 spiegelende tegeltjes die als boekje aan elkaar bevestigd zijn

Observaties

Kringactiviteit (ongeveer 30 - 35 minuten)

Kinderen zitten in een kring en krijgen elk een dubbele spiegel en gaan van alles uitproberen. Juf Karen vraagt steeds wat ze ontdekt hebben. Wanneer een kind dan rapporteert, dan imiteren anderen vaak de positie van de spiegels om hetzelfde te zien.

Direct in het begin zijn er al een aantal (bv het meisje naast me) die zien dat je steeds meer beelden krijgt naarmate de hoek tussen de spiegels kleiner wordt. Die ontdekken zo maar even een regel. Het is ze opgevallen en dan experimenteren ze spontaan om de regel te verifiëren!

Observaties van kinderen:

Mijn buurmeisje: ik heb wat ontdekt en ze laat me meteen zien wat er gebeurt als je de spiegels onder een kleine hoek houdt.

Juf Karen vraagt kinderen, velen zitten met hun hand omhoog.

Een meisje: Ik heb 3 dingen ontdekt

1. als je de tegels helemaal omkeert naar de buitenkant dan heb je 2 spiegels

2. als je ze vlak bij elkaar houdt, dan zie je jezelf wel 100 x

3. ben ik nu vergeten

De andere kinderen imiteren dit direct.
Blauwe meisje: als ik “zo” doe, dan zie ik Ayode (haar buurvrouw)

Sjeng: Als je de spiegel open doet, is het net als een laptop

Risette: als je drie spiegels combineert dan is het net een huis met een dak. Ze proberen dat even allemaal. Ze zijn vrij goed in het imiteren van deze toch wel ingewikkelde stand van spiegels.

Sophie: houdt haar oog vlakbij de rand van een spiegel en de andere spiegel is onder iets minder dan 90 graden. Nu zie je jezelf heel veel keer.

Nog een ander: als je de spiegels steeds dichter doet, dan wordt het steeds groener en ook donkerder.

Sjeng houdt de spiegels onder een hoek en zet de op zijn borst....zo lijkt het wel een pizza. Anderen proberen en hebben het meteen in de gaten.

Een ander: nu heb ik 100 ogen.....nee 9x zie ik.

Je kan een spiegelboekje maken, elke pagina is een spiegel.

Maakt kubus van 2x2 spiegels. .....dit is een spiegelmagnetron. Blijkbaar zijn er magnetrons (niet de witte) die erg spiegelen aan de buitenkant.

Als je een spiegel net boven je ogen houdt, dan zie je de grond bij het plafond.

Anderen merken op dat ze dat de vorige keer al gedaan hebben.

Brit: als je de spiegel beweegt, dan kun je ze allemaal zien.

Een ander: “Je hebt geen hoofd”

Bewegen in grotere en kleinere hoeken is mooi

Als je de spiegel wat op en neer beweegt (horizontale positie, spiegel naar beneden) dan kun je ze (de kinderen) besturen.

Door de spiegel te bewegen kun je een reuzenrad ronddraaien.

Bij een bepaalde hoek: dan zie je een kruis (velen hadden dat ontdekt). Iemand heeft het ook even over het kruis van de broek...zelfde woord, twee betekenissen.

Juf Karen: Wat kun je anders met twee spiegels dat je met een spiegel niet kunt?

Ze gaan vergelijken.....je ziet de dingen vaker

Individueel werk aan tafeltjes (11.40 – 12.15)

De kinderen krijgen een paper (A4) met een streep en een cirkel. Op het bord verschijnt een driehoek met 3 cirkels. Hoe kun je die met je spiegels maken?

Een aantal kinderen doet dit heel snel, anderen kopiëren.
Dan een vierkant op het bord..dit is nu een makkie,
“ik heb ‘m”, “ik heb ‘m” hoor je overal.

11.45 Tijd voor de volgende opdracht en die volgt ook meteen, de kralenopdracht. De kinderen krijgen kralen en kunnen die voor de spiegel leggen. Sommigen maken echt gebruik van de spiegels en komen tot patronen die er met de spiegels extra mooi uitzien. Bij anderen is het minder het geval.

De volgende opdracht is een kleurentekening te maken die er extra mooi uitziet met de spiegels. Iedereen is hard aan de gang.

Voorlopige analyse

Wat kunnen de kinderen leren van deze activiteiten?

Observeren en observaties beschrijven: Hier is veel gelegenheid voor, de kinderen zijn ook vrij duidelijk en de anderen kunnen meestal de observaties direct imiteren. Het beschrijven van observaties is ook voor taal interessant, maar daar werd nog niet systematisch aan gewerkt in deze les. Dat kon ook nog niet zo’n eerste keer.

Experimenteren: Kinderen die zien hoe je bij een kleine hoek veel spiegelbeelden krijgt en vervolgens systematisch nagaan op dat klopt door de hoek te variëren, zijn aan het experimenteren. Er is een idee en dat wordt getoetst. Hetzelfde gebeurde met de patronen (zie onder). Via dit experimenteren vindt schema?modelvorming plaats (zie onder).

Schema/-modelvorming: het is duidelijk dat veel kinderen tijdens de activiteit een schema/model in hun hoofd krijgen dat ze in staat stelt spiegelverschijnselen te voorspellen. Bv meer beelden bij een kleine hoek; of het maken van een driehoek of vierhoek, of vijfhoek; of mooie kralenpatronen. Hieruit kun je zien dat er iets geleerd is!

Dit is maar een aanzet, er valt meer te analyseren.

Commentaar en Follow-up


b. Onder analyse staan wat leerdoelen. Je zou toch even een complete opsomming moeten geven van mogelijke doelen en daar dan prioriteiten kiezen. Denk bv aan de lijst van process skills:

1. Observeren.
2. Classificeren.
3. Gebruik van getallen.
4. Meten.
5. Gebruik van ruimte-tijd relaties.

6. Communiceren.

7. Voorspellen.

8. Inferring..(conclusies trekken, maar eigenlijk is het meer dan dat, het verder gaan dan de gegevens, dat verder gaan kan in conclusies, of in nieuwe voorspellingen, of op andere manieren)


10. Formuleren van hypothesen.

11. Interpreteren van gegevens.

12. Controlling variables, dat is het in de hand houden en manipuleren van variabelen.


Verder kun je denken aan taal, creativiteit, motoriek, ruimtelijk inzicht (kinderen kopiëren spiegelstanden en dat vereist toch inzicht en motoriek).

c. Duurde de kringfase iets te lang? Zouden de kinderen eerder naar hun tafeltjes moeten gaan? Met wat voor opdracht? Of zouden ze juist in het begin in groepjes moeten gaan en elkaar vertellen wat ze ontdekken en dan een kringgesprek? Kunnen ze dat, zo’n groepjesactiviteit? De kernvraag is hoe kun zo veel mogelijk kinderen het best aan het observeren, vragen, experimenteren, en redeneren krijgen?

d. Hoe zou je het denken en redeneren van de kinderen nog meer kunnen stimuleren? De opdrachten zijn okay, maar welke vragen stel je plenair in de kring, welke vragen kun je kinderen stellen (inspelend of wat ze doen) om nog meer denken en redeneren te krijgen (spelenderwijs natuurlijk)?

e. Hoe zou je ze hun observaties kunnen laten documenteren? In het franse programma La Main a la Pate laten ze kinderen zelf hun observaties documenteren vanaf groep 1&2. Dat brengt bewustwording op gang over wat ze zelf geleerd hebben en het ontwikkelt communicatie vaardigheden. Hoe zou je dat kunnen doen?

f. Hoe kun je als onderzoeker zoveel mogelijk van deze ervaring leren? Dan is het nodig het totaal beeld te beschrijven (heb ik onder observaties heel ruw gedaan) en te filmen zodat we terug kunnen kijken. Het is ook nodig enkele kinderen (bv 3 of 4) iets beter te volgen om te proberen hun ontwikkeling tijdens de lessenserie in kaart te brengen.

g. Stel dat andere scholen het materiaal willen gebruiken, wat is er dan nog nodig aan instructies naast wat je al geschreven hebt? Je kunt bv de manier waarop drijven/zinken is opgeschreven als voorbeeld nemen en je kunt delen van de beschrijving gebruiken die je eerder aan de docenten stuurde.
Cycle 1 Kindergarten observation lesson 5 (Reflection)

Observeerder: Vincent Dorenbos

Maandag 18 december 2006-12-19

Les van 11.00 – 12.10

Onderwerp: Spiegels. In deze les kwamen een spiegel en een zaklamp, later 2 spiegels en een zaklamp en een discobal aan de orde.

Observaties

Er is eerst ca. 25 minuten een kringgesprek. De kinderen zitten rond een grote ronde tafel. De juf geeft de kinderen de gelegenheid met de zaklamp en de spiegel iets te laten zien. Er komen, voor mij verrassend veel, verschillende verschijnselen aan bod.

Er zijn 14 kinderen in de klas (9 meisjes, 5 jongens tussen 4 en 6 jaar oud) en 5 volwassenen: naast Juf Machtelt, juf Welmoet en ikzelf, nog twee geïnteresseerden stagiaires, waarvan er één ook meedraait in de naschoolse opvang (en daar aan Welmoet gevraagd heeft om ook één of twee lessen rond spiegels te komen doen). Ik heb geprobeerd de uitspraken zo letterlijk mogelijk op te schrijven. Ben niet zeker van de spelling van de namen.

Omdat het erg zonnig is, heeft de juf de luxaflex dichtgedaan zodat er een beetje gedempt licht is in het lokaal.

11.04


Een ll vraagt: Maak je hem nu viezer?

Juf M: Nee schoner.

Sacha (jongen ws. 6 jaar) springt op: “Dan wordt het plafond licht.” Hij krijgt de lamp en spiegel en doet het direct voor.

Juf: Hoe komt dat?

Lara zegt: Als je hem (de lamp) erop doet, zie je het helemaal niet meer. (ze heeft niet de lamp)

Juf M. vraagt hoe dit kan

Faye: Omdat hij dicht is. Hij drukt de lamp op de spiegel.

Dan kan er geen licht meer door heen. Dan zit hij vast tussen deze twee glaasjes (wijst naar spiegel en naar glasplaat voor de lamp

Jamie: Je ziet wel een wit randje licht.

De andere kinderen beamen.

Yousri: Probeert ook om de lichtstraal te weerkaatsen. Dit lukt niet, maar hij ‘vangt’ wel een reflectie van de zon.

De anderen merken de ‘zonnevlek’ direct op, maar hebben niet door dat deze van de zon afkomstig is.

Juf vraagt waarom het beeldje zo snel beweegt.

Jill (over Yousri): Omdat hij hem niet stil houdt.

Dan krijgt Jill de lamp en de speigel. Jill beweegt de lamp en laat zien dat de vlek dan op het plafond beweegt.

Tobias schijnt rechtstreeks op het plafond. Hij ziet randjes licht (die rechtstreeks van de lamp komen). Probeert ook wat met de spiegel en kijkt er in, maar schijnt er langs. Hij houdt de spiegel zelfs boven de lamp.

Anne (meisje): Ik zie de plantjes [de schaduw van de herfstwerkjes die in een lijn door de klas hangen. Ik heb gemist of ze het licht hierbij direct van de lamp of via de spiegel liet komen]
Daarna ziet ze de lamp in de spiegel. Ze houdt ze zo:

(11.10)

De kinderen reageren enthousiast op de lichtvlek.


Juf M: “Judy houdt de lamp stil, toch beweegt hij [de lichtvlek]. Hoe komt dat?”

Sacha: “Hij beweegt de spiegel.”

Judy schijnt en Jasmijn heeft de spiegel en probeert de lamp in de spiegel te zien/vangen [Judy zit in de kring diametraal t.o.v. Jasmijn]. Ze ziet hem

Alle kinderen zoeken heel enthousiast waar de lichtvlek nu is. Soms verwarren ze de lichtplekjes van de zon die door de luxaflex vallen met de gespiegelde lichtbundel van de zaklamp.

De hele klas met juf M en Welmoet gaan nu in de poppenhoek staan. De poppenhoek is een vrij donkere afgesloten ruimte in een hoek van het klaslokaal. Boven op de poppenhoek is nog een speelhoek.

Sacha heeft de lamp en Isa de spiegel. Ze doen na wat Judy en Jasmijn eerder deden. Nu is de lichtplek van de zaklamp veel duidelijker te zien omdat het in de poppenhoek donkerder is.

Juf vraagt of dit ook met twee spiegels kan. Ze geeft Sacha nu ook een spiegel.

Sacha schijnt in zijn spiegel naar Isa. Isa weerkaatst de lichtbundel verder naar het plafond van de poppenhoek. De kinderen juichen dat het gelukt is.
De kinderen gaan weer terug naar de kring.


Juf draait de discobal. “Hoe zou dit komen [de vlekjes]?”

Sacha: “Omdat je hem draait.”

Juf: “Lieve?”

Lieve: “Omdat die vierkantjes ook…”

Juf: “Ja, wat zijn die vierkantjes?”

Lieve: “Stippeltjes… Vierkante… spiegeltjes!”

Juf laat nog een keer zien wat er gebeurt als ze met de lamp op de draaiende discobal schijnt.

“Juf Welmoet heeft er zelf één gemaakt. Zullen we kijken of hij het doet?” Hij doet het.

De kinderen gaan knutselen en maken hun eigen discobal. Er zijn ballen van piepschuim en Welmoet heeft lange stroken papier met een glanzend zilveren laag geknipt.

Tobias: “Juf Welmoet, ik weet iets.” Hij loopt naar de luxaflex met zijn strook zilverpapier en laat zien dat de strook “een beetje goud lijkt” als hij hem in de buurt van de zonverlichte gele luxaflex houdt.

Sacha zegt: “Ik heb een standaard gemaakt.” Hij heeft de bal op de omgekeerde dop van de prittstift gelegd, zodat de bal niet wegrolt tijdens het beplakken.

Juf M neemt zijn idee uit en deelt alle kinderen een frisdrankflesdopje uit om hun bal op te leggen.

Vier oudere kinderen gaan om 11.30 u naar de kerstmusical (oefenen).

De overige kinderen knutselen tot ca. 11.50 u geconcentreerd door en zingen af en toe lichtjes. Dan mogen ze als de bal klaar is bij juf Welmoet een draad halen die zij met een speld in de bal prikt. En daarna naar de poppenhoek om te kijken of hun discobal het doet. Alle ballen doen het.

Als alle kinderen klaar zijn en de boel is opgeruimd om 12.03 u dan doet juf M. de luxaflex open en zegt: “Kijken of het ook lukt met de zon. De zon is net een hele grote zaklantaarn.”

Sommige kinderen kijken ook nog wat er gebeurt als ze hun bal boven het spiegeltje houden dat omgekeerd op de grote ronde tafel ligt.

Tot slot bedankt juf M Welmoet voor haar lessen. De kinderen klappen voor haar.
**Cycle 2 Kindergarten 1 observation lesson 1 (Discover the mirror)**

*Observerder: Welmoet Damsma*

- veel meisjes in de klas, redelijk volwassen
- maar 1 echt klein kind, heet waars. Pelle

Duur les: ongeveer 35 minuten

Eerste les, A. (leerkracht) heeft geen ervaring met spiegels of dit soort onderwerpen. Ze is nog wat onzeker, maar ze blijft heel rustig en doet het goed. A. heeft het groepsgesprek minder onder controle dan M. De kinderen zijn ook erg bezig met hun spiegel in de kring en luisteren niet zo goed naar elkaar, maar ze dwingt ze ook niet echt. Aan het eind van de les zegt ze ook dat ze ze vooral lekker wilde laten experimenteren, dus het was min of meer bewust, maar ze is ook wel minder in staat om goede vragen te stellen lijkt het.

Tijdens het rondlopen van de kinderen houdt ze haar eigen spiegel vast en interacteert zo met de kinderen. Die komen naar haar toe om dingen te laten zien en ze ‘spiegelt naar hen terug’. Ze stelt weinig vragen, het is meer een soort zwijgende aanmoediging. Het werkt wel goed. De kinderen vinden heel veel uit, A. haalt dat er wel uit tijdens het kringgesprek, maar het moet nog even afgewacht worden of ze leermomenten echt kan benutten en sturen. Zoals gezegd, ze stelt niet echt (door)vragen.

De groep begint in de kring. De spiegels liggen op de tafel in het midden van de kring. Als de kinderen binnenkomen zien ze die liggen en gaan er meteen in kijken en hallo tegen zichzelf en de anderen zeggen, maar ze pakken ze nog niet op. A. heeft een grote spiegel en vraagt wat je ermee kan. De kinderen suggereren alleen dingen als ‘erin kijken, haren kammen, make-up doen’. Dit was bij M. ook zo. Daarna krijgen ze een eigen spiegel en krijgen de opdracht te kijken wat ze ermee kunnen. A. zegt ook nog dat ze ook mogen rondlopen, maar de kinderen blijven zitten. Ze gaan er eerst vooral veel in kijken en naar zichzelf zwaaien. Langzamerhand ontdekken ze dat ze het plafond kunnen zien, de wereld op z’n kop etc. Er is ook redelijk wat interactie tussen de kinderen. Sommigen werken echt wel samen. Enkelen komen al best ver door met de spiegel achter zich te kijken. Er volgt een kort gesprek, waarna A. ze nu echt laat rondlopen. De kinderen lopen overal naar toe, ook naar de gang. Er volgt weer een gesprek, er komen weer veel andere dingen uit. A. imiteert een aantal dingen en laat de kinderen het ook na doen, waarna ofwel instemming ofwel tegenwerpingen volgen. Er wordt nog niet echt iets uitgewerkt. Niet alle opmerkingen worden door de hele klas gehoord, omdat ze wel druk zijn.
A. laat ze nogmaals rondlopen. De kinderen verzamelen erg veel dingen op de tafel, naar eigen zeggen omdat ze die op z’n kop zagen. A. praat daar nog een laatste keer over en geeft de opdracht om de spullen ‘op z’n kop’ weer terug te brengen. Sommigen doen dat duidelijk, anderen niet echt.

**Opvallende dingen:**

- In principe kwam de groep met dezelfde dingen als de groep van M., maar kwam iets verder, in de zin van dat ze het achter zich kijken ontdekten. In de groep van M. waren er een aantal kinderen die dit ook wel even deden, maar niet echt registreerden. Een meisje kijkt ook via meerdere spiegels.
- Aan de andere kant hebben niet alle kinderen alles gedaan, omdat het kringgesprek wat chaotischer was dan bij M. In principe is dit niet erg, omdat het echt als introductie bedoeld is, en ze hebben wel veel ontdekt, maar de concentratie zou dan misschien iets langer vastgehouden zijn. De kinderen van M. leken creatiever met de beperkte middelen, maar dit kan ook geweest zijn omdat ze meer gelegenheid hadden hun zegje te doen.
- Bij het rondlopen zijn een heel aantal kinderen duidelijk de spiegel aan het manipuleren (heen en weer bewegen) om te zien wat er gebeurt.
- De kinderen kunnen goed vertellen wat ze hebben gezien, hoewel op het eerste gezicht niet iedereen aan het vertellen mee doet. Het is dus moeilijk in te schatten hoe goed iedereen het begrijpt. Tijdens het rondlopen lijkt wel iedereen met de spiegel bezig.
- Het grootste succes is uiteraard het op z’n kop kijken. Andere ontdekkingen zijn het zien van het plafond (door de spiegel op de vloer te leggen of door hem onder je neus te houden), het zien van vier ogen (door de spiegel vlak onder of boven je ogen te houden) en het zien van je buurvrouw of –man door de spiegel voor je te houden en schuin achter je te kijken.
- Er is een meisje dat ontdekt dat je op het plafond kan lopen en dat verder de hele les ook daadwerkelijk doet, dwz met haar voeten loopt/stampt terwijl ze in de spiegel kijkt die ze op haar buik houdt.
- Aan het eind zet een meisje de spiegel op een hele grote dobbelsteen die in de vensterbank staat en zegt dat het beeld dubbel wordt. Dit is precies wat in de les symmetrie aan de orde komt.
- Een meisje is erg bezig met de onderkant van de spiegel. Ze zegt dat het daar donker is.

Deze les hoeft niet aangepast te worden. Het werkt goed met die cyclus van ontdekken en vertellen etc. Het resultaat hangt een beetje af van de vaardigheid van de juf in het groepsgesprek, maar er komt altijd veel uit. De kinderen ontdekken veel meer dan de juffen verwachten. Het is ook echt bedoeld als introductieles. De kinderen vinden het krijgen van de spiegels al zo leuk dat ze het ding eerst een tijdje gewoon in handen gehad moeten hebben om er gerichter mee te kunnen werken.
Cycle 2 Kindergarten 1 observation lesson 2 (Discover more mirrors)

Observerder: Welmoet Damsma

Duur van les: ongeveer 40 minuten


We gaan weer in de kring, zonder de spullen, maar er liggen spullen van een groepje op de tafel. De kerstbal wordt als eerste genoemd. Een meisje zegt dat als je bijvoorbeeld je vinger erbij houdt dat die heel dik wordt. A. laat dat aan alle kinderen zien en vraagt hoe dat kan. Het antwoord is … (weet niet precies, maar niet dat het komt doordat hij bol is). A. gaat er verder niet op in. Een jongetje komt met de lepel en het op zn kop staan. A. vraagt wat niet spiegelde. Het papier wordt genoemd en nog een aantal dingen.
A. zegt dat ze vanmiddag verder gaan door tekenen te maken in het spiegelboekje. Dit komt als een verrassing voor mij, want ik wist niet dat ze dit de vorige keer ook had gedaan. De werkbladen zijn ook eigenlijk voor groep ¾, want deze kinderen kunnen nog niet lezen. Ik heb wel gemerkt dat er een grote behoefte is bij sommige kinderen om er iets mee te doen, zoals bij een tekening. Het is natuurlijk het begin van een labjournaal, dus wetenschappelijk gezien helemaal verantwoord. Als we napraaten na de les lijkt ze wat teleurgesteld met hoeveel de kinderen kwamen. Doordat kinderen soms zo dominant zijn in de groepjes komt het echt ontdekken er niet uit, tenminste niet in haar ogen. Ze vindt ze nog wel heel jong om op deze manier te werken. Ik zeg dat het een ander soort les is dan de vorige keer en wat je natuurlijk hoopt is dat ze nu zelf een beetje gaan opletten en af en toe iets zien en daarmee zullen komen en dat je zo langzaam de ogen opent. Bovendien gaat ze er vanmiddag dus in een soort hoek nog verder mee doen, voor de kinderen die willen. Het is ook wel spannend, zo’n doos met spulletjes.

Ik vond het in principe heel goed gaan. De kinderen waren minder druk dan de vorige keer en de les was goed georganiseerd. Het was wel weer zo dat er meer zat in het groepsgesprek dan eruit kwam. In principe hebben de kinderen hun ontdekkingen gedaan en hoeft er niet uitgelegd worden, maar met wat extra vragen, bijvoorbeeld over de kerstbal en de schaduw, had A. de kinderen beter kunnen laten nadenken.

**Losse opmerkingen**

Het lijkt het geval dat kinderen glinsteren nog wel eens verwarren met spiegelen. Als je ze dwingt om te erkennen dat het geen spiegel is, dan weten ze het wel, maar ze houden ook gewoon erg van glinsters.

- De kinderen in deze klas zijn niet bijzonder opmerkelijk. Het wordt ook niet heel goed gestimuleerd door A., dat wil zeggen, ze trekt het er niet echt uit, maar ze lijken wat passiever dan een aantal uit M's klas.
Cycle 2 Kindergarten 1 observation lesson 4 (the double mirror)

Observers are students from the pabo HvA

Spiegelles les 4: Observatie op de Nieuwe Kring groep 1/2

Op maandag 2 april 2007 hebben wij (Assia Ameziane en Maryam Khamlichi) geobserveerd in groep ½ op de Nieuwe Kring school te Diemen. Dit is een Jenaplanschool. Toen we aankwamen om 11.00 waren de kinderen nog buiten aan het spelen. Even later gingen ze naar binnen en kon de spiegel-les beginnen. De les begon om 11.15 en duurde tot 12.00

De les begon in de kring. Bij binnenkomst in het lokaal gingen de kinderen in de kring zitten. Juf Anita begon aan het begin van de les eerst met een terugblik naar de vorige les. Ze liet verscheidene kinderen aan het woord die mochten vertellen wat ze nog was bijgebleven van de vorige les. De leerkracht gaf een paar kinderen de beurt die hun vinger hadden opgestoken. Deze kinderen vertelden wat ze nog bijgebleven was. De leerkracht nam geen genoegen met enkele woorden maar vroeg steeds door, waardoor de kinderen meer vertelden. Zo vertelde een kind dat ze vond dat de vorige keer de kerstbal het meest spiegelde. De leerkracht vroeg hierop door en betrok hierbij ook andere kinderen door hen ook vragen te stellen. Zo kwamen meer kinderen aan het woord en wisten steeds meer kinderen terug te blikken naar de vorige les.

Het les-materiaal lag in een gesloten doos op tafel in de kring. Na de terugblik vertelde de leerkracht wat er ging gebeuren. Ze vertelde dat iedereen een spiegel zou krijgen. Daarbij herhaalde ze ook de regels. Zo maakte ze duidelijk dat er voorzichtig gedaan moest worden met de spiegels. Daarna deelde de leerkracht de spiegels uit. Ze vertelde hierbij niet wat de kinderen moesten doen. Het leuke was dat ieder kind wat anders deed met de spiegel. Het ene kind kreeg de dubbele spiegel niet eens open, terwijl een ander kind al haar benen aan het bekijken was. Zo liet de leerkracht de kinderen even aanrommelen met de spiegels. Dit duurde ongeveer 5 minuten. Het leuke was ook dat de leerkracht foto’s nam van de kinderen en hun ontdekkingen. De kinderen vonden dit leuk, omdat er dan werd vastgelegd wat zij ontdekt hebben. Dit geeft de kinderen een stimulans omdat ze hierdoor het gevoel krijgen dat ze serieus worden genomen en dat wat zij zien en ontdekken ook belangrijk is. De
leerkracht observeerde veel vanuit haar stoel, waardoor ze rust uitstraaldde. Dit had ook effect op de
kinderen waardoor ze rustig in de kring bleven. De leerkracht vertelde dat iedereen rustig op zijn plek
mocht gaan zitten. Daarna vroeg ze naar wat er allemaal gezien is. De kinderen kregen de gelegenheid
om te laten zien wat ze hebben ontdekt in hun spiegel. Een kind kwam tot de ontdekking dat als ze de
spiegel op haar been zette, dat ze haar benen in viervoud terugzag in de spiegel. De leerkracht ging hier
rustig op in en vroeg aan de rest van de kinderen dit uit te proberen. Ze gaf ze hier even de tijd voor.
Haar vraag was dan ook aan alle kinderen: “Hoe kan het nou dat je zoveel benen ziet?” Wat ons opviel
was dat de leerkracht goed inging op de reacties van de kinderen en hier ook erg serieus op inging. De
kinderen kregen hierdoor ook het gevoel dat ze serieus genomen werden en dus ook alles konden
zeggen. Je zag dat er een goede vertrouwensband was tussen de kinderen en de leerkracht waardoor de
kinderen open konden zijn en alles durfden te zeggen.

De leerkracht vertelde dat de kinderen op onderzoek uit mochten gaan. Ze hoefden daarbij niet in de
kring te blijven zitten. We zagen dat de kinderen dat heel erg leuk vonden. Ze gingen individueel maar
soms ook in groepjes op onderzoek uit. Ze gingen hierbij de verschillende hoeken in en spiegelden
vanalles. Sommigen gingen ook de gang op, en als er wat moois was gezien kwamen ze dat bij de
leerkracht melden. Die ging er dan naartoe. Ze vroeg hierbij veel door en maakte foto’s van wat de
kinderen hadden gezien. We zagen dat sommige kinderen ook naar de kasten toeliepen en materialen
pakten en dat gingen spiegelen. Zo zag je kinderen met viltstiften lopen en kinderen die bakjes met
kralen hadden gepakt en dat op tafel neerzetten en daarna keken. Na een een tijdje vroeg de
leerkracht of iedereen weer plaats wilde nemen in de kring. Een kind liep naar de middelste tafel toe,
waar allemaal plantjes op stonden. Ze zette haar spiegel naast de plant neer en was heel verwonderd
over het feit dat je dus “opeens” meerdere planten zag. Ze vroeg of de juf wilde komen kijken. Vele
kinderen volgden en zetten hun spiegeltje naast dat van het eerste meisje. Zo stond er een hele
opstelling van spiegels rond de plantjes. Hier werden ook foto’s van genomen. En toen nam iedereen
echt plaats en ging de leerkracht verder met de uitleg voor de volgende opdracht.

De volgende opdracht was dat iedereen een werkblad kreeg. Daar stonden een lijn en een stip op.
De kinderen werden in groepjes verdeeld en mochten hierbij aan de tafels gaan zitten. De leerkracht
vertelde dat je de lijn en de stip mocht gaan spiegelen, hierbij mochten stiften om te tekenen, en kralen
om neer te leggen bij gebruikt worden. De kinderen gingen aan de slag. We zagen dat de kinderen
enthousiast te werk gingen en hier dus ook volop gebruik maakten van de materialen. Sommige
kinderen maakten hele tekeningen met stif die ze dan gingen spiegelen. Anderen pakten het weer anders aan en legden figuren van kraaltjes, terwijl weer anderen het simpel hielden en genoegen namen met enkele lijnen. De leekracht liep ook bij dit deel van de les weer rond, ze stimuleerde de kinderen door positieve feedback te geven en foto’s te maken.

De kinderen werkten bij deze les niet samen. De opdrachten waren gericht op het individueel werken. We zagen wel dat de kinderen bij het op onderzoek uitgaan in de klas, veel met elkaar bezig waren. Ze werkten hierbij niet samen maar werkten naast elkaar. Ze lieten elkaar dingen zien en bespraken ook de ontdekkingen maar voor de rest was het wel echt “ieder voor zich”.

Wij vinden het materiaal dat gebruikt werd bij deze les heel toegankelijk. Het materiaal is simpel, maar heel goed te gebruiken door de kinderen. Dit maakt de les geschikt voor zowel jongste als oudste kleuters, omdat het materiaal laagdrempelig is. De kinderen kunnen allemaal op eigen niveau aan de slag. Dit maakt de les voor de leerkracht ook makkelijk en vergt niet veel voorbereiding. Als je deze les wilt geven moet je wel beschikken over genoeg spiegels. Elk kind moet namelijk beschikken over een eigen spiegel. Samen doen met een spiegel is lastig.

Wat ons wel opgevallen is, is dat er niet gezamenlijk werd geevalueerd. De kinderen die klaar waren mochten hun spiegel opruimen en in de kring gaan zitten. Dit zou je volgens ons beter gezamenlijk kunnen afsluiten, door in de kring naar de ervaringen van de kinderen te vragen.
Cycle 2 Kindergarten 2 observation lesson 1 (Discover the mirror)

Duur les: Ongeveer 30 minuten.

Er is een stagiaire, Kimberley.


Maartje zegt dat ze ook rond mogen lopen. Ze zijn erg enthousiast bezig. Het is duidelijk dat ze veel ontdekken, waarvan een aantal dingen niet terugkomen in de kring, zoals dat je kunt rondlopen zonder te botsen als je alleen in de spiegel kijkt.


Daarna wordt er nog een rondje in de klas gelopen. De kinderen zijn nog steeds druk met de spiegels, maar laten zich nu iets meer afleiden. Een meisje is in de hoek dingen uit de legobak op de spiegel aan het zetten. Een jongetje houdt twee spiegels bij elkaar. Een aantal meisjes is bezig met het van boven in de spiegel kijken, zodat het lijkt alsof je naar beneden valt. Een meisje draait rondjes met de spiegel boven haar ogen (ze vertelt dit later ook in de kring).


Anna is duidelijk de slimste van de klas. Ze laat ook veel aan andere kinderen zien die daar goed op reageren. Lotte is ook heel actief, maar die doet veel samen met Anna. Er zitten een paar lastigere
kinderen in de klas, zoals Tjerk, die M. naast zich laat zitten, die zich niet lang kan concentreren en Finn, die kennelijk snel boos is. Verder is het vooral een vrij drukke klas, maar wel lekker actief. M. stimuleert dit ook door veel grapjes te maken en vragen te stellen. Ze deed het kringgesprek erg goed. Ze stelde wedervragen en zorgde dat de kinderen de dingen nageden. De kinderen hebben erg veel ontdekt, niet alleen dankzij Anna. Na een half uur was de concentratie inderdaad wel op (M. zei al dat ze nogal onrustig zijn), maar ze vonden het wel leuk.

A’s les

Aan het eind ga ik nog even bij A. langs, die met de derde les heeft gegeven op de manier die ze had willen doen, namelijk niet met de hele klas knutselen, maar met een groepje. Ze zegt dat ze de introductie samen heeft gedaan en dat de kinderen vrij snel doorhadden dat je een donkere kleur nodig hebt voor een goede spiegel. Heel goed gedaan, want bij de eerste groep kwam dit er wel uit, maar niet helemaal. Zes kinderen wilden ook wel de spiegel maken en hebben dat gedaan. De meesten hebben een donkerblauwe spiegel, een meisje een zwarte. Dat is meestal het geval (de blauwe is een compromis tussen zo donker mogelijk en een leuke kleur). Dit was al best druk volgens A. De rest van de groep heeft hoekenwerk gedaan
Cycle 2 Kindergarten 2 observation lesson 4 (the double mirror)

Observers are students from the pabo HvA

Verslag les spiegels bij de kleuters

Hoe lang duurt de les? De les duurde 45 minuten

Hoe verloopt de les? Wat wordt er gedaan?
Aan het begin van de les introduceerde juf Maartje de spiegelles. Ze vertelde onder andere dat de kinderen iets heel spannends gingen doen. Ook herhaalde ze wat de kinderen de vorige spiegelles hadden gedaan. Na deze introductie deelde de juf aan ieder kind spiegeltjes uit. Deze zaten aan elkaar vast zoals een boek. Juf Maartje zei verder niet zoveel en liet de kinderen vooral zelf ontdekkingen doen met hun spiegel. Na een tijdje wordt er besproken wat de kinderen allemaal is opgevallen.

Wat ontdekken de kinderen? Beschrijf wat ze aan het doen zijn. Hoe formuleren ze hun ontdekkingen tijdens het zelf werken? Hoe formuleren ze hun ontdekkingen in de kring?
Het belangrijkste dat de kinderen deze les volgens mij hebben ontdekt, is dat ze door die twee spiegels aan elkaar heel andere dingen kunnen zien dan wanneer de spiegels los van elkaar zijn. Ook ontdekten sommige kinderen dat het er leuk uitziet als je met kralen patronen maakt, andere kinderen hebben dit niet ontdekt.
Tijdens het zelfstandig werken riepen kinderen wel eens iets wat ze ontdekt hadden. Tijdens de kring was dit eigenlijk het zelfde, de kinderen vertelden de juf wat ze hadden ontdekt.

Werken de kinderen samen? Zo ja, hoe dan en wat zeggen ze tegen elkaar? Zo nee, waarom denk je van niet?
De kinderen werken niet echt samen, maar ze kijken wel vaak naar wat een ander heeft gemaakt. Dingen worden dan ook van elkaar nagedaan. Dat ze niet meer hebben samengewerkt komt denk ik doordat het keuters zijn. Die zijn nu eenmaal nog veel met zichzelf bezig.


Hoe gedraagt de leraar zich? (zie hiervoor het observatieinstrument leraren om te kijken waar je op kunt letten)
Zie onder.
Zijn er momenten in de les waarop je denkt: dat had de leraar beter anders aan kunnen pakken, of daar had ze beter dit of dat kunnen zeggen? Misschien had de afsluiting iets langer gekund. Er werd nu niet echt besproken wat de conclusies waren. Ook had ze misschien op een gegeven moment de kinderen iets meer kunnen helpen met de kralen omdat sommige kinderen niet echt doorhadden wat je er precies mee kon doen.

Wat vind je van de les? Gaat het goed? Hoe zou je deze les nog kunnen verbeteren?
Ik vond het een erg leuke les en ik denk dat dit ook zeker voor de kleuters gold. Er was 1 ding waar ik wat over twijfelde, dat was waarom er voor gekozen was om op het a4tje een streep en een rondje te zetten. Ik snapte wel de bedoeling, maar het werd niet uitgelegd aan de kinderen en ik denk dat ze aan een leeg a4tje met de kralen ook wel genoeg hadden gehad. Elk kind legde het blaadje ook weer anders ten opzichte van de spiegel. Wel gebruikten sommige kinderen het lijntje om er kralen op te leggen.

Observatie Instrument Leraren
Met dit instrument observeert de LOOL medewerker de leraar zoals die de lessen uitvoert.
**Opening**

De leraar:

- Maakt een mededeling over de manier van werken;  
  Nee

- Creëert een open situatie gericht op vragen van kinderen;  
  Ja, de kinderen voelen zich heel vrij om vragen te stellen en om dingen te vertellen.

- Biedt uitdaging aan en wekt nieuwsgierigheid op;  

- Brengt structuur aan; zo ja, welke?  
  Door de regels nog even met de kinderen te bespreken. Bijvoorbeeld, als je door de klas loopt met een spiegel, waar moet je dan op letten?

- Maakt een groepsindeling; zo ja, op welke manier?  
  Nee
Vragen stellen en begeleiden

De leraar:

- Legt leerlingen uit hoe het gesprek verloopt:
  - Luisteren naar elkaar;
    Redelijk, maar door hun enthousiasme vergeten ze het wel is.
  - Reageren op wat gezegd wordt;
    Ja
  - Reageren op elkaar, niet alleen op wat de juffrouw of meester zegt.
    Ja

- Laat leerlingen vertellen:
  - “Hoe denk je dat...?”
    Nee dit wordt niet echt gevraagd.
  - “Hoe zou het kunnen dat...?”
    Nee, ook niet.
  - “Wat zag je?”
    Ja, dit wel.
“Hoe ging dat?”
Nee

Door te ‘hummen’;
?

“Wat gebeurde er?”
Ja, dit wordt wel gevraagd

“Wat betekent dat?”
Nee, maar dit is ook niet nodig.

Stimuleert leerlingen vragen te stellen;
Nee niet echt.

Speelt vragen door naar andere leerlingen;
Ja, als een kind een vraag stelt probeert de juf eerst of een ander kind het antwoord weet.
. Focust vragen;
Nee

. ‘Revioict’ vragen en opmerkingen;
Nee

. Laat leerlingen voorspellingen doen;
Nee

. Vraagt leerlingen wat de conclusies zijn.
Nee

Omgaan met het materiaal

. Hoeveel materiaal is er beschikbaar gesteld?
Genoeg
Hoe toegankelijk is het materiaal?
Heel toegankelijk. Vooral de kralen, de vrolijke kleuren spreekt de kinderen erg aan.

Hoe gaan de leerlingen om met het materiaal?
Met de spiegels voorzichtig. Met de kralen gaat elk kind weer anders om (voorzichtig/ruw etc.)

Logboek  NVT

Inhoudelijk
De leraar:
. Beschikt over de basiskennis van het onderwerp;
Ja dat denk ik wel, maar ze laat het niet echt merken.

. Kan met moeilijke vragen omgaan;
Die worden niet gesteld.

. (Bij begin lessenserie): Verklapt Weinig;
Ja, ze verklapt vrijwel niets.
(Aan eind lessenserie): Combineert uitspraken en brengt verdieping aan.
Niet echt. Dit mis ik een beetje.

Reflectie/Afsluiting

- Vindt er een reflectie/afsluiting plaats?
  Ja, kort. De juf stelt voor een spiegelhoek te maken omdat de kinderen zo enthousiast over de les zijn.

- Zo ja, op welke manier?
  Concluderend;
  Nee, er worden eigenlijk geen conclusies getrokken.

  Afspraken maken voor het vervolg;
  Ja, juf Maartje spreekt af een spiegelhoek te maken.

- En waarover gaat de afsluiting?
  Over de les of de kinderen het leuk vonden en over de spiegelhoek.
Cycle 2 Kindergarten 2 observation lesson 4 (The double mirror)

Observeerder: Ed van den Berg

12-04-2007

De les voor ons was er een moeder die vertelde over haar beroep: logopediste. Kinderen kwamen met aardig wat vragen.


9.15 M. leidde het in het een verwijzing naar een sprookje en naar een toverspiegel. De dubbele spiegel is een toverspiegel! Kinderen kregen de spiegels en ze konden er mee rondlopen. Vervolgens in de kring. Bij dat rondlopen waren er een paar die de spiegels als schep gebruikten in de zandbak.

Ontdekkingen in de kring: Tim: zo zie ik heel veel broeken. Milan: als je ‘m dichter doet, dan zie je er nog meer. Anna: als ik ‘m zo doe, dan zie ik steeds meer Anna’s en vakjes (ik weet niet wat ze met vakjes bedoelde).

9.27 Juf M. haalt paper, legt het op de grond, en vraagt een kind was ze nu met de spiegel kan doen. Het eerste kind houdt de spiegel horizontaal. Het tweede kind ziet meteen dat je ‘m vertikaal kan zetten met een hoek en dat dan het patroon op het papier er interessant uit ziet.

9.31 Kinderen zitten aan tafel met papier en met kralen.

Juf: wat zie je als je de spiegel beweegt?

Sommigen leggen slechts enkele kralen neer en krijgen mooie patronen. Anderen leggen een hele vracht neer en zien niet zo veel. Een jongetje heeft een hele berg kralen, maar heeft die aan een kant ingeduwd en zo ontstaat met de spiegel onder kleine hoek toch een prachtig patroon.

Ik zie enkele interacties waarbij juf M. goede vragen stelt.

9.41 nog volop “on task”

9.47 juf M. zegt...loop eens rond en ga eens bij elkaar kijken. Slechts enkele kinderen doen dat. Later wordt het nog eens aangekondigd en meer kinderen gaan op pad.

9.57 opruimen

Enkelen van de hele kleintjes zitten er wat verloren bij. Ik vroeg een van de kleinsten wat hij zag....”weet ik niet”.

Juf M. is enthousiast over de activiteiten. Ze ziet duidelijk verschil tussen de groep 1 en groep 2 kinderen. Wie er wat meer “sophisticated” gedrag met spiegels zou laten zien, was volgens haar tamelijk voorspelbaar. Ze wil graag verder met dit soort dingen, want hier zou ze nooit zelf opgekomen zijn.
Ook in deze groep 1&2 groep kunnen kinderen de relatie tussen hoek en aantal beelden ontdekken. Vergelijk met de groep 3&4 die ik zag in december, was er minder variëteit in de ontdekkingen en ook iets meer moeite om naar elkaar de luisteren.

Didactisch kan er zeker nog het een en ander verbeterd worden. Bv maken van een lijstje mogelijke vragen aan kinderen terwijl ze met kralen bezig zijn. Juf M.: Bespreken van ontdekkingen met kleinere groepjes kinderen terwijl anderen iets anders doen. Bv juf kan rondgaan langs groepjes terwijl de rest met de kralen bezig is. Wat zijn goede startvragen? Hoe te reageren op bepaalde ontdekkingen, etc. Interviews met spiegelactiviteiten zouden kunnen helpen deze vragen te genereren.

Sprankelmomenten?

Ik heb niet echt sprankelmomenten gezien, maar het is duidelijk dat kinderen van deze leeftijd geboeid kunnen raken door spiegels en een tijd geconcentreerd bezig kunnen zijn en daarbij ook het een en ander kunnen ontdekken. Wat ze precies leren, zal moeten blijken uit interviews.

**Cycle 2 Kindergarten 2 observation lesson 2 (More mirrors)**

*Observer is a student from the pabo HvA*

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**Spiegelles**

De Nieuwe Kring

2 april 2007

**Hoe lang duurt de les?**

De les duurt ongeveer een half uur.

**Hoe verloopt de les? Wat wordt er gedaan?**

Introductie

Praten over de vorige spiegelles. Wat spiegelt er allemaal? (raam, televisie, glas, ogen)

Een kind zegt ‘Licht spiegelt ook!’

**Activiteit 1**

Na 5 minuten kring mogen de kinderen door de klas lopen en op zoek gaan als ‘onderzoekers’ wat er allemaal spiegelt in de klas. Er wordt gevraagd of ze fluisteren. De kinderen brengen de objecten naar de kring.

Een kind zwaait met zijn hand langs voorwerpen om te kijken of het spiegelt.

De kinderen vinden veel, in eerste instantie denk je dat dingen niet spiegelen. (jurk) maar dan zit er een
klein knoopje op wat wel spiegelt. De kinderen zien veel.
Helaas zijn er enkele kinderen die in de zandbak gaan spelen.
Enkelen hebben moeite met het verschil tussen spiegelen en glanzen.
Wanneer de kinderen in de kring gaan zitten zijn ze enigszins onrustig door de voorwerpen die ze daar vinden. Wanneer de rust is teruggekeerd gaan ze bespreken wat ze hebben gevonden en de kinderen mogen ermee een rondje door de kring lopen. (telefoon, knoop aan jurk, riem, elastiekje, vrachtwagen) Er is een koffiebeker die spiegelt maar daar is ook vloeistof uit gelopen. De kinderen bewonderen de vloeistof die spiegelt.
Een aantal kinderen merken op dat je in sommige vormen er gek uitziet.

Activiteit 2
De kinderen moeten uitzoeken wat spiegelt en wat niet. (heel erg/beetje/niet)
Per drie kinderen krijgen ze een doos met voorwerpen die ze moeten onderven. Sommige kinderen vinden het lastig om de groepjes te maken en gaan spelen met de voorwerpen. Hier komen leuke dingen uit. (spelen met zonlicht en de weerkaatsing daarvan)
Vooral echt jonge kleuters hebben moeite met het verdelen in groepjes.
Er zitten ook zonnebrillen bij. De kinderen zetten die op en lopen ermee door de klas.
De aandacht is bij sommigen snel weg, terwijl anderen goed doorwerken. Ze lopen door de klas en kijken bij elkaar. Twee meisjes spelen in de zandtafel.

Evaluatie
Ook het thema schaduw komt ook even ter sprake.
Cycle 2 Kindergarten 2 observation lesson 2 (More mirrors)

Observer is a student from the pabo HvA

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Observatieverslag spiegel les maandag 2 april

De les duurt 35 minuten. Ik denk een goede lengte voor kleuters.

De leidster (verder aangeduid als L.) vraagt terug naar de vorige les.
Wat hebben we toen gedaan?
Hier wordt goed op gereageerd door de kinderen, veel hebben er wat over te zeggen. Ik had wat meer specifieke dingen willen horen van de vorige les. Een ervaring van een kind of iets heel opvallends. Ik vond het een beetje oppervlakkig.

Dan vraagt L. of er nog meer dingen spiegelen behalve een spiegel.
Een paar kinderen komen met antwoorden zoals raam, televisie.
L. vraagt door.
Na een tijdje komen de kinderen tot de ontdekking dat je ogen spiegelen. Je kunt jezelf zien in de ogen van de ander. (mooie ontdekking!) Dit vind ik een bijzondere opmerking van een kind. Het is voor ons logisch dat je ogen weerspiegelen wat je ziet maar voor een kind helemaal niet. Hier zou ik op in spelen. Niet perse op dat moment maar kan ook een andere keer.

Dan krijgen de kinderen de opdracht om in de klas dingen te zoeken die ook spiegelen en in de kring te leggen. Eerst loopt iedereen een beetje wazig rond maar als ze zien dat een aantal kinderen spullen gaan pakken en naar de kring gaan brengen, gaat de rest ook overstag. Ook ontstaan er 2 groepjes met leiders waar een paar andere kinderen maar achteraan hobbelten. Meer stimulatie om zelf iets te zoeken zou hier gepast zijn omdat ze daarna al in groepjes gaan werken.

Voordat iedereen opstaat zegt een kind nog gauw; “als iets heel schoon is spiegelt het”. L. knikt maar gaat hier niet op in. Dit vind ik zonder, want hier kun je juist heel goed het verschil uitleggen tussen glimmen en spiegelen.

Het valt me op dat een paar kinderen met dingen aan komen zetten die niet spiegelen zoals een kussen

Dan volgt de nabespreking in de kring. Dit gaat goed. De kinderen luisteren naar elkaar en als kinderen rondgaan met de voorwerpen wordt er gefascineerd gekeken. Ik vind dat L. weinig zegt over de voorwerpen in de kring die niet spiegelen. Het is een beetje verwarrend wat nou precies onder spiegelen valt en wat niet.

Er is per ongeluk thee omgevallen. De kinderen ontdekken dat dat ook spiegelt. L. gaat hier goed op in. Dit is een “leuk ongelukje”. Misschien leuk om standaard in de les kist te verwerken (dranken, water en spiegelen).

Ze krijgen de opdracht in groepjes spullen uit een doos te sorteren op drie hoopjes; spiegelt heel erg, spiegelt een beetje, spiegelt niet. Jammer dat L. dit niet met de voorwerpen in de kring heeft voorgedaan. Ik denk dat de kleuters er dan gerichter mee aan het werk waren gegaan.


Nu moeten ze langs andere groepjes om naar elkaars hoopjes te kijken. Dit wordt erg rommelig veel kinderen gaan er aan zitten en corrigeren terwijl het naar mijn idee juist de bedoeling is om te vergelijken (dat heeft niets te maken met goed of fout). Dit zou ik of achterwege
laten omdat ik het een verre stap vind voor kleuters of ik zou dit per groepje in een kring bespreken zodat alle kinderen het zien en ook het vergelijken duidelijk wordt.

De kinderen ruimen netjes op en komen dan terug in de kring. L. vraagt snappen jullie het allemaal? Er komt weinig respons. Op de vraag of ze het leuk vinden des te meer. Soms is het ook gewoon leuk als de kinderen lol hebben en of ze er dan 10 dingen of 1 ding van opsteken is niet erg. De consequenties daarvan liggen eraan hoe vaak dat voor komt.

Afsluiting
Ik vond het een hele leuke les. Als leerkracht zou ik het heel leuk vinden om zo’n kist te krijgen met de les of een lessencyclus. In elke klas pakt zoiets weer anders uit dus mijn aanwijzingen zijn ook maar subjectief. Ook zie je natuurlijk veel meer als je observeert dan dat je zelf les geeft. Van sommige dingen weet ik ook niet of jij het in de lesvoorbereiding hebt gezet of dat dat de uitvoer is van de leidster.