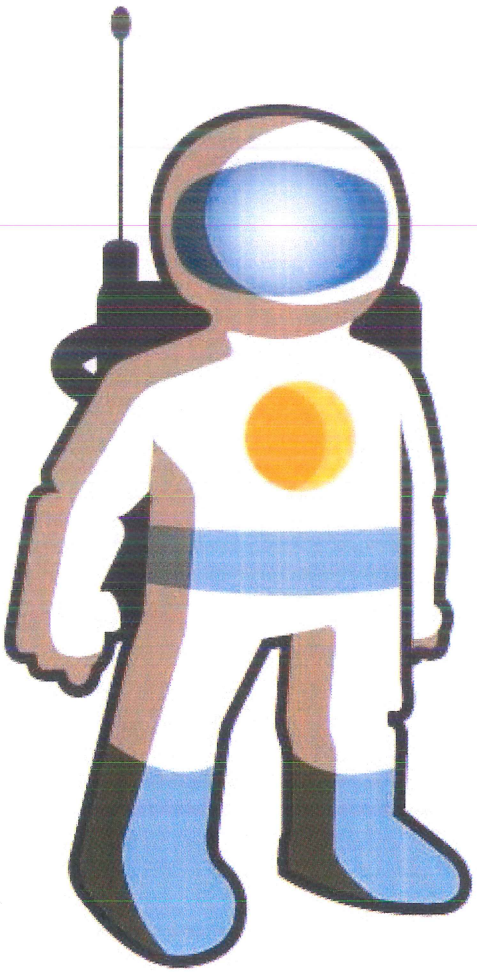
3th to 6th grade students' and their teachers' understanding of astronomical concepts

Monique Ankoné

Supervisors:
Martin Goedhart
Peter Barthel



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3^{th} to 6^{th} grade students' and their teachers' understanding of astronomical concepts.

Monique Ankoné

Abstract

This study investigates the understanding of elementary students of astronomical concepts before and after participation in the Mission Moon project. The Mission Moon project is a project where elementary students learn about astronomical- and especially lunar concepts. Pre-test and post-test data of 47 students and 7 elementary teachers were used in this study. Interviews were used to identify the knowledge of elementary students and their teachers of astronomical concepts. The interviews were transcribed, analyzed and the responses were categorized. Analyzing the quantitative data of the pre-test and post-test with a paired samples t-test show a positive change in students' understanding of astronomical concepts.

Introduction

The oldest science which probably fascinates everyone is astronomy. This fascination arises by looking at the sky on a cloudless night, seeing all the shinning stars and our moon. The first civilization who recorded their observations were the Babylonians. Baked clay tablets prove that Babylonians recorded the positions of the sun, the moon and the planets with their sexagesimal systems in 3000 BC.
The Babylonian myth, Enuma Elish, is a story that tells how the world is created. This myth shows that Babylonians observed the phases of the moon and the position of the moon with respect to the sun. After weeks of recording they noticed a pattern, they recognized as the cycle of the moon (Kavanagh, Agan & Sneider, 2005):

He cause the Moon to shine forth; and put the night under her command.
He appointed her to dwell in the night and mark out the time;
Month after month unceasingly he caused her grow.
At the beginning of the month, as thou risest over the land,
Thou shalt shine for six days;

And with a half disk on the seventh day.
At the full Moon thou shalt stand in opposition to the Sun, in the middle of each month. When the Sun has overtaken thee on the eastern horizon,
Thou shalt shrink and shape thy crescent backwards.
As invisibility approaches, draw near to the path of the Sun.
And on the twenty-night day thou shalt stand in line with the Sun a second time.

In *The Childs Conception of the World*, Jean Piaget (1929) wrote down the ideas that children have about astronomical concepts. In his interviews he shows that children have their own alternative ideas about the sun, the earth and the moon. Piaget asked the children to explain for example the cause of the lunar phases and found that children do not have a scientific conception of the cause of the lunar phases.
Alternative ideas may arise for several reasons. Cohen & Lucas (1999) claim that the misconception of the phases of the moon arise with the standard moon diagram. See figure 1.

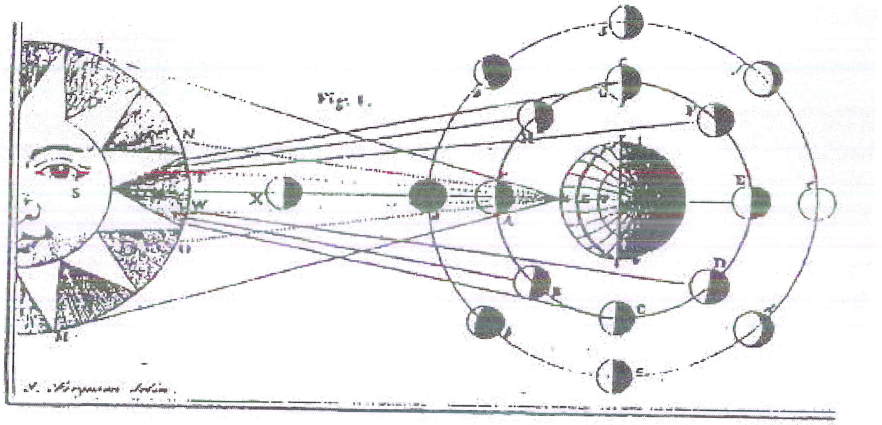

Figure 1: Ferguson created this moon diagram in 1756

This diagram was created by Ferguson in 1756 and shows the parts of the moon that reflects the sunlight. Cohen & Lucas (1999) stated that this diagram contains a lot of problems. The first problem is that this diagram does not show in which direction the moon rotates around the earth. The second problem is that the diagram shows two perspectives. It shows the parts of the moon that reflect the sunlight seen from the earth and it is observed from space looking down to earth, more specifically the North Pole. The two perspectives causes confusion by a lot of people and especially children.
Another plausible explanation of how alternative ideas may arise is due to children's literature. Astronomical concepts like the moon and its phases often appear in films and literature. Ault (1984) investigated the representation of the described and visualized moons in children's literature. He showed in his research that the misconception of the moon phases originates from the literature of children. This was confirmed in a research done by Kazemek et al. (2004), who noticed that children get an idea of how the world works through books. Particularly books that parents read to them, because those books contain a lot of images of our moon. Those images could confuse children and are probably the cause that they are left with misconceptions or alternative conceptions about the phases of our moon. In 2008 Trundle et al. investigated 80 children's books, including books that were rewarded with one or two awards. The text and the images of books were studied and here they paid attention to:

1. The shapes of the moon
2. The labels of the phases of the moon
3. The sequence of the shapes of the moon

Of the 772 images in total only 80% were scientific whereas 20% were prescribed as non-scientific, which indicates that children's books include incorrect illustrations of the moon. Trundles findings were consistent with her previous research (Trundle, 2005). Misrepresenting the moon may promote or reinforce alternative conceptions about lunar phases. (Trundle et al., 2008)
Children may also create their own ideas of astronomical phenomena based on their everyday experience but those ideas are mostly scientifically incorrect or incomplete due to lack of experience. (Harlen, 2000a p54)

Before dealing with the alternative ideas, these ideas must be identified. Over 20 years the alternative ideas about astronomical concepts have been identified. In 1989 Baxter studied the understanding of astronomical events and noticed that students have alternative ideas about the planet earth in space and the gravitational field, day and night, the seasons and the phases of the moon. 2 years later this list was extended by Phillips (1991):
3^{rd} grade students:

- The earth is larger than the sun
- The sun disappears at night

4^{th} to 6^{th} grade students:

- The earth is round like a pancake

4^{th} to 9^{th} grade students:

- We live on the flat middle of a sphere.
- Phases of the Moon are caused by a shadow from the Earth
- Different countries see different phases of the Moon on the same day.
- The Moon goes around the earth in a single day.
- The Moon makes light the same way the Sun does.
- The Earth's revolution around the sun causes night and day
- Day and night are caused by the Sun going around the Earth

He also noticed that adults do not have a scientific correct idea about astronomical concepts:

- The Sun goes around the Earth.
- The Sun goes around the Earth in less than a year

Similar results was obtained by Schoon (1992, 1995) who studied the understanding of earth science. The instrument used in the studies was a written questionnaire, which included several multiple choice questions. These studies have shown that there are a substantial number of people, including elementary students, have alternative ideas about astronomical concepts.

According to the National Science Education Standards (National Research Council [NRC], 1996) 4^{th} grade students need to know that the moon changes its shape every night and students from grade 5 to 8 need also to explain this phenomenon:
By observing the day and night sky regularly, children in grades K-4 will learn to identify sequences of changes and to look for patterns in these changes... They can draw the moon's shape for each evening on a calendar and determine the pattern in the phases over several weeks. These understandings should be confined to observations, descriptions, and finding patterns. (NRC, 1996, pp. 131, 133)

Also the Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS]) give teachers guidelines for teaching scientific topics to elementary students. The scientific topics also include astronomical concepts. For students of grade 6 to 8 Benchmarks states:
The benchmarks here call for students to be able to explain two phenomena, the seasons and the phases of the moon, that are usually not learned well.
At the end of grade 8, students should be able to explain that "the moon's orbit around the earth once in 28 days changes what part of the moon lighted by the sun and how much of that part can be seen from the earth the phases of the moon" (AAAS, 1993, p.66).
Most previous research has shown that elementary students do not meet the expectations of the National Science Education Standards and the Benchmarks for Science Literacy (Stahly et al., 1999; Trundle et al., 2007).

Schoon (1995) believed that many alternative ideas of (elementary) students originate in the classroom and that teachers cannot be expected to help their students with alternative ideas if they hold these or other alternative conceptions themselves. The results of many researches that investigated the pre-service's understandings of astronomical concepts showed that most pre-service teachers were likely to hold alternative conceptions about astronomical concepts. (Callison & Wright, 1993; Trundle et al., 2002, 2007)

To accept astronomical concepts, (pre-service) elementary teachers and their students have to change their alternative ideas. Trundle et al. (2007) suggested that pre-service teachers should have science lessons to help pre-service elementary teachers to have a scientific idea about astronomical concepts. The additional lessons could also be used by the pre-service elementary teachers to help their students who have alternative ideas about astronomical concepts in the future. Also constructivist-based instruction helps (pre-service) elementary teachers and elementary students to understand astronomical concepts. (Slater, 1993). Over the years several instructions including hands-on activities for elementary schools have been developed and designed to be implemented in classrooms. An example is the MOON project. In this project, 4^{th} to 8^{th} grade

students communicated with elementary students in different parts of the world and shared their moon observations. The MOON project gives the students insight in the lunar phases, their names and the order of the shapes. (Trundle et al., 2006).

Another activity that was developed, was that students had to observe the moon for a month and the students had to draw the observed shapes and eventually identify the pattern of the moon cycle and draw this pattern (Trundle et al., 2007). As the computer and internet became more accessible to elementary schools, computer programs like the planetarium software Starry Night helped elementary students to understand astronomical concepts like the lunar phases and eclipses. (Hobson et al., 2009).

Research has shown that instruction improved the knowledge of (pre-service) elementary teachers about astronomical concepts. (Callison & Wright, 1993; Trundle et al., 2002, 2006, 2007). And it has shown that elementary students' understanding after instruction do meet the expectations of the National Science Education Standards and the Benchmarks for Science Literacy. (Stahly et al., 1999; Hobson et al., 2009).

Purpose of Study

The curriculum of the elementary schools in the Netherlands developed by the Netherlands Institute for Curriculum development, SLO, consist of 58 attainment targets. These targets are spread over 7 learning areas. The attainment targets indicate what elementary students' knowledge and skill has to be at the end of a grade of the elementary school. The intermediate targets are guidelines for teachers to achieve the attainment targets. Astronomical concepts are included in the 'Orientation of yourself and the world' learning area and the associated attainment target is:
Elementary students learn that the position and orientation of the earth with respect to the sun causes the seasons and day and night.[1]

From the 3^{rd} and 4^{th} grade elementary students is expected that:

- The students do know the motions of the earth with respect to the sun
- The students do know what causes day and night

The expectations of the elementary students of grade 5 and 6 are:

- The students need to know the different shapes of the moon and have to recognize the pattern.
- The students need to know the motion of the moon with respect to the earth and the motion of the earth and the moon with respect to the sun.
- The students have to understand the day/night cycle and have to understand what causes the seasons.[2]

The intermediate targets are comparable to the guidelines provoked by the National Science Education Standards and the Benchmarks for Science Literacy.

The Standards and the Benchmarks both required the same astronomical concepts as the intermediate targets developed by the SLO.

In 2009, the international year of astronomy, several science and astronomical institutes (ESERO, Netherlands Space Office, NEMO, NOVA, Space Expo, the national public observatories, Universe Awareness, Camras and the foundation De Koepel.) organized the Mission Moon project to encourage elementary students to show interest in astronomy. Elementary schools could sign up for the Mission Moon project and they could register whether they wanted a visit from someone working at an observatory who could bring a telescope and inform the students about our moon and other astronomical concepts. The Mission Moon project, is a project what gave the elementary students the opportunity to observe the moon through a homemade and/or a professional telescope and learn about astronomical concepts.

At the time of registration, the elementary schools received the ESERO (European Space Education Resource Office) sourcebook. ESERO is ESA's education office and provide educational materials for primary and secondary schools to motivate students in science, technology, engineering and mathematics.[3]
The sourcebook from ESERO contains 80 lessons, mainly constructivist lessons, about astronomical topics. From the 80 lessons, 20 lessons are developed for the 3^{th} and 4^{th} grade students and another 20 lessons are developed for the 5^{th} and 6^{th} grade students. (See appendix B) The topics in the lessons covered in the ESERO sourcebook are the solar system, the day/night cycle, gravity and the lunar phases.
In one of the the constructivist lessons, students had to look up the sizes of the planets and then made a scale model of our solar system. While the students build their solar system, they learned the names and properties of the planets and got an idea about the relative sizes of the planets in our solar system.
In an other constructivist lesson, the students had to model the day/night cycle and the phases of the moon with an exposed light bulb (the sun) and a ball (the moon), where the head of the students represents the earth. As the students held the ball at arm's length in front of them and towards the bulb, they had to discover the cause of the day/night cycle and the cause of the moon phases. A similar teaching method was used in a paper of Mathews et al. (2006) and Hobson et al. (2009).
To learn about gravity, students had to calculate their weight on the different planets of our solar system and conclude that their weight and therefore gravity increases with a bigger planet than the earth and decreases when the planet is smaller than the earth.

In addition webquests for the Mission Moon project were created by myself and can be found at `http://missie-maan-groep-5-6.webkwestie.nl/` and `http://missie-maan-groep-7-8.webkwestie.nl/`.
In the webquest for 3^{rd} and 4^{th} grade elementary students, the students learn how the moon looks like by learning about the lunar maria and craters on the moon. The elementary students of grade 5 and 6 learn about the lunar phases and finally they have to make a poster where they explain the cause of the lunar phases. The webquests are based on the ESERO sourcebook.

In this study I would like to know whether Dutch students have the same alternative ideas as American students and find out what the Dutch elementary students' and their teachers' understandings are of the moon, the moon phases and other astronomical concepts before and after the Mission Moon project. In this study I addressed the following question:

- What conceptual knowledge of our moon and other astonomical phenomena do elementary students and their teachers have regarding astronomical conceptions before and after instruction?
- What are the differences between the urban elementary school and the suburban elementary school regarding to the knowledge of the elementary students and their teachers of lunar- and astronomical concepts?

Methodology

The research is conducted in a Frisian suburban elementary school 'Driemaster' and an urban elementary school in Amsterdam 'De Springplank'. The suburban elementary school 'Driemaster' is a public school with a total of 120 students. The urban elementary school in Amsterdam 'De Springplank' is a catholic school with 187 students. The elementary schools are selected because teachers from both schools used the lessons of the ESERO sourcebook and had a visit from a person from an observatory, who brought a telescope and informed the students about the moon and other astronomical concepts.

Data Collection Methods
An instrument like a written questionnaire used in the studies of Baxter (1989) and Schoon (1992) gives students not the possibility to share their ideas with the researchers. To discover and interpret the ideas elementary students and their teachers have about astronomical concepts, I interviewed the elementary students and their teachers.

The interview questions for 5^{th} and 6^{th} grade students are more extensive than the interview questions for the 3^{rd} and 4^{th} grade students, because it will include more questions about the moon phases and question about eclipses. Additional interviews with the elementary teachers of grade 3 to 6 are similarly conducted. (See appendix for the interview questions). The interview questions are mainly based on the questions used by Vosniadou (1989) and Vosniadou & Brewer (1990). The questions consist of factual questions designed to test the students knowledge of facts. (e.g. 'What is the shape of the earth/moon?') and explanation questions designed to lead the students to explain facts (e.g. 'If a person standing on the earth/moon and has a ball in his/her hands and drops it, where would the ball go to?' 'How is it possible that the moon changes its shape every night?').
Astronomical phenomena are not as direct as some physical events on earth, it is nevertheless important to create strong beliefs about the size, shape, movement of the earth, the moon and the sun and give rise to certain kinds of explanations of natural phenomena such as gravity, the day/night cycle, phases of the moon and solar and lunar eclipses. (Vosniadou, 1989) The following list show the concepts that were investigated in this study:

Solar objects:

- Moon
- Earth
- Sun

Phenomena:

- Day/nigh cycle
- Phases of the moon
- Eclipses

Concepts:

- Shape of celestial objects
- Size of celestial objects
- Motion of celestial objects
- Location of celestial objects
- Gravity

The questions about the shape, sizes, locations of the earth and the moon and gravity are left out in the interview questions of the elementary teachers, because those concepts develop through the years and I assume that teachers know those concepts. (See appendix for the interview questions.)

Sample
The sample used in this study consist of 47 elementary students (age 8-12 years) and 7 elementary teachers from the elementary schools. 23 elementary students of grade 3 to 6 and their 3 elementary teachers of the suburban school and 24 elementary students of grade 3 to 6 and their 4 elementary teachers of the urban school participated this research. I visited both schools before and after the Mission Moon project. From each grade, 6 students were interviewed before and after the Mission Moon project. 1 6^{th} grade student of the suburban elementary school was ill and therefore I interviewed 5 instead of 6 6^{th} grade students in the post-test.
The students were selected by their teacher. The teachers selected students who mainly represent the class based on their class results. From each grade (3^{th} to 6^{th}) 6 students are interviewed individually in a separate room before and after the Mission Moon project. This semi-structured interview has been audio-taped, which was used for data analysis.

Data Analysis
The interviews are transcribed verbatim and analysed. The analytic analysis is done by reading the transcripts to obtain a better perspective of the students' and teachers' understanding of astronomical concepts. The responses are categorized in different notions. Students' and teachers' drawings were coded as reflecting knowledge consistent with a scientific understanding or knowledge consistent with a non-scientific, or alternative conception (Hewson & Hewson, 1983).
The drawings are categorized into scientific drawings and non-scientific drawings. An example of a drawing with scientific moon shapes and their names can be seen in figure 2.

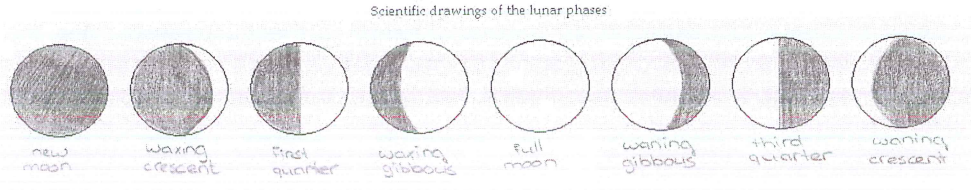

Figure 2: Examples of scientific drawings

Most of the non-scientific drawings are consistent with the understanding of moon phases being caused by the earths shadow or an extended version of the first and third quarter. The non-scientific drawings in this study are labelled and presented in figure 3.

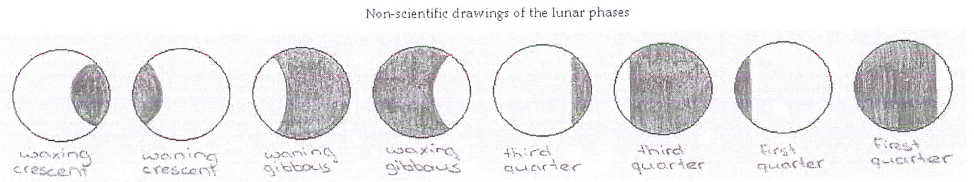

Figure 3: Examples of non-scientific drawings

Discussing the drawings in the results I used the term over-articulating and under-articulating (Trundle et al., 2006). If a moon phase is over-articulating in shape the lines exceeds the midline of the moon. See figure 4.

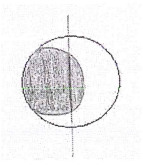

Figure 4: Example of an over-articulating phase

If a crescent moon phase is under-articulating in shape the lines do not reach the midline of the moon. See figure 5.

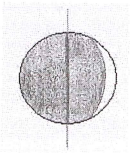

Figure 5: Example of an under-articulating phase

Finally, the understanding of astronomical concepts of elementary students and their teachers before and after the Mission Moon project was determined. The obtained data was analyzed using SPSS 17.0 and a paired samples t-test analyses were conducted to examine the development between the pre- and post-test results.

Results and Discussion

For clarity of presentation, the results of the interviews for an astronomical topic are presented by sections. In the sections the (alternative) ideas will be discussed in more detail and an overview of the results are presented in tables. The tables show the pre- and post-test results of both elementary schools. The correct answers or explanations are presented in bold letters and the numbers in the tables represent the number of students or teachers choosing that particular answer.

Students

Factual Questions

Earth's Shape.
Figure 6 shows the elementary students' responses to the factual question 'what is the shape of the earth?'. The students could chose between 5 different notions: flat, circle, round, oval and sphere. 'Sphere' is the most frequently chosen response in the pre-test and the post-test of the students from Sneek and Amsterdam, except in the Sneek pre-test of grade 4. For the Sneek students of grade 4 'round' was the most preferred response, what is similar to the findings of the study of Phillips (1991). 'Round' was the second most preferred answer of the elementary students from Sneek and Amsterdam.

Comparing the responses of the pre-test results and the post-test results a small increase in the correct answer can be seen in the 4^{th}, 5^{th} and the 6^{th} grade of the elementary school from Sneek. An increase in the correct answer can also be seen in the post-test results of the 4^{th} and 5^{th} grade students from Amsterdam. The number of students who said that the shape of the earth is a sphere increased with age. The post-test results of the 5^{th} grade elementary students from Sneek and Amsterdam show that all participants chose the correct answer.

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Flat	0	0	0	0	0	0	0	0
Circle	1	1	0	1	1	0	0	0
Round	2	3	1	1	2	2	0	2
Oval	0	0	0	0	0	0	0	0
Sphere	**3**	**2**	**5**	**4**	**3**	**4**	**6**	**3**

Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Flat	1	1	0	0	0	0	0	0
Circle	1	0	0	0	1	0	0	1
Round	1	2	2	2	2	2	0	0
Oval	0	0	1	0	0	0	0	1
Sphere	**3**	**3**	**3**	**4**	**3**	**4**	**6**	**4**

Figure 6: Responses to the question, 'what is the shape of the earth?'

Moon's Shape.
The responses to the factual question 'what is the shape of the moon?' is more distributed over the 5 notions: flat, circle, round, oval and sphere. (See figure 7). The youngest students from Sneek preferred the response 'round' in the pre-test while the responses of the 4^{th} grade students are divided over 'circle' and 'sphere'. The most common response in the pre-test of the 5^{th} and 6^{th} grade students from Sneek is 'sphere' where the students in the latter group all chose this response.
The pre-test results of the elementary students from Amsterdam show a lot of distribution in the students responses and do not have a preferred answer, except the students of grade 6. 3 6^{th} grade students from Amsterdam have chosen the term 'sphere' before the Mission Moon project.

The responses of the elementary students in the post-test differ slightly from the responses in the pre-test. Comparing the pre-test and post-test responses of grade 6 of the Sneek elementary school and grade 3 of the Amsterdam elementary school, a small decrease in the correct answer 'sphere' can be seen. This is probably due to their observational experience, because observing the moon with or without a telescope, the moon looks like a round surface instead of a sphere. Luckily, more 3^{rd} and 5^{th} grade students from Sneek and 5^{th} grade students from Amsterdam preferred 'sphere'.
There is only a small increase in the correct response and this can be due to the fact that elementary students from Sneek and Amsterdam do not know the word 'sphere' or find it difficult to distinguish round, circle and sphere. (Vos-

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Flat	0	0	1	0	0	0	0	0
Circle	0	3	0	0	0	0	0	1
Round	4	0	1	0	1	3	0	1
Oval	1	0	0	0	3	0	1	0
Sphere	**1**	**3**	**4**	**6**	**2**	**3**	**5**	**3**

Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Flat	0	1	0	0	0	0	0	0
Circle	1	1	2	0	4	1	1	2
Round	2	0	1	2	1	1	2	1
Oval	1	2	1	1	0	2	0	0
Sphere	**2**	**2**	**2**	**3**	**1**	**2**	**3**	**3**

Figure 7: Responses to the the question, 'what is the shape of the moon?'

niadou & Brewer, 1989). The elementary students can also be confused by the moon phases. The following fragment of a 3^{rd} grade Sneek student shows these difficulties:

Interviewer:
What shape has the earth? You can chose one of the following answers: flat, circle, round, oval or sphere, just like a ball?

Lotte:
Yes. A circle is something round? What means that it is the same right?

...

Interviewer:
And what is the shape of the moon? You can again choose one of the following answers: flat, circle, round, oval or sphere.

Lotte:
Round..

Interviewer:
Round.

Lotte:
Or is it oval?

Interviewer:
Oval?

Lotte:
Yes

Interviewer:
Why do you have doubts?

Lotte:

Well, sometimes the moon is not a full circle. Sometimes it is just the half.

Relative Size.

Figure 8 represents the responses of the elementary students regarding the relative size of the earth, moon and sun. The students were asked to arrange the earth, the moon and the sun from the smallest object to the largest object. Most 3^{rd} grade Sneek students believed before the Mission Moon project that the Sun is the smallest celestial object followed by the moon and then the earth, what is consistent with the findings of Philips (1991). 4^{th} grade students from Sneek mainly believe that the earth is the smallest celestial object than the moon and they believe that the sun is the biggest celestial object. The pre-test results of the 5^{th} grade students show a lot of distribution and while the Sneek students from grade 5 have no preferred answer, the Sneek students from grade 6 have. Their most common answer is the correct answer.

The pre-test results of the Amsterdam students of grade 3 are equally divided over 3 notions. Most 4^{th} grade students from Amsterdam believed that the moon is the smallest object and the earth the biggest. Due to the fact that the second most preferred order was sun-moon-earth, you can say that the greater part of the 4^{th} grade students from Amsterdam thought that the earth is the biggest celestial object. Unlike the 4^{th} grade students all the 5^{th} grade students from Amsterdam believed that the sun is the biggest celestial object. Nonetheless half of the 5^{th} grade students believed that the earth is the smallest celestial object while the other half believed that the moon is smaller. Also the greater part of the 6^{th} grade students from Amsterdam believed that the sun is bigger than the earth and the moon.

A great increase in the correct answer can be seen in the post-test of students from both schools. Almost every student from each grade of both schools were able to arrange the earth, the moon and the sun correctly, except the students of grade 6 from the elementary school in Amsterdam. However all the 6^{th} grade students knew that the Sun is the biggest celestial object. The amount of elementary students who said that the sun is larger than the earth increased with age. Note that all 6^{th} grade students from Sneek and all the 4^{th} grade students from Amsterdam gave the correct answer.

Location of the Earth

The responses to the factual question where the students had to point out the earth, a picture of the solar system was used. (See appendix). Figure 9 shows that before the Mission Moon project most 3^{rd} grade students from Sneek pointed out the largest planet of our solar system, Jupiter. The pre-test results of the Sneek students of grade 4 to 6 show that most of the students were able to point out the earth. what is inconsistent with their previous response. Unlike most of the 3^{rd} grade students from Sneek, most of the 3^{rd} grade students from Amsterdam were able to point out the earth in the picture correctly before the Mission Moon project. However the 4^{th} grade students from Amsterdam preferred to point out the planets Venus and Jupiter. Most Amsterdam students of grade 5 and 6 could point out the earth before the Mission Moon project.

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Earth-moon-sun	1	4	2	0	0	0	0	0
Earth-sun-moon	0	1	0	0	0	0	0	0
Moon-sun-earth	1	0	1	1	0	0	0	0
Moon-earth-sun	**1**	**0**	**1**	**5**	**4**	**5**	**5**	**5**
Sun-earth-moon	0	0	0	0	0	0	0	0
Sun-moon-earth	3	1	2	0	2	1	0	0
Same size	0	0	0	0	0	0	1	0

Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Earth-moon-sun	2	0	3	3	1	0	1	3
Earth-sun-moon	0	0	0	0	0	0	0	0
Moon-sun-earth	2	3	0	0	1	0	0	0
Moon-earth-sun	**2**	**1**	**3**	**1**	**4**	**6**	**5**	**3**
Sun-earth-moon	0	0	0	0	0	0	0	0
Sun-moon-earth	0	2	0	2	0	0	0	0
Same size	0	0	0	0	0	0	0	0

Figure 8: Responses to the question regarding the relative sizes of the earth, the moon and the sun.

After the Mission Moon project almost all elementary students were able to point out the earth correctly and notice that all the 6^{th} grade students from both schools pointed out the correct celestial object. It is also interesting to see that the second most favourite response of the elementary students is Neptune, what could be chosen due to the colour of the planet. Most students were aware of the fact that the earth is a blue planet, like the 6^{th} grade student from Amsterdam:

Interviewer:
Could you point out the earth in this picture?

Oussama:
The earth.. wait a minute.. I debating whether it is this one [pointing to Neptune] or this one [pointing to the Earth]

Interviewer:
Why do you have doubts?

Oussama:
This one [pointing to Neptune] is completely blue and the sea is blue too if you look on a map.. [thinking]. However I choose this one [pointing to the Earth].

Location of the Moon
When the students were asked to point out the moon in the picture of the solar system, many students pointed to a planet or even the sun before they took part in the Mission Moon project. (See figure 10).

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Sun	0	0	0	0	0	0	0	0
Mercury	0	0	0	0	0	0	0	0
Venus	0	0	0	0	0	0	0	0
Earth	1	3	3	5	3	4	3	5
Moon	0	0	0	0	0	0	0	0
Mars	0	0	0	0	0	0	0	0
Jupiter	4	0	1	0	2	0	1	0
Saturn	0	0	0	0	0	0	0	0
Uranus	0	0	0	0	0	0	0	0
Neptune	1	3	2	1	1	2	2	0
Not in the picture	0	0	0	0	0	0	0	0

Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Sun	0	0	0	0	0	0	0	0
Mercury	2	0	0	0	1	0	0	0
Venus	0	2	0	0	0	0	0	0
Earth	3	1	3	5	5	5	5	6
Moon	0	0	0	0	0	0	0	0
Mars	0	0	0	0	0	0	0	0
Jupiter	1	2	0	1	0	0	0	0
Saturn	0	0	0	0	0	0	0	0
Uranus	0	0	0	0	0	0	0	0
Neptune	0	1	3	0	0	1	1	0
Not in the picture	0	0	0	0	0	0	0	0

Figure 9: Responses to the instruction, 'Point to the earth' in a picture of the Solar System.

The pre-test results show that none of the 3^{rd} grade students from Sneek were able to point out the moon. Only 1 of the Sneek students of grade 4 and 2 Sneek students of grade 5 and 6 were able to point out the moon.
Similar to the Sneek students most of the students from Amsterdam were also not able to point out the moon in the solar system picture before the Mission Moon project. Only 1 3^{rd} grade student and 2 6^{th} grade students from Amsterdam pointed out the moon correctly. There was even 1 6^{th} grade students from Amsterdam, who claimed that the moon was not present in the picture.

After the Mission Moon project an increase in the correct answer can be seen. The most preferred celestial object of the 4^{th} and 6^{th} grade students from Amsterdam however is the planet Mercury. The planet Mercury is the second most chosen celestial object in all the other grades. This can probably be explained due to the color, because most of the students know the color of the moon and were therefore looking for a grey celestial object. Some students from Amsterdam pointed to the moon based on their knowledge of the motion of the moon around the earth:

Interviewer:
Could you point to the earth?

Marouan:
Here is the earth [pointing to the earth] and the moon moves around the earth.

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Sun	2	0	0	0	1	0	0	0
Mercury	0	1	1	2	0	1	1	0
Venus	0	0	0	0	0	0	0	0
Earth	0	0	0	0	0	0	0	0
Moon	**0**	**1**	**2**	**2**	**3**	**3**	**3**	**5**
Mars	0	1	0	0	0	1	1	0
Jupiter	1	1	1	0	0	0	0	0
Saturn	1	0	0	0	0	0	0	0
Uranus	2	2	1	2	2	1	1	0
Neptune	0	0	1	0	0	0	0	0
Not in the picture	0	0	0	0	0	0	0	0

Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Sun	0	2	0	0	0	0	0	0
Mercury	2	3	1	3	0	3	2	4
Venus	0	0	0	0	1	0	0	0
Earth	0	0	0	0	0	1	0	0
Moon	**1**	**0**	**0**	**2**	**4**	**2**	**4**	**2**
Mars	1	0	1	0	0	0	0	0
Jupiter	0	0	1	0	0	0	0	0
Saturn	0	0	0	0	0	0	0	0
Uranus	2	1	3	0	1	0	0	0
Neptune	0	0	0	0	0	0	0	0
Not in the picture	0	0	0	1	0	0	0	0

Figure 10: Responses to the instruction, 'Point to the moon' in a picture of the Solar System.

Gravity Questions

The following 2 questions are concerning the abstract concept gravity. Students had to explain where the ball goes when the boy (See 53 and 54) standing on the earth and moon drops it. The students' responses regarding the gravity questions are presented in figure 11 and 12. Students' responses to the gravity questions are categorized into 3 notions: the ball moves from the earth/moon, the ball moves towards or near the earth/moon or the students had no idea. Most of the students were confused by the picture. They did not realise that the person on the earth/moon is standing on the surface of the earth/moon but thought that the person is floating near the earth/moon. Therefore the students who claimed that when the person drops the ball, the ball will move towards the earth/moon and will then orbit the earth/moon are categorized into the 'towards or near the earth/moon' notion. Because gravity not only causes objects with mass to fall but gravity also causes objects like a satellite to orbit the earth/moon.

Gravity and the earth

The explanations of the students to the question 'where would the ball go if the person standing on earth drops the ball?' are shown in figure 11. Remarkably most students of grade 3 to 6 of both elementary schools have a good understanding of gravity on earth before the Mission Moon project. The pre-test results show that most of the students from grade 3 to 6 know that the ball will

fall towards the earth.

After the Mission Moon project all 3^{rd} grade students from Sneek and all the 3^{rd} and 5^{th} grade students Amsterdam were able to explain where the ball would go to correctly. The number of students of grade 4 to 6 from Sneek and the 4^{th} grade from Amsterdam however show a slight decrease. The post-test results of the Amsterdam students of grade 5 and 6 on the contrary show a slight increase in the correct answer.

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Away from the earth	2	2	1	1	0	4	2	2
Toward or near the earth	4	4	5	5	6	2	4	3
I do not know/ No response	0	0	0	0	0	0	0	0

Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Away from the earth	1	2	2	2	0	3	0	1
Toward or near the earth	5	4	4	4	6	3	6	5
I do not know/ No response	0	0	0	0	0	0	0	0

Figure 11: Responses to the question, 'where would the ball go if the person standing on the earth would let go of the ball?'

Gravity and the moon
The 2^{nd} gravity question is similar to the previous question but now the person is standing on the moon instead of the earth. The students' explanations to the question where would the ball go if the person standing on the moon drops the ball? are shown in figure 12.
Before the Mission Moon project most of the 3^{rd} grade students from Sneek believe that the ball will move towards or near the moon while Sneek students of grade 4 and 6 believe that the ball moves away from the moon before the Mission Moon project.
The pre-test results of 4^{th} and 5^{th} grade students from Amsterdam show that students' responses was equally divided over the 2 notions 'away from the moon' and 'towards or near the moon'. The pre-test results of most 6^{th} grade students from Amsterdam show that they were aware of the fact that the ball will move toward the moon.

After the Mission Moon project the greater part of the students of grade 3 to 5 from Sneek believed that the ball would move toward or near the moon while the post-test results of the 6^{th} grade students from Sneek show a small decrease.
The greater part of the students from Amsterdam on the contrary, believed that the ball will move into space and therefore away from the moon, except the 4^{th}

grade students. The greater part of the 4^{th} grade students from Amsterdam explained the gravity question correctly. The post-test results of the 5^{th} and 6^{th} grade students from Amsterdam show a decrease compared to the pre-test results, only 2 5^{th} grade and 2 6^{th} grade students from Amsterdam knew that the ball will move toward the moon due to gravity.

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Away from the moon	2	4	3	4	1	3	2	4
Toward or near the moon	4	2	3	2	5	3	4	1
I do not know/ No response	0	0	0	1	0	0	0	0
Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Away from the moon	4	3	3	1	4	2	4	4
Toward or near the moon	2	3	3	4	2	4	2	2
I do not know/ No response	0	0	0	1	0	0	0	0

Figure 12: Responses to the question, 'where would the ball go if the person standing on the moon would let go of the ball?'

A great alternative idea these students have is that there is no gravity on the moon, because the moon does not have air. Most students connect gravity with the existence of air, what means that as soon as the earth's atmosphere ends so will gravity. This is consistent with the study of Berg & Brouwer (1991), Bar et al. (1997) and Chandler (1991):

Interviewer:

I show you this images [image of the person standing on earth] maybe you can recognize it from the previous time. Here you see the earth and this person is standing on the earth and is holding a ball. Now, he lets go of the ball, can you tell me where the ball goes to?

Yassit:

The ball is moving from here to here [towards earth]

Interviewer:

Is the ball falling on earth?

Yassit:

Yes.. No, if the person is in space then the ball does not fall but if the ball is under the earth's atmosphere then the ball will fall down on earth.

Motion Questions
The following questions concern the motion of the earth with respect to the sun and the motion of the moon with respect to the earth.

Motion of the moon
In figure 13 you see the students' responses to the question 'does the moon move around the earth or does the earth move around the moon?'. The greater part of the students of grade 3 to 6 from Sneek were able to explain this question correctly before the Mission Moon project. The pre-test results of the Sneek students show that 4 3^{rd} grade students, 5 4^{th} grade students, 3 5^{th} grade students and 5 6^{th} grade students were able to explain that the moon orbits the earth. Remarkable was that 1 5^{th} grade student from Sneek claimed that the earth and the moon move around each other.
Similar to the pre-test results of the greater part of the 3^{rd} and 4^{th} grade students from Sneek also the greater part of the 3^{rd} and 4^{th} grade students from Amsterdam believed before the Mission Moon project that the moon orbits the earth. Most of the 5^{th} and 6^{th} grade students from Amsterdam however believed the contrary. Only 2 5^{th} grade students and 2 6^{th} grade students from Amsterdam explained that the moon orbits the earth before the Mission Moon project.

Sneek

	Pre-test Grade				Post-test Grade			
	3	4	5	6	3	4	5	6
Earth moves around the moon	2	1	2	1	0	1	2	0
Moon moves around the earth	4	5	3	5	6	5	4	5
Move around each other	0	0	1	0	0	0	0	0

Amsterdam

	Pre-test Grade				Post-test Grade			
	3	4	5	6	3	4	5	6
Earth moves around the moon	1	0	4	4	2	0	2	3
Moon moves around the earth	5	6	2	2	4	6	4	3
Move around each other	0	0	0	0	0	0	0	0

Figure 13: Responses to the question, 'does the moon move around the earth or moves the earth around the moon?'

After the Mission Moon project an increase of the number of students from both elementary schools, who gave a good explanation of the motion of the moon around the earth, can be seen in figure 13. All 3^{rd} and 6^{th} grade students from Sneek could explain the question correctly. The number of 4^{th} grade students from Sneek who were able to explain it correctly stayed constant and instead of 3 5^{th} grade students in the pre-test, 4 5^{th} grade students from Sneek believed that the moon moves around the earth.
A slight decrease in the correct answer can be seen in the post-test results of Amsterdam. However an increase in the number of students who could explain

the question correctly can be seen in the post-test results from Amsterdam of grade 5 and 6. Note that the greater part of the Amsterdam students from grade 3 to 5 explained the motion of the moon with respect to the earth correctly and that even all 4^{th} grade students from Amsterdam were able to explain that the moon moves around the earth.

Motion of the earth
The sun on the contrary does not orbit the earth like the moon. The results of the students to the question 'does the earth orbit the sun or does the sun orbit the earth?' are shown in figure 14. The pre-test results show that 4 3^{rd} grade, 3 4^{th} grade, 2 5^{th} grade and 4 6^{th} grade students from Sneek believed in a heliocentric model. In a geocentric model on the contrary the earth is the centre of our Universe and every celestial object including the sun, orbits the earth. Most of the Amsterdam students of grade 3, 5 and 6 knew before the Mission Moon project that the earth orbits the sun, they believed in a heliocentric model. In the heliocentric model the Sun instead of the earth is the centre of our universe.
Most 4^{th} grade students from Amsterdam on the contrary believed in a heliocentric model. This alternative idea elementary students have is probably due to students' everyday experience, because standing on the earth they see the Sun and moon moving in one line in the sky.

Sneek

	Pre-test Grade				Post-test Grade			
	3	4	5	6	3	4	5	6
Earth moves around the sun	2	3	4	2	6	5	5	5
Sun moves around the earth	4	3	2	4	0	1	1	0
Move around each other	0	0	0	0	0	0	0	0

Amsterdam

	Pre-test Grade				Post-test Grade			
	3	4	5	6	3	4	5	6
Earth moves around the sun	4	2	4	4	5	4	6	4
Sun moves around the earth	2	4	2	2	1	2	0	1
Move around each other	0	0	0	0	0	0	0	1

Figure 14: Responses to the question, 'does the earth moves around the sun or moves the sun around the earth?'

Fortunately, the post-test results of both elementary schools show that the number of students believing in the Copernican model increased enormously with respect to the pre-test results. 5 4^{th} grade students , 5 5^{th} grade students and all students of grade 3 and 6 from Sneek were able to explain the motion of the earth with respect to the sun correctly.
Also the greater part of all elementary students from Amsterdam believed in the Copernican model. An enormous increase in the correct answer with respect to the pre-test results from the Amsterdam students can be seen in the post-test

results of grade 4. Instead of only 1 4^{th} grade student of Amsterdam, 4 4^{th} grade students believed after the Mission Moon project that the earth orbits the sun. The 5^{th} grade students from Amsterdam were all able to explain the motion of the earth with respect to the sun correctly.

Day/night cycle
The students' ideas of the day/night cycle were investigated by asking 2 questions 'where is the sun at night?' and 'how is it possible that we have day and night?'.

The Sun at night
Students' explanations to the question 'where is the sun at night?' was categorized into 7 distinct notions. The prevalence of each notion is shown in figure 15. The pre-test results of the students from both elementary schools show that some students from Sneek and Amsterdam thought that the sun is near or behind the moon.
One 3^{rd} grade student from Sneek gave an animistic (Piaget, 1929) explanation and explained the disappearance of the sun during the night by saying that the sun has to go to sleep. However most students were more likely to say that the sun is at the other side of the earth or that the sun stays where it is before the Mission Moon project.

After the Mission Moon project the number of students, who could explain the question stayed in general constant. 1 4^{th} grade student from Sneek changed his believes. Before he participated to the Mission Moon project he gave a correct explanation while after the Mission Moon project he thought that the Sun is behind the moon, what causes the darkness. Whereas 1 3^{rd} grade student from Sneek positively changed his mind. He thought that the sun disappears behind the moon during the night however he realised after the Mission Moon project that the sun is at the other side of the earth.
A slight decrease in the post-test results of the Amsterdam students of grade 4 and 5 can be seen. However the greater part of students of grade 3 to 6 from both elementary schools could explain this question correctly. Most of the students explained that when we are sleeping, people in America or Australia go to school. Note that all the 6^{th} grade students from Amsterdam were able to explain where the sun is at night.

The cause of the day/night cycle
Next the students were asked to explain why it gets dark at night. The explanations of the students to the question 'how is it possible that we have day and night?' fell into 9 distinct notions. (See figure 16). The pre-test results of the students from Sneek show that only 1 3^{rd} grade students, 2 4^{th} grade students, none 5^{th} grade students and 2 6^{th} grade students could explain the day/night cycle correctly. The number of students from Amsterdam who were able to explain the daynight cycle correct was even less. Only 1 3^{rd} grade student, none 4^{th} grade student, 1 5^{th} grade student and 1 6^{th} grade student believed that the day/night cycle is caused by the earth's rotation on its axis. The most common alternative idea students of grade 3 to 6 from both elementary schools have is that the day/night cycle is caused by the sun and/or moon orbiting the earth, or the earth orbiting the sun. Students of grade 5 and 6 from Sneek and students

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Do not know/ No response	1	0	0	0	0	0	0	0
Near or behind the moon	1	1	1	0	0	2	1	1
West, south or down (under the earth)	1	0	1	2	2	0	1	0
Sleeps	1	0	0	0	1	0	0	0
With the planets	0	0	0	0	0	0	0	0
Other side of earth or world	2	5	4	4	3	4	4	4
In space, universe	0	0	0	0	0	0	0	0

Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
Do not know/ No response	0	0	0	1	1	0	0	0
Near or behind the moon	1	2	0	0	0	1	1	0
West, south or down (under the earth)	1	0	0	1	1	1	1	0
Sleeps	0	0	0	0	0	0	0	0
With the planets	0	0	0	0	0	1	0	0
Other side of earth or world	2	4	5	4	3	3	3	5
In space, universe	2	0	1	0	1	0	1	1

Figure 15: Responses to the question, 'where is the sun at night?'

of grade 3, 4 and 5 from Amsterdam believed that the day/night cycle is caused by the moon covering the Sun at night. The alternative ideas are consistent with previous studies of Baxter (1989) and Vosniadou & Brewer (1990).

The post-test results of the Sneek students show a decrease in the correct explanation while an increase in the correct explanation can be seen in the post-test results of the Amsterdam students. After the Mission Moon project some students from both elementary schools thought that the day/night cycle is caused by the earth's motion around the sun or believed that the day/night cycle is caused by the earth's movement around the sun and the earth's rotation around its axis. The greater part of the Sneek students believe that the day/night cycle is caused by the earth movement around the sun or the sun orbiting the earth. A slight increase in this most common alternative idea can be seen in the post-test results of the 3^{rd} and 4^{th} grade students from Sneek and a slight decrease

of this alternative idea can be seen in the post-test results of 5^{th} and 6^{th} graders from Sneek.

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
I do not know /no response	0	1	0	0	0	1	1	1
At night moves the moon in front of the sun and in the daytime the sun moves in front of the moon	0	0	1	2	0	0	0	1
The earth rotates on its Axis	**1**	**2**	**0**	**2**	**0**	**1**	**0**	**2**
Due to the earth rotation and the movement around the Sun.	0	1	0	0	1	1	1	1
The Sun and/or the moon move around the earth	2	2	2	2	2	0	2	0
Sun has to sleep at night, in daytime the moon has to sleep	1	0	0	0	1	0	0	0
Because the Sun and/or the moon move(s) up and down	2	0	1	0	1	0	0	0
The earth moves around the Sun and/or the moon	0	0	2	0	1	3	2	0

Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
I do not know /no response	0	0	0	2	0	1	0	0
At night moves the moon in front of the sun and in the daytime the sun moves in front of the moon	1	1	1	0	0	1	0	0
The earth rotates on its Axis	**1**	**0**	**1**	**1**	**2**	**0**	**3**	**2**
Due to the earth rotation and the movement around the Sun.	0	0	0	0	1	0	0	1
The Sun and/or the moon move around the earth	1	4	0	1	1	2	0	1
Sun has to sleep at night, in daytime the moon has to sleep	0	0	0	0	0	0	0	0
Because the Sun and/or the moon move(s) up and down	1	1	1	1	1	0	1	2
The earth moves around the Sun and/or the moon	2	0	3	1	1	2	2	0

Figure 16: Responses to the question, 'how is it possible that we have day and night?'

The 3^{rd} grader from Sneek, who in the previous question believed that the sun is sleeping at night, did not changed her mind after the Mission Moon project and had also an animistic explanation for the day/night cycle :

Interviewer:

When we are in bed it is very dark outside. How is that possible? Where is the sun at night?

Lotte:

The.. it sleeps.

Interviewer:
When we are in bed it is very dark outside. How is that possible? Where is the sun at night?

Lotte:
The.. it sleeps.

Interviewer:
It sleeps?

Lotte:
Yes, it seems that the moon goes to sleep.

Interviewer:
And can you explain to me how it is possible that we have day and night?

Lotte:
Yes, the sun has to sleep as well.

Interviewer:
The sun has to go to sleep?

Lotte:
Yes and the moon.

Interviewer:
And when does the moon sleep? And when the sun?

Lotte:
The sun sleeps at night and the moon sleeps in the morning.

An increase in the correct answer can be seen in the post-test of the Amsterdam students. 2 3^{rd} grade students, 3 5^{th} grade students and 2 6^{th} grade students from Amsterdam could explain that the day/night cycle is caused by the earth's rotation around its axis. Many students knew that the day/night cycle was caused by the movement of the earth but had difficulty explaining this phenomenon. 1 3^{rd} grade student and 1 6^{th} grade student from Amsterdam explained the day/night cycle by mentioning both movements of the earth. Another 3^{rd} grade student, 2 4^{th} grade students and 2 5^{th} grade students believed that the day/night cycle is caused by the movement of the earth around the sun.

Moon Orbit
The responses to the question 'how long does it take the moon to orbit the earth once?' can be seen figure 17. With this question students could chose between 4 multiple choice options: about 1 hour, about 1 day, about 1 month or about 1 year. The pre-test results of students from Sneek show that most of the 3^{rd} and 6^{th} grade students from Sneek believed that the moon orbits the earth in just 1 day, what is consistent with a study of Dove (2002). Sneek students from grade 4 and 5 were more likely to say that it takes the moon about 1 month to orbit the earth even before the Mission Moon project. Note that 1 5^{th} grade student from Sneek claimed that the moon takes 1 week to orbit the earth, what was

not included in the multiple choice answers.
Students of grade 3 to 5 from Amsterdam were more likely to say that the moon only takes about 1 day to orbit the earth. Most of the 6^{th} grade students from Amsterdam on the contrary believed that the moon orbits the earth in 1 year. Some students knew that it takes the moon about 1 month to orbit the earth, because moon and month are cognates:

Interviewer:

how long does it take the moon to orbit the earth once? You can chose 1 of the following answers: is it about 1 hour, about 1 day, about one month or about one year?

Adnan:

A month. That's why they called it a month!

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
About one hour	0	0	0	0	0	0	0	0
About one day	4	1	2	4	0	0	0	1
About one week	0	0	1	0	0	0	2	0
About one month	**2**	**3**	**3**	**2**	**5**	**4**	**4**	**3**
About one year	0	1	0	0	1	2	0	1
I do not know /no response	0	1	0	0	0	0	0	0

Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
About one hour	0	1	0	0	0	0	1	1
About one day	3	5	3	2	3	6	5	0
About one week	0	0	0	0	0	0	0	0
About one month	**1**	**0**	**2**	**1**	**1**	**0**	**0**	**4**
About one year	2	0	1	3	2	0	0	1
I do not know /no response	0	0	0	0	0	0	0	0

Figure 17: Responses to the question, 'how long does it take the moon to orbit the earth once?'

After the Mission Moon project the greater part of Sneek students were able to tell that the moon orbits the earth in about 1 month. Remarkable is that the number of students, who gave the correct answer decreased with age. Surprisingly the believe of most of the Amsterdam students, that the moon orbits the earth in just 1 day does not decrease after the Mission Moon project. Indeed this number slightly increased. Every 4^{th} grade students and almost every 5^{th} grade students thought that the movement of the moon around the earth takes about 1 day. 4 6^{th} grade students however were able to explain this question correctly. Although students were not able to give the correct answer to this question, some of them could however tell how long it takes the earth to orbit the sun:

Interviewer:

In one of the previous questions you told me that the moon orbits the earth. But my next question is how long does it take the moon to orbit the earth once? You can chose 1 of the following answers: is it about 1 hour, about 1 day, about 1 month or is it about 1 year?

Omar:

One year is not possible.

Interviewer:

Why not?

Omar:

Because the earth orbits the sun in 1 year.

Interviewer:

Okay, and how long does it take the moon to orbit the earth?

Omar:

I think it is 1 day.

Lunar Phase Questions

Moons appearance

Interviewees were asked whether the moon does shine. The results are presented in figure 18. The students only had to answer 'yes' or 'no' an explanation for the moons appearance is asked in the next question. The pre-test results of the Sneek students show that all the 3^{rd} grade students believed that the moon does shine whereas the frequently chosen response for students of grade 4 and 5 from Sneek was that the moon does not shine. The responses of the 6^{th} grade students from Sneek was equally distributed over the 3 notions before the Mission Moon project.

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
The moon does give light	6	1	0	2	2	1	0	0
The moon does not give light	**0**	**5**	**6**	**2**	**4**	**4**	**6**	**5**
I do not know /no response	0	0	0	2	0	1	0	0
Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
The moon does give light	6	5	4	5	2	4	1	2
The moon does not give light	**0**	**1**	**2**	**1**	**3**	**2**	**5**	**4**
I do not know /no response	0	0	0	0	1	0	0	0

Figure 18: Responses to the question, 'does the moon shine?'

The greater part of the students from Amsterdam said that the moon does shine. All the students of grade 3, 5 students of grade 4, 4 students of grade 5 and 5 students of grade 6 said that the moon does shine.

The post-test results of the Sneek students of grade 3 and 6 show an increase in the correct answer. The number of Sneek students of grade 4 and 5, who thought that the moon does not shine stayed constant.
Similar to the Sneek students also the greater part of the students from Amsterdam believed that the moon does not shine.

More important are the students' explanations to the question 'how is it possible that we see the moon?'. This is important, because I wanted to know if the students were aware of the fact that we can see the moon due to the sunlight reflecting on the surface of the moon. Figure 19 shows that the students' responses are categorized into 8 distinct notions.

Sneek

	Pre-test Grade				Post-test Grade			
	3	4	5	6	3	4	5	6
I do not know /no response	1	0	0	1	0	0	0	0
Due to the light of the Sun	**3**	**6**	**6**	**5**	**5**	**6**	**6**	**5**
Because the moon is made of white material	2	0	0	0	0	0	0	0
The moon is close to the earth	0	0	0	0	0	0	0	0
Due to the fact that the moon arises	0	0	0	0	0	0	0	0
The moon shines like the Sun	0	0	0	0	1	0	0	0
Stars shine on the moon	0	0	0	0	0	0	0	0
On the moon is no electricity	0	0	0	0	0	0	0	0

Amsterdam

	Pre-test Grade				Post-test Grade			
	3	4	5	6	3	4	5	6
I do not know /no response	3	4	1	3	1	0	0	0
Due to the light of the Sun	**0**	**0**	**1**	**1**	**5**	**4**	**5**	**4**
Because the moon is made of white material	2	0	2	1	0	2	1	0
The moon is close to the earth	0	0	0	0	0	0	0	2
Due to the fact that the moon arises	1	0	0	0	0	0	0	0
The moon shines like the Sun	0	2	0	1	0	0	0	0
Stars shine on the moon	0	0	1	0	0	0	0	0
On the moon is no electricity	0	0	1	0	0	0	0	0

Figure 19: Responses to the question, 'how is it possible that we see the moon?'

Remarkably the pre-test results of the Sneek students show that the greater part of the 3^{rd} grade students, all the 4^{th} and 5^{th} grade students and 5 6^{th} grade students knew that we are able to see the moon due to the sunlight. 2 3^{rd} grade students thought that we could see the moon due to the material the moon is made of.
The pre-test of the Amsterdam students on the contrary show a lot of distribution over the 8 notions. Most 3^{rd}, 4^{th} and 6^{th} graders from Amsterdam could not explain why we can see the moon at night. The explanations of the 5^{th} grade students from Amsterdam are distributed over 5 different notions.

Comparing the pre-test results and the post-test results of both elementary schools an increase in the correct explanation can be seen. An extreme increase can be seen in the post-test results of the students from Amsterdam. Except for 1 3^{rd} grade student every student from Sneek could explain how it is possible that we see the moon.
Similar to the Sneek students, the greater part of the students from Amsterdam could explain that the moon does not produce its own light but looks bright because it reflects light from the sun. Only a few Amsterdam students thought that we are able to see the moon because of the material the moon is made of or because the moon is so close to the earth.

Phases of the moon
Figure 20 shows the students' explanations to the question 'how is it possible that the moon changes its shape every night?'. All students knew that we do not always see the same shape of the moon however to explain this phenomenon was for most students a difficult task, especially before the Mission project.
In the pre-test results it can be seen that 1 3^{rd} student, 3 4^{th} grade students, 2 5^{th} grade students and 1 6^{th} grade students from Sneek were able to give a correct explanation. The second most preferred explanation of 4^{th} and 5^{th} grade students from Sneek was the 'eclipse explanation'. The eclipse explanation is the most commonly alternative idea for the causes of lunar phases. In this explanation people explain the cause of the lunar phases by telling that it is the earth that casts a shadow on the moon. (Stahly et al., 1999). The explanations of the 6^{th} grade students are divided over multiple notions.
Only 1 5^{th} grade student from Amsterdam was able to explain why the moon has a different shape every night. Most students from Amsterdam had no idea why the moon was able to change its shape and 2 5^{th} grade students thought lunar phases are caused by clouds covering parts of the moon, what is consistent with the findings of the study of Baxter (1989).

After the Mission Moon project an increase in the correct answer can be seen in the post-test results of students from both elementary schools. 2 3^{rd} grade students, 2 4^{th} grade students, 5^{th} grade students and 2 6^{th} grade students from Sneek could explain the phases in terms of the portion of the illuminated side of the moon visible from the earth. The second most preferred explanation however is still the eclipse explanation.
A small increase can also be seen in the post-test results of the 3^{rd} and 4^{th} grade students from Amsterdam, while 2 3^{rd} grade students and 2 4^{th} grade students still had no idea how the moon changes its shape every night, 1 3^{r}d grade student and 1 4^{th} grade student were after the Mission Moon project

able to explain this correctly. The number of Amsterdam students explaining the moon phases correctly increased with age. 5^{th} and 6^{th} grade students from Amsterdam were after the Mission Moon project more likely to say that the phases can be explained in terms of the portion of the illuminated side of the moon visible from the earth. Remarkable is that the second most preferred explanation of the Amsterdam students is not the eclipse explanation. Some young students had after the Mission Moon project no idea to explain the moon phases and therefore this was the second most favourite response of the young students.

Sneek								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
I do not know /no response	2	0	1	1	1	0	0	1
Clouds cover the part of the moon	1	0	0	0	0	0	0	0
Planets cast shadows on the part of the moon	0	0	0	1	0	1	0	1
The shadow of the Sun falls on the Moon	0	0	0	0	1	0	0	0
The shadow of the earth falls on the Moon	1	3	2	1	1	2	2	1
The phases are explained in terms of the portion of the illuminated side of the moon visible from the earth	1	3	2	1	2	3	4	2
Due to the fact that the moon moves towards and away from the earth	0	0	0	0	0	0	0	0
Due to the movement of the earth around the moon/sun	0	0	1	1	1	0	0	0
Due to the movement of the Sun around the moon	0	0	0	0	0	0	0	0
The shape changes over some time (a season, a month, one week, etc.)	1	0	0	1	0	0	0	0
The moon becomes bigger/smaller	0	0	0	0	0	0	0	0

Amsterdam								
	Pre-test				Post-test			
	Grade				Grade			
	3	4	5	6	3	4	5	6
I do not know /no response	5	3	2	0	2	2	1	0
Clouds cover the part of the moon	0	1	2	0	0	1	1	0
Planets cast shadows on the part of the moon	0	0	0	0	0	0	0	1
The shadow of the Sun falls on the Moon	0	0	0	0	0	0	0	0
The shadow of the earth falls on the Moon	0	0	1	0	0	0	0	0
The phases are explained in terms of the portion of the illuminated side of the moon visible from the earth	0	0	1	0	2	1	3	3
Due to the fact that the moon moves towards and away from the earth	1	0	0	0	1	0	0	0
Due to the movement of the earth around the moon/sun	0	0	0	1	0	0	1	2
Due to the movement of the Sun around the moon	0	0	0	0	0	1	0	0
The shape changes over some time (a season, a month, one week, etc.)	0	1	0	5	1	1	0	0
The moon becomes bigger/smaller	0	1	0	0	0	0	0	0

Figure 20: Responses to the question, 'how is it possible that the moon changes its shape every night?'

drawings of moon phases
Students of grade 5 and 6 were asked before the previous question to draw the moon shapes they knew. After making their drawings they were asked to explain how the moon was able to change its shape every night, what was discussed in the previous section. Figure 21 and figure 25 show the results to the instruction to draw different phases of the moon and if they knew the name, they could also label their phases. The full moon will not be discussed, because the full moon is given as an example in the interviews.

drawings of 5^{th} grade students
Figure 21 show the results of the drawings of the 5^{th} grade students from Sneek and Amsterdam. Pre-test results of the Sneek students show that a number of students could draw the waning gibbous phase, the third quarter, a waning crescent phase, a new moon and the first quarter. None of the students from Sneek however drew a scientific waxing gibbous moon and a scientific waxing crescent moon.

Grade 5

Sneek

	Pre-test			Post-test		
Moon phases	Scientific	Non-scientific	Name	Scientific	Non-scientific	Name
Full	5	0	5	6	0	6
Waning gibbous	1	0	0	0	0	0
Third quarter	2	0	0	5	0	1
Waning crescent	5	2	0	3	1	0
New	3	0	1	1	0	2*
Waxing crescent	0	0	1*	5	1	1*
First quarter	2	1	0	4	0	1
Waxing gibbous	0	0	0	0	0	0

Amsterdam

	Pre-test			Post-test		
Moon phases	Scientific	Non-scientific	Name	Scientific	Non-scientific	Name
Full	6	0	2	5	0	3
Waning gibbous	0	0	0	0	1	0
Third quarter	1	0	0	1	2	0
Waning crescent	1	1	0	2	1	0
New	0	0	0	0	0	2*
Waxing crescent	2	1	0	1	1	0
First quarter	2	0	0	3	1	0
Waxing gibbous	0	0	0	0	0	0

Figure 21: Responses to the question, 'do you know the names of the different shapes of the moon?'. The $*$ indicates that the name of the phase is correct however not in combination with the drawing.

2 5^{th} grade students from Sneek drew non-scientifical moon phases. 1 of the non-scientifical drawings was an extended first quarter:

Figure 22: A non-scientific drawing of the first quarter.

Only 1 Sneek student from was able to give the names of 2 phases. The term waxing crescent was correct however not correct in combination with the associate drawing.
The pre-test results of the students from Amsterdam show that only a small number of students could draw different phases of the moon. 5 5^{th} grade students from Amsterdam could draw beside the full moon an other moon phase. None of the 5^{th} grade students were able to label the moon phases. 2 Amsterdam students drew a non-scientific moon phase. The non-scientific drawings resembled an over-articulating phase and it resembled a partial lunar eclipse:

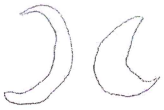

Figure 23: Non-scientific drawings of over-articulating phases.

In the post-test results of the Sneek students can be seen that students were more capable to draw scientific phases. Especially the third quarter, the waning crescent phase and the new moon were drawn by the students. There was only 1 non-scientific drawing of an over-articulating waxing crescent. 3 students named their drawn phases but 2 students labelled their waxing or waning crescent phase as first or third quarter.
An increase in the scientific drawings and the names of the phases can also be seen in the post-test results of the 5^{th} grade students from Amsterdam. 2 students labelled one of their drawings as new moon but 1 of the students labelled his waxing crescent phase drawing as a new moon. Most of the non-scientific drawings resembled an extended waxing or waning crescent phase which are mostly drawn like a curved half moon like a partial lunar eclipse or an extended version of the first and third quarters:

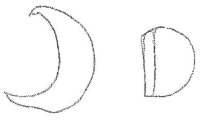

Figure 24: Non-scientific drawings

drawings of 6^{th} grade students
Students of grade 6 were also asked to draw the phases of the moon. The pre-test results and the post-test results can be seen in figure 25. Before the Mission Moon project the waning gibbous moon and the waxing gibbous moon were not drawn by the 6^{th} grade students from Sneek.

Grade 6

Sneek						
	Pre-test			Post-test		
Moon phases	Scientific	Non-scientific	Name	Scientific	Non-scientific	Name
Full	0	0	0	3	0	3
Waning gibbous	0	0	0	2	0	0
Third quarter	3	0	0	3	1	1*
Waning crescent	5	3	0	3	0	0
New	1	0	1	3	0	1
Waxing crescent	3	0	0	1	1	0
First quarter	1	1	0	1	1	2**
Waxing gibbous	0	0	0	0	1	0

Amsterdam						
	Pre-test			Post-test		
Moon phases	Scientific	Non-scientific	Name	Scientific	Non-scientific	Name
Full	6	0	6	6	0	6
Waning gibbous	0	0	0	1	0	0
Third quarter	2	0	0	1	0	1*
Waning crescent	4	3	0	4	2	0
New	1	0	0	1	0	1
Waxing crescent	0	2	0	2	1	0
First quarter	0	0	0	0	0	1*
Waxing gibbous	0	0	0	1	0	0

Figure 25: Responses to the question, 'do you know the names of the different shapes of the moon?'. The $*$ indicates that the name of the phase is correct however not in combination with the drawing.

The third quarter moon, the waning crescent moon, the new moon, the first quarter and the waxing crescent moon were multiple drawn by the 6^{th} grade Sneek students. 3 students drew a partial lunar eclipse and those drawings were categorized as non-scientific drawings:

Figure 26: A drawing of a partial lunar eclipse.

Only 1 student was able to label her drawing of the new moon:

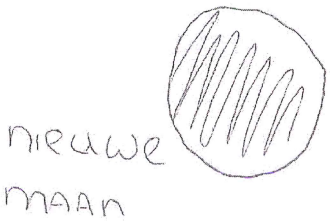

Figure 27: A scientific drawing of a new moon labelled.

4 students from Amsterdam were able to draw besides the full moon 1 or 2 different phases of the moon however they only drew a new moon, a waning crescent moon and a third quarter moon. None of the other phases were drawn and none of the students could name the moon phases. The non-scientific drawings included drawings of extended waxing and waning crescent phases and partial lunar phases.

After the Mission Moon project students were more capable to draw more different scientific moon phases. The Sneek students drew more third quarters, waning crescent phases and new moons. 3 students named their drawn phases but 2 students labelled their waxing or waning crescent phase as first or third quarter respectively.
The students from Amsterdam were also able to draw more different moon phases. The students were able to draw all the different moon phases except the first quarter. 2 students from Amsterdam drew a waning of waxing phase which resembled a partial lunar eclipse and were therefore categorized as non-scientific drawings. A few students knew some names of the moon phases but they were mostly not combined with the correct drawing. Waxing and waning crescent phases were labelled as first and third quarter.

Lunar Phase Questions

Position on earth and the moon phases
The results to the question 'if I am in the Netherlands and I see a full moon, does someone in Africa see also a full moon?' are presented in figure 28. The pre-test results show that most 5^{th} grade students and all 6^{th} grade students believe that the moment of the full moon is not the same for all of the earth. Before the Mission Moon project the greater part of the 5^{th} and 6^{th} grade students from Amsterdam believed that a person in Africa sees a different shape and that the position on earth is relevant for the moon phase.

After the Mission Moon project most 5^{th} grade students from Sneek still believed that a person in Africa does not see the same shape as someone in the Netherlands. The believes of the 6^{th} grade students are divided. Only 2 6^{th} grade students from Sneek believe that the position on earth is relevant for the observable moon phase while 2 other 6^{th} grade students from Sneek believed

that the position on earth is irrelevant for the observable moon phase and could tell that a full moon occurs at exactly the same time everywhere in the world. The post-test results of the 5^{th} grade students from Amsterdam show that their responses are equally divided over the 2 notions. The 6^{th} grade students from Amsterdam however all were able to tell that the observer's position on earth is irrelevant.

	Sneek			
	Pre-test		Post-test	
	Grade		Grade	
	5	6	5	6
Yes, we see the same shape	**1**	**0**	**1**	**2**
No, we do not see the same shape	4	6	5	2
No response/ I do not know	1	0	0	1

	Amsterdam			
	Pre-test		Post-test	
	Grade		Grade	
	5	6	5	6
Yes, we see the same shape	2	2	3	6
No, we do not see the same shape	4	4	3	0
No response/ I do not know	0	0	0	0

Figure 28: Responses to the question, 'if I am standing in Africa and see a full moon, does someone in the Netherlands also see a full moon?'

Dark side of the moon
Figure 29 show the students' responses to the question 'if we see the moon, do we always see the same side?'. The pre-test results of the Sneek students show that the greater part of the 5^{th} grade students believed that we do not always see the same side but that we can also see other sides of the moon. Most of the students however were not aware of the fact that the moon also rotates on its axis. The responses of the 6^{th} grade students from Sneek before the Mission Moon project was equally divided over the 1^{st} and 2^{nd} notion.
Similar to most of the 5^{th} grade students from Sneek, most of the 5^{th} grade students from Amsterdam also did not believe before the Mission Moon project that we always observe the same side of the moon due to the fact that the moon rotates on its axis while orbiting the earth. They did not realise that the moon makes one rotation on its axis for each revolution it makes around the earth, so it keeps the same side facing the earth. The pre-test results of the Amsterdam students show that the greater part of the 6^{th} grade students on the contrary believed that we always see the same side of the moon.

The post-test results show that after the Mission Moon project a few students from Sneek of grade 5 and 6 could tell that we only observe one side of the moon. One 5^{th} grade students could additionally mention the following:

Interviewer:
If we see the moon, do we always see the same side?

Jeroen:
Yes, you can not see the back

Interviewer:
How is that?

Jeroen:
Yes, only with a satellite.

Striking is that after the Mission Moon project the preferred response of the 5^{th} and 6^{th} grade students from Amsterdam is that we do not always see the same side of the moon. The prevalence for this notion is probably due to the fact that most of the students were not aware that the moon also rotates on its axis:

Interviewer:
Do we always see the same side of the moon? Or do we see different sides of the moon?

Songül:
Each day?

Interviewer:
If we observe the moon tonight and a week later, do we see the same side of the moon?

Songül:
No

Interviewer:
No? So we can see different sides of the moon?

Songül:
Yes, because it orbits the earth!

Sneek				
	Pre-test		Post-test	
	Grade		Grade	
	5	6	5	6
Yes, we see the same side	2	3	4	4
No, we do not see the same side	4	3	2	1
Amsterdam				
	Pre-test		Post-test	
	Grade		Grade	
	5	6	5	6
Yes, we see the same side	1	4	2	2
No, we do not see the same side	5	2	4	4

Figure 29: Responses to the question, 'do we always see the same side of the moon?'

Eclipses
In a lunar eclipse and a solar eclipse moves one celestial object into the shadow of another. During a lunar eclipse the moon moves into the shadow of the earth and during a solar eclipse the moon's shadow crosses the earth's surface. Students have difficulty in articulating the role that the earth's and moon's shadows play in lunar and solar eclipses. (Hobson et al., 2009) To investigate the students' understanding of eclipses 2 questions were asked 'what happens during a lunar eclipse?' and 'what happens during a solar eclipse?'. Figure 30 and 31 show the explanations of the elementary students before and after the Mission Moon project.

Lunar eclipse
The explanations of a lunar eclipse are summarized in figure 30. Before the Mission Moon project most 5^{th} grade students from Sneek were aware that we have a lunar eclipse when the earth moves between the moon and the sun. The explanations of the 6^{th} grade students from Sneek are divided over 4 notions as can be seen in figure 30.
The pre-test results of the Amsterdam students show that no 5^{th} grade student and only 1 6^{th} grade student were able to explain this phenomenon.

After the Mission Moon project a decrease in the correct 3^{rd} notion can be seen in the post-test results of grade 5 and 6 from Sneek.
Despite that the greater part of the 5^{th} and 6^{th} grade students from Amsterdam knew the motions of the moon around the earth and the earth around the sun, only a few students could explain the position of the sun, the earth and the moon during a lunar eclipse and the other students were wrestling with the positions of the celestial objects. Unlike a solar eclipse there is no object moving in front of the moon however most of them knew that during a lunar eclipse the moon disappears:

Interviewer:
Do you know what happens during a lunar eclipse?

Savannah:
No, I do not know.

Interviewer:
But you know what a lunar eclipse is? You probably have seen it on the television.

Savannah:
Yes.

Interviewer:
And what is happening during a lunar eclipse?

Savannah:
It becomes very dark for a few minutes. But that is all I know.

Luckily, the number of Amsterdam students who chose the correct answer slightly increased after the Mission Moon project. Most student students could explain that the moon disappears for some time but were not able to explain this cause.

Sneek				
	Pre-test Grade		Post-test Grade	
	5	6	5	6
The Sun moves between the earth and the moon	0	1	2	0
The moon moves between the earth and the Sun	0	0	2	2
The earth moves between the moon and the Sun	4	2	2	1
A planet moves in front of the moon or cast a shadow on the moon	1	2	0	0
The moon disappears behind the clouds	0	0	0	0
The moon disappears behind the horizon	0	0	0	0
The moon does not shine Anymore	0	0	0	0
The moon changes its Shape	0	0	0	0
No response/ I do not know	1	1	0	2

Amsterdam				
	Pre-test Grade		Post-test Grade	
	5	6	5	6
The Sun moves between the earth and the moon	1	1	0	1
The moon moves between the earth and the Sun	0	0	3	2
The earth moves between the moon and the Sun	0	1	2	2
A planet moves in front of the moon or cast a shadow on the moon	0	0	0	0
The moon disappears behind the clouds	1	0	0	0
The moon disappears behind the horizon	0	1	0	0
The moon does not shine Anymore	1	0	0	0
The moon changes its Shape	1	0	0	0
No response/ I do not know	2	3	1	1

Figure 30: Responses to the question, 'what happens during a lunar eclipse?'

Solar eclipse
Students' explanations of a solar eclipse are presented in figure 31. Before the Mission Moon project most 5^{th} grade students from Sneek knew that during a solar eclipse the moon moves between the sun and the earth. Most 6^{th} grade students from Sneek on the contrary had no idea what happens during a solar eclipse.
The pre-test results of the Amsterdam students of grade 5 and 6 show that only 1 5^{th} grade student and 2 6^{th} grade students were able to explain a solar eclipse.

The post-test results show minor differences compared to the pre-test results, only a small increase in the correct answer can be seen in the post-test results of the 5^{th} grade students from Sneek. The number of 6^{th} grade students from Sneek who chose the correct answer is the same as before the Mission Moon project. 5 5^{th} grade students and 2 6^{th} grade students were able to explain

what happens during a solar eclipse.
A small increase for the correct answer can also be seen in the post-test results of the 5^{th} grade students from Amsterdam. 2 5^{th} grade students and 2 6^{th} grade students explained a solar eclipse. 1 5^{th} grade student from Amsterdam knew that the sun disappears but could not explain this phenomenon. During the interviews I noticed that students have difficulties in developing conceptual understandings of the relationships between the earth, the moon and the sun.

Sneek				
	Pre-test		Post-test	
	Grade		Grade	
	5	6	5	6
The Sun moves between the earth and the moon	0	0	1	1
The moon moves between the earth and the Sun	4	2	5	2
The earth moves between the moon and the Sun	1	0	0	0
A planet moves in front of the sun or cast a shadow on the sun	0	1	0	0
The sun disappears behind the Clouds	0	0	0	0
The sun disappears behind the horizon	0	1	0	0
The sun rises	0	0	0	0
The moon does not shine anymore	0	0	0	0
No response/ I do not know	1	3	0	2

Amsterdam				
	Pre-test		Post-test	
	Grade		Grade	
	5	6	5	6
The Sun moves between the earth and the moon	0	1	0	1
The moon moves between the earth and the Sun	1	2	2	2
The earth moves between the moon and the Sun	0	0	1	2
A planet moves in front of the sun or cast a shadow on the sun	0	0	0	0
The sun disappears behind the Clouds	1	0	1	0
The sun disappears behind the horizon	2	1	0	0
The sun rises	0	0	0	0
The moon does not shine anymore	1	0	0	0
No response/ I do not know	1	2	2	1

Figure 31: Responses to the question, 'what happens during a solar eclipse?'

what happens during a solar eclipse.
A small increase for the correct answer can also be seen in the post-test results of the 5^{th} grade students from Amsterdam. 2 5^{th} grade students and 2 6^{th} grade students explained a solar eclipse. 1 5^{th} grade student from Amsterdam knew that the sun disappears but could not explain this phenomenon. During the interviews I noticed that students have difficulties in developing conceptual understandings of the relationships between the earth, the moon and the sun.

Sneek				
	Pre-test		Post-test	
	Grade		Grade	
	5	6	5	6
The Sun moves between the earth and the moon	0	0	1	1
The moon moves between the earth and the Sun	4	2	5	2
The earth moves between the moon and the Sun	1	0	0	0
A planet moves in front of the sun or cast a shadow on the sun	0	1	0	0
The sun disappears behind the Clouds	0	0	0	0
The sun disappears behind the horizon	0	1	0	0
The sun rises	0	0	0	0
The moon does not shine anymore	0	0	0	0
No response/ I do not know	1	3	0	2

Amsterdam				
	Pre-test		Post-test	
	Grade		Grade	
	5	6	5	6
The Sun moves between the earth and the moon	0	1	0	1
The moon moves between the earth and the Sun	1	2	2	2
The earth moves between the moon and the Sun	0	0	1	2
A planet moves in front of the sun or cast a shadow on the sun	0	0	0	0
The sun disappears behind the Clouds	1	0	1	0
The sun disappears behind the horizon	2	1	0	0
The sun rises	0	0	0	0
The moon does not shine anymore	1	0	0	0
No response/ I do not know	1	2	2	1

Figure 31: Responses to the question, 'what happens during a solar eclipse?'

Teachers

Motion Questions.

Motion of the moon
All the teachers of grade 3 to 6 had to answer the same question as their students 'does the moon move around the earth or does the earth move around the moon?'. The results are presented in figure 32, The pre- and post-test results of the teachers from Sneek show that all the teachers of grade 3 to 6 were able to give a correct explanation of the motion of the moon around the earth.
3 of 4 elementary teachers from Amsterdam were able to explain that the moon orbits the earth. Rather shocking is that the 5^{th} grade teacher from Amsterdam was not aware of the fact that the moon orbits the earth and that his believes did not change after the Mission Moon project.

Sneek		
	Pre-test	Post-test
Earth moves around the moon	0	0
Moon moves around the earth	3	3
Move around each other	0	0
Amsterdam		
	Pre-test	Post-test
Earth moves around the moon	1	1
Moon moves around the earth	3	3
Move around each other	0	0

Figure 32: Responses to the question, 'does the moon move around the earth or moves the earth around the moon?'

Motion of the earth.
Teachers were also asked the following question 'does the earth orbit the sun or does the sun orbit the earth?'. The responses can be seen in figure 33. The pre-test and the post-test results of both elementary schools show that all the teachers knew that the earth orbits the sun.

Sneek		
	Pre-test	Post-test
Earth moves around the sun	3	3
Sun moves around the earth	0	0
Move around each other	0	0
Amsterdam		
	Pre-test	Post-test
Earth moves around the sun	4	4
Sun moves around the earth	0	0
Move around each other	0	0

Figure 33: Responses to the question, 'does the earth move around the sun or does the sun move around the earth?'

The day/night cycle.
Similar to the students, the day/night cycle was investigated by asking 2 questions 'where is the sun at night?' and 'how is it possible that we have day and night?'.

Sun at night.
The teachers' responses to the question 'where is the sun at night?' is presented in figure 34. 2 of the 3 elementary teachers from Sneek gave a scientifically correct answer whereas 1 teacher (the 5^{th} and 6^{th} grade teacher) believed that the sun is behind the moon at night.
All the teachers from Amsterdam on the other hand gave all a scientifically correct explanation.

After the Mission Moon project 2 of 3 teachers had still a scientifically correct explanation to the question. The 5^{th} and 6^{th} grade teacher however changed his mind but believed after the Mission Moon project that the sun is in the southern hemisphere at night. Remarkable is that the 5^{th} and 6^{th} grade students from Sneek who could not explain where the sun is at night correctly and that those students chose either the 2^{nd} or the 3^{rd} notion, which was the teachers' idea in the pre- and post-test respectively.
None of the teachers from Amsterdam changed their minds and had after the Mission Moon project still a scientifically correct answer to the question.

Sneek		
	Pre-test	**Post-test**
Do not know/ No response	0	0
Near or behind the moon	1	0
West, south or down (under the earth)	0	1
Sleeps	0	0
With the planets	0	0
Other side of earth or world	**1**	**1**
In space, universe	**1**	**1**

Amsterdam		
	Pre-test	**Post-test**
Do not know/ No response	0	0
Near or behind the moon	0	0
West, south or down (under the earth)	0	0
Sleeps	0	0
With the planets	0	0
Other side of earth or world	**1**	**1**
In space, universe	**3**	**3**

Figure 34: Responses to the question, 'where is the sun at night'

The day/night cycle.
The prevalence for the explanations of the teachers to the question 'how is it possible that we have day and night?' can be seen in figure 35. None of the teachers from Sneek knew that day and night is the result of (only) the rotation of the earth on its axis. The 5^{th} and 6^{th} grade teacher from Sneek believed that the earth's motion around the sun creates night and day. The other teachers from Sneek believed that the day/night cycle is caused due to the earth's rotation on its axis and the earth's orbit around the sun.
The teachers from Amsterdam on the contrary could all explain before the Mission Moon project that when the earth rotates around its axis it creates day and night on earth.

The 5^{th} and 6^{th} grade teacher from Sneek did not change his mind after the Mission Moon project and had an incorrect explanation for the cause of day and night. He still claimed that the day/night cycle is caused by the earth's revolution around the sun. 2 5^{th} grade students from Sneek shared the same idea as their teacher what would indicate the teachers' influence on their students. The teachers of grade 3 and 4 however changed their ideas and had a correct and

scientific idea of the day/night cycle after participating to the Mission Moon project.
Unfortunately, the 4^{th} grade teacher from Amsterdam changed her idea of the cause of the day and night cycle and believed that the earth's motion around the sun was also responsible for causing the day/night cycle. The other teachers on the contrary did not change their minds and were still able to explain that the earth's rotation on its axis causes day and night.

Sneek		
	Pre-test	Post-test
I do not know /no response	0	0
At night moves the moon in front of the sun and in the daytime the sun moves in front of the moon	0	0
The earth rotates on its Axis	0	2
Due to the earth rotation and the movement around the Sun.	2	0
The Sun and/or the moon move around the earth	0	0
Sun has to sleep at night, in daytime the moon has to sleep	0	0
Because the Sun and/or the moon move(s) up and down	0	0
Sun is far away in the night and closer to the earth at daytime	0	0
The earth moves around the Sun and/or the moon	1	1
Amsterdam		
	Pre-test	Post-test
I do not know /no response	0	0
At night moves the moon in front of the sun and in the daytime the sun moves in front of the moon	0	0
The earth rotates on its Axis	4	3
Due to the earth rotation and the movement around the Sun.	0	1
The Sun and/or the moon move around the earth	0	0
Sun has to sleep at night, in daytime the moon has to sleep	0	0
Because the Sun and/or the moon move(s) up and down	0	0
Sun is far away in the night and closer to the earth at daytime	0	0
The earth moves around the Sun and/or the moon	0	0

Figure 35: Responses to the question, 'Why do we have day and night?'

Moon orbit.
The elementary teachers was asked the following question 'how long does it take the moon to complete one circle around the earth?'. All the elementary teachers from Sneek and Amsterdam knew that the moon orbits in one month around the earth, except 1 teacher from Sneek. The 4^{th} grade teacher gave no response to this question. (See figure 36).

After the Mission Moon project all the teachers from both elementary schools were able to tell that the moon orbits the earth in about one month.

Sneek		
	Pre-test	Post-test
About one hour	0	0
About one day	0	0
About one week	0	0
About one month	**2**	**3**
About one year	0	0
I do not know /no response	1	0

Amsterdam		
	Pre-test	Post-test
About one hour	0	0
About one day	1	1
About one week	0	0
About one month	**3**	**3**
About one year	0	0
I do not know /no response	0	0

Figure 36: Responses to the question, 'how long does it take the moon to complete one circle around the earth?'

Moon's appearance .
The answers of the elementary teachers to the question 'does the moon shine?' are presented in figure 37. Before the Mission Moon project the teachers from Sneek and all the teachers from Amsterdam could answer this question correctly.

The post-test results show that the elementary teachers from Sneek did not change their minds but one of the elementary teachers from Amsterdam did. The 3^{rd} grade teacher believed that the moon does shine.

In the following question the teachers had to explain how it is possible that we see the moon. The explanations are presented in figure 38. The pre- and post-test results of both elementary schools show that the teachers were aware of the fact that the moon does not produce its own light but reflects light from the sun. Remarkable is that even the 3^{rd} grade teacher from Amsterdam could explain this question correct while she gave an incorrect answer to the previous question.

Sneek		
	Pre-test	Post-test
The moon does give light	0	0
The moon does not give light	3	3
I do not know /no response	0	0
Amsterdam		
	Pre-test	Post-test
The moon does give light	0	1
The moon does not give light	4	3
I do not know /no response	0	0

Figure 37: Responses to the question, 'does the moon shine?'

Sneek		
	Pre-test	Post-test
I do not know /no response	0	0
Due to the light of the Sun	3	3
Because the moon is made of white material	0	0
The moon is close to the earth	0	0
Due to the fact that the moon arises	0	0
The moon shines like the Sun	0	0
Stars shine on the moon	0	0
On the moon is no electricity	0	0
Amsterdam		
	Pre-test	Post-test
I do not know /no response	0	0
Due to the light of the Sun	4	4
Because the moon is made of white material	0	0
The moon is close to the earth	0	0
Due to the fact that the moon arises	0	0
The moon shines like the Sun	0	0
Stars shine on the moon	0	0
On the moon is no electricity	0	0

Figure 38: Responses to the question, 'how it is possible that we see the moon?'

The phases of the moon

Drawings of moon phases
Teachers were asked to draw different phases of the moon and if they knew the name they could also label their drawn lunar phases. The full moon will not be discussed, because the full moon is given as an example in the interviews.

Teachers

Sneek						
	Pre-test			Post-test		
Moon phases	Scientific	Non-scientific	Name	Scientific	Non-scientific	Name
Full	2	0	1	2	0	0
Waning gibbous	0	0	0	0	0	0
Third quarter	0	0	1*	3	0	2*
Waning crescent	2	2	0	2	0	1*
New	0	0	0	1	0	0
Waxing crescent	3	2	1	2	0	0
First quarter	1	0	1*	3	0	3*
Waxing gibbous	0	0	0	0	0	0

Amsterdam						
	Pre-test			Post-test		
Moon phases	Scientific	Non-scientific	Name	Scientific	Non-scientific	Name
Full	4	0	4	3	0	3
Waning gibbous	1	0	2*	2	0	1
Third quarter	4	1	0	3	0	2**
Waning crescent	3	0	0	3	0	0
New	2	0	1	0	0	0
Waxing crescent	1	0	0	3	0	1
First quarter	2	0	0	3	0	3***
Waxing gibbous	0	0	2*	1	0	1

Figure 39: Responses to the instruction to to draw different phases of the moon. The $*$ indicates that the name of the phase is correct however not in combination with the drawing.

Figure 39 show that all teachers from Sneek drew a waxing crescent moon and 2 of 3 Sneek teachers were able to draw a waning crescent phase. Only 1

teacher from Sneek drew the first quarter and none of the teachers drew phases like waning gibbous, third quarter, new moon and waxing gibbous. The non-scientific waning and waxing crescent phase were drawn as over-articulating:

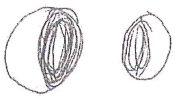

Figure 40: Over-articulating shapes.

As the pre-test results show, 2 elementary teachers from Sneek labelled their drawings. The 5^{th} and 6^{th} grade teacher labelled his drawing of a waxing crescent correct the other teacher, the 4^{th} grade teacher, labelled his drawing incorrect. He labelled his waning and waxing crescent phase as third and first quarter respectively.
The elementary teachers from Amsterdam were able to draw at least 3 different phases before the Mission Moon project and only 1 teacher drew a non-scientific phase. The 5^{th} grade teacher from Amsterdam drew an extended third quarter:

Figure 41: An non-scientific third quarter.

3 teachers could also label their drawings however some names do not associate with their drawings.

Fortunately, post-test results reveal an improved knowledge regarding the shape of the moon phases. All teachers from Sneek drew a first and third quarter and 2 of 3 teachers from Sneek were able to draw a waning and waxing crescent phase. The teachers knew the names of 3 phases however some teachers named their drawings incorrectly. The 3^{rd} grade teacher labelled her waning crescent drawing as waxing crescent and the 4^{th} grade teacher labelled his waxing crescent phase as third quarter and his waning crescent phase as first quarter.
A slight increase in the number of different phases can be seen in the post-test results of the elementary teachers from Amsterdam. 3 of 4 teachers were able to draw a scientific waning and waxing crescent phase, a third quarter phase and a first quarter phase. The elementary teachers of grade 5 and 6 drew a waning gibbous phase and the 6^{th} grade teacher drew also a waxing gibbous phase. None of the teachers drew a non-scientific phase. 3 of the teachers were able to label their drawings however most of the teachers knew the names of some lunar phases but were not able to combine the names with the associate drawing. Most of the teachers labelled their waning and waxing phase drawings as first or third quarter.

Moon phases
After the teachers made the drawings, they were asked to explain the cause of the different lunar phases. The teachers' explanations to the question 'how it is possible that the moon changes its shape every night?' are presented in figure 42.
The pre-test results of the elementary teachers from Sneek show that only the 4^{th} grade teacher was able to explain the cause of the different lunar phases while the other 2 teachers believed that the lunar phases are caused by the shadow of the earth: the eclipse explanation:

Interviewer:
How is it possible that we see a different shape of the moon every night?

3^{rd} grade teacher from Sneek:
Because of the movements.

Interviewer:
Movements of what?

3^{rd} grade teacher from Sneek:
The earth with respect to the moon. And the moon.. no the moon with respect to the earth otherwise my answer to the previous question is not correct! [The question where she had to answer whether it is the moon moving around the earth or the earth around the moon.]

Interviewer:
So due to the movement of the moon with respect to the earth?

3^{rd} grade teacher from Sneek:
Yes. And we also have the sun, because the sun shines not completely on the moon and the earth is somewhersystem:/home/studie/MoonMisconceptionse in between.

Interviewer:
So, it is the shadow of the earth?

3^{rd} grade teacher from Sneek:
Yes.

Before the Mission Moon project 3 elementary teachers from Amsterdam believed that the different shapes of the moon are caused by the earth's shadow. The 3^{rd} grade teacher on the contrary did not believe in the eclipse explanation, she was able to explain that the phases in terms of the portion of the illuminated side of the moon visible from the earth.

After the Mission Moon project the elementary teachers from Sneek did not change their believes of the cause of the different lunar phases. Only the 4^{th} grade teacher was able to answer explain the question correctly while the other teachers mistakenly believe that the moons phases are caused by the earth's shadow.
The post-test results of the elementary teachers from Amsterdam show that 1 teacher changed her believe of the lunar phases. The 3^{rd} and 4^{th} grade teachers were able to explain that we see different shapes of the moon on earth due to

Sneek		
	Pre-test	Post-test
I do not know /no response	0	0
Clouds cover the part of the moon	0	0
Planets cast shadows on the part of the moon	0	0
The shadow of the Sun falls on the Moon	0	0
The shadow of the earth falls on the Moon	2	2
The phases are explained in terms of the portion of the illuminated side of the moon visible from the earth	**1**	**1**
Due to the fact that the moon moves towards and away from the earth	0	0
Due to the movement of the earth around the moon/sun	0	0
Due to the movement of the Sun around the moon	0	0
Due to the movement of the moon	0	0
The shape changes over some time (a season, a month, one week, etc.)	0	0
The moon becomes bigger/ smaller	0	0

Amsterdam		
	Pre-test	Post-test
I do not know /no response	0	0
Clouds cover the part of the moon	0	0
Planets cast shadows on the part of the moon	0	0
The shadow of the Sun falls on the Moon	0	0
The shadow of the earth falls on the Moon	3	2
The phases are explained in terms of the portion of the illuminated side of the moon visible from the earth	**1**	**2**
Due to the fact that the moon moves towards and away from the earth	0	0
Due to the movement of the earth around the moon/sun	0	0
Due to the movement of the Sun around the moon	0	0
Due to the movement of the moon	0	0
The shape changes over some time (a season, a month, one week, etc.)	0	0
The moon becomes bigger/ smaller	0	0

Figure 42: Responses to the question, 'how it is possible that we see different shapes of the moon every night?'

moon's orbit around the earth and the sunlight reflecting on the surface of the moon. The other elementary teachers still thought that the lunar phases are caused by the earth's shadow. The low number of students who were able to explain the different lunar phases could be due to the fact that the elementary teachers were also not able to explain the phases of the moon correctly. Remarkable however is that the number of students who were able to explain the lunar phases correctly even when their teacher could not explain this phenomenon are equal or even higher than the number of students who just like their teacher could explained the lunar phases correctly. This suggests that students are able to create their own ideas of the lunar phases.

The position of the earth and the moon phases
To investigate if the teachers knew that the position on earth is irrelevant for the observable lunar phase, they had to answer the following question 'if I am standing in the Netherlands and I see a full moon, does someone in Africa also see a full moon?'. The results can be seen in figure 43. Before the Mission Moon project all the elementary teachers from Sneek could explain that the position on earth is irrelevant for the moon phase you observe.
The pre-test results of the elementary teachers from Amsterdam show that only 2 teachers could explain this question correctly. The 3^{rd} and the 4^{th} grade teacher both thought that a person in Africa and a person in the Netherlands see both a full moon while the 5^{th} grade teacher from Amsterdam thought the opposite and the 6^{th} grade teacher gave no response.

Sneek		
	Pre-test	Post-test
Yes, we see the same shape	3	1
No, we do not see the same shape	0	2
No response/ I do not know	0	0
Amsterdam		
	Pre-test	Post-test
Yes, we see the same shape	2	1
No, we do not see the same shape	1	3
No response/ I do not know	1	0

Figure 43: Responses to the question, 'if I am standing in the Netherlands and I see a full moon, does someone in Africa also see a full moon?'

After the Mission Moon project the 3^{rd} grade teacher and the 5^{th} and 6^{th} grade teacher from Sneek changed their believes and thought that the shape of the moon depends on the position on earth. This can probably explain the increase in the 2^{nd} notion of the 5^{th} grade students from Sneek. Only 1 5^{th} grade student and 2 6^{th} grade students from Sneek were able to tell that the position on earth

is not relevant for the shape of the moon.
The post-test results of the Amsterdam teachers show that 3 teacher were not able to explain the question correctly. The 3^{rd}, 4^{th} and 5^{th} grade teacher believed after the Mission Moon project that the position on earth is relevant for the observable lunar phase. The 6^{th} grade teacher however knew that the position on earth is irrelevant. Remarkable is that all 6^{th} grade students were able to explain that the position on earth does not depend the shape of the moon and this can be due to the fact that only the 6^{th} grade teacher was able to explain this question correctly.

Dark side of the moon
Figure 44 show the results to the question 'if we see the moon, do we always see the same side of the moon?'. Before the Mission Moon project 2 of the 3 teachers from Sneek believed that we are able to observe different sides of the moon from the earth. Only the 4^{th} grade teacher knew that we observe always the same side of the moon:

Interviewer:
Do we always see the same side of the moon? Or do we see different sides of the moon?

4^{th} grade teacher from Sneek:
The moon rotates in such a kind of way, that we alway see the same side of the moon. You always see the same staining pattern and this has to do with the rotation of both.. Well, we are only capable to see one side of the moon.

The pre-test results of the elementary teachers from Amsterdam show that only 1 teacher was able to explain that we see always the same side of the moon, while the other 3 teachers thought that we are capable to see all sides of the moon.

Sneek		
	Pre-test	Post-test
Yes, we see the same side	1	3
No, we do not see the same side	2	0
Amsterdam		
	Pre-test	Post-test
Yes, we see the same side	1	1
No, we do not see the same side	3	3

Figure 44: Responses to the question, 'do we always see the same side of the moon?'

After the Mission Moon project all the elementary teachers from Sneek knew that we can only observe one side of the moon from the earth.
The Amsterdam teachers on the contrary did not change their minds after the Mission Moon project. 3 of the teachers believed that we are able to observe different sides of the moon. The fact that the greater part of the 5^{th} grade students chosen this answer can be due to the influence of their teacher, because

he also believed that we can observe different sides of the moon. The 6^{th} grade teacher from Amsterdam on the contrary was the only elementary teacher who could explain this question correctly even before the Mission Moon project but he probably did not share his beliefs with his students, because the greater part of this students believed that we do not always see the same side of the moon.

Sneek		
	Pre-test	Post-test
The Sun moves between the earth and the moon	0	0
The moon moves between the earth and the Sun	0	0
The earth moves between the moon and the Sun	2	3
A planet moves in front of the moon or cast a shadow on the moon	0	0
The moon disappears behind the clouds	0	0
The moon disappears behind the horizon	0	0
The moon does not shine Anymore	0	0
The moon changes its Shape	0	0
No response/ I do not know	1	0

Amsterdam		
	Pre-test	Post-test
The Sun moves between the earth and the moon	2	0
The moon moves between the earth and the Sun	0	0
The earth moves between the moon and the Sun	2	4
A planet moves in front of the moon or cast a shadow on the moon	0	0
The moon disappears behind the clouds	0	0
The moon disappears behind the horizon	0	0
The moon does not shine Anymore	0	0
The moon changes its Shape	0	0
No response/ I do not know	0	0

Figure 45: Responses to the question, 'what happens during a lunar eclipse?'

Eclipses
To investigate whether the teachers have also difficulty explaining the lunar eclipse and the solar eclipse, they were asked to explain what happens during a lunar eclipse and during a solar eclipse and the results are presented in figure 45 and 46.

Lunar eclipse
The results to the question what happens during a lunar eclipse? can be seen in figure 45. Before the Mission Moon project 2 of the 3 elementary teachers from Sneek were aware that we have a lunar eclipse when the earth moves between the moon and the sun.
The pre-test results of the elementary teachers from Amsterdam show that the ideas of the teachers is equally divided over the 1^{st} and 3^{rd} notion. The 3^{rd} and 4^{th} grade teachers from Amsterdam mistakenly believed that during a lunar eclipse the sun is between the moon and the earth while the 5^{th} and 6^{th} grade teachers were able to explain that during a lunar eclipse the earth moves between the sun and the moon.

After the Mission Moon project all the elementary teachers from both schools were able to explain that during a lunar eclipse the earth moves between the sun and the moon and the earth's shadow causes the disappearance for the moon: a lunar eclipse.

Solar eclipse
The teachers' explanations of a solar eclipse are presented in figure 46. The pre-test results show that all the teachers from Sneek knew what happens during a solar eclipse.
Similar to most of the elementary teachers from Amsterdam however the 5^{th} grade teacher, who was able to explain what happens during a lunar eclipse, had no idea what happens during a solar eclipse.

The teachers' ideas of the solar eclipse did not change after the Mission Moon project. All the teachers, who believed correctly that the moon moves in front of the sun believed after the Mission Moon project the same. The 5^{th} grade teacher from Amsterdam, who had no clue what happens during a solar eclipse had after the Mission Moon project still no idea that the moon causes the disappearance of the sun during a solar eclipse.

Sneek		
	Pre-test	Post-test
The Sun comes between the earth and the moon	0	0
The moon comes between the earth and the Sun	3	3
The earth comes between the moon and the Sun	0	0
A planet comes in front of the sun or cast a shadow on the sun	0	0
The sun disappears behind the clouds	0	0
The sun disappears behind the horizon	0	0
The sun rises	0	0
The moon does not shine anymore	0	0
No response/ I do not know	0	0

Amsterdam		
	Pre-test	Post-test
The Sun comes between the earth and the moon	0	0
The moon comes between the earth and the Sun	3	3
The earth comes between the moon and the Sun	0	0
A planet comes in front of the sun or cast a shadow on the sun	0	0
The sun disappears behind the clouds	0	0
The sun disappears behind the horizon	0	0
The sun rises	0	0
The moon does not shine anymore	0	0
No response/ I do not know	1	1

Figure 46: Responses to the question, 'what happens during a solar eclipse?'

Differences between the suburban elementary school and the urban elementary school

Students

Figure 47 shows the number of correct responses of students before and after the Mission Moon project with the exception of the question where theywere asked to draw different moon shapes.

Comparing the total number of correct answers of both elementary schools, it shows that the Sneek students were able to give more correct answers before and after the Mission Moon project than the students from Amsterdam even with the absence of a 6^{th} grade Sneek student.
An extreme difference in the pre-test results of both elementary schools can be seen when the students had to explain why we are able to see the moon at night. However this was due to the television programme 'Klokhuis', which the students saw before the participated in the Mission Moon project. In this programme the students learned that the moon is like a reflector and reflects the sunlight to the earth. Most of the students were able to explain this question correctly like the 4^{th} grade Sneek student:

Interviewer:
Do you know whether the moon shines or not?

Sanne:
No

Interviewer:
Why not?

Sanne:
The sun.. the moon is some kind of reflector because the Sun shines on it.

Interviewer:
Could you explain it in more detail?

Sanne:
Well.. the moon is a reflector and shines because the sun shines on it and that's why we see the moon at night, because of the sun.

Sneek			
	Pre-test	Post-test	Gain
Grade 3			
Dean	8	12	4
Adnan	6	7	1
Larissa	4	5	1
Maya	7	12	5
Lotte	4	9	5
Renske	4	12	8
Grade 4			
Ivardo	10	11	1
Leslie	8	4	-4
Sanne	6	11	5
Myrthe	10	11	1
Jessie	6	10	4
Rianna	7	9	3
Grade 5			
Danny	10	15	5
Jeroen	15	17	2
Maureen	6	10	4
Mees	9	13	4
Sharon	9	10	1
Ruben	12	11	-1
Grade 6			
Jan	8	16	8
Savannah	6	11	5
Bo	13	15	2
Mick	12	14	2
Karin	8	9	1
Total	188	255	67
Amsterdam			
	Pre-test	**Post-test**	**Gain**
Grade 3			
Mohamed	9	13	4
Mustafa	7	8	1
Nabil	3	4	1
Yassit	6	11	5
Aouydane	4	7	3
Aya	3	8	5
Grade 4			
Anwar	6	7	1
Candice	4	6	2
Murat	7	6	-1
Sehar	5	10	5
Suheda	3	10	7
Yasmin	2	8	6
Grade 5			
Gamze	3	7	4
Marouan	6	11	5
Melissa	5	11	6
Nada	5	10	5
Omar	11	15	4
Saber	10	16	6
Grade 6			
Dilara	4	8	4
Emma	9	12	3
Mariam	10	8	-2
Oussama	6	9	3
Songül	7	14	7
Zakaria	10	16	6
Total	146	235	89

Figure 47: Post-test results and gains from the pre-test results of the elementary students

20 out of 24 Sneek students were able to explain that the moon's appearance is caused by the sun whereas only 2 out of 24 Amsterdam students were able to explain the moon's appearance. Also Sneek students were able to give more correct answers to the questions 'what is the shape of the moon?' and 'how long does it take the moon to orbit the earth once?'. Despite that only 7 students from Sneek were able to explain the question 'how is it possible that the moon changes its shape every night?' only 1 students from Amsterdam could answer this question correctly.
After the Mission Moon project the Sneek students could still answer more questions correctly compared to the students from Amsterdam however the difference in the post-test results of each question is not very large. At most 3 or 4 students from Sneek could answer some questions more than the students from Amsterdam, with one exception. An enormous difference can be seen in the number of correct answers to the question 'how long does it take the moon to orbit the earth once?'. 16 students from Sneek could explain this question correctly compared to 5 students from Amsterdam. This can be due to the fact that Sneek students can often observe the moon, because they have no high buildings near their school and home as the students in Amsterdam have.
In spite of the fact that Sneek students often gave more correct answers compared to the Amsterdam students the reverse can also be seen. 21 students from Amsterdam could point out the earth in the solar system picture in comparison with 15 Sneek students. This was not the only question were more Amsterdam students were able to give the correct answers compared to the students form Sneek. The post-test results of the questions 'where would the ball go to if the person standing on the earth let go of the ball?' and the question 'How is it possible that we have day and night?' show that the Amsterdam students scored higher than the Sneek students.

drawings
The Sneek students of grade 5 and 6 drew more scientific moon phases before and after the Mission Moon project than the 5^{th} and 6^{th} grade students from Amsterdam. (See figure 48). The number of scientific drawings do not include the drawings of a full moon, because this was given as an example during the interviews.
Before the Mission Moon project 5^{th} grade Sneek students could draw 12 scientific lunar phases whereas the 5^{th} grade students from Amsterdam drew 6 scientific lunar phases.
The 6^{th} grade Sneek students drew 13 scientific lunar phases before the Mission Moon project compared to 7 scientific lunar phases drawn by the 6^{th} grade students from Amsterdam.
After the Mission Moon project the sneek students drew still more scientific drawings of lunar phases than the students from Amsterdam. The 5^{th} grade Sneek students were able to draw 18 scientific lunar phases after the Mission Moon project whereas the students from Amsterdam only managed to draw 7 scientific lunar phases. The 6^{th} grade students were after the Mission Moon project not able to draw more scientific lunar phases however they drew 13 scientific lunar phases which is more compared to the 10 scientific phases drawn by the 6^{th} grade students from Amsterdam.

Sneek			
	Pre-test	Post-test	Gain
Grade 5			
Danny	2	4	2
Jeroen	3	3	0
Maureen	3	2	-1
Mees	1	4	3
Sharon	1	2	1
Ruben	2	3	1
Total	12	18	6
Grade 6			
Jan	2	2	0
Savannah	2	3	1
Bo	4	3	-1
Mick	2	2	0
Karin	3	3	0
Total	13	13	0
Amsterdam			
	Pre-test	Post-test	Gain
Grade 5			
Gamze	0	1	1
Marouan	1	2	1
Melissa	1	0	-1
Nada	1	1	0
Omar	2	3	1
Saber	1	0	-1
Total	6	7	1
Grade 6			
Dilara	1	1	0
Emma	1	2	1
Mariam	1	2	1
Oussama	1	1	0
Songül	0	0	0
Zakaria	3	4	1
Total	7	10	3

Figure 48: Post-test results and gains from the pre-test results of the drawings of the elementary students

Teachers

Due to the small number of interviewed elementary teachers, no extreme difference can be seen between the elementary teachers from both schools and in addition there has to be taken into account that the elementary school in Sneek only had 3 elementary teachers instead of 4 as in the elementary school in Amsterdam. (See figure 49) However before the Mission Moon project there is one notable difference. No elementary teacher from Sneek could explain the day/night cycle correctly while all the elementary teachers from Amsterdam could explain the day/night cycle correctly.
After the Mission Moon project an other difference between the post-test results of both schools can be seen. The question 'do we always see the same side of the moon?' was correct answered by all the Sneek teachers whereas only 1 teacher from Amsterdam could explain this question correctly.

Sneek			
	Pre-test	Post-test	Gain
Teacher grade 3	8	11	3
Teacher grade 4	10	11	1
Teacher grade 5/6	8	8	0
Total	26	30	4
Amsterdam			
	Pre-test	Post-test	Gain
Teacher grade 3	10	8	-2
Teacher grade 4	9	9	0
Teacher grade 5	6	7	1
Teacher grade 6	10	11	1
Total	35	35	0

Figure 49: Post-test results and gains from the pre-test results of the elementary teachers

Drawings
The number of scientific drawings of the elementary teachers from Sneek is less than the scientific drawings of the elementary teachers of Amsterdam. (See figure 50) This however is due to the fact that I interviewed 4 elementary teachers from Amsterdam and 3 elementary teachers from Sneek, because one teachers teaches the 5^{th} and the 6^{th} grade. the Sneek teachers drew before the Mission Moon project 6 scientific drawings and the teachers from Amsterdam drew 13 scientific lunar phases.
Only 3 names were mentioned by the Sneek teachers and 5 names by the Amsterdam teachers before the Mission Moon project. The number of scientific drawings of both schools is smaller after the Mission Moon project. The teachers from Sneek were able to draw 11 scientific drawings compared to 15 scientific drawings drawn by the teachers from Amsterdam. After the Mission Moon project the Sneek teachers could name 6 lunar phases and the elementary teachers from Amsterdam could name 8 lunar phases.

Sneek			
	Pre-test	Post-test	Gain
Teacher grade 3	2	5	3
Teacher grade 4	2	4	2
Teacher grade 5/6	2	2	0
Total	6	11	5
Amsterdam			
	Pre-test	Post-test	Gain
Teacher grade 3	4	4	0
Teacher grade 4	4	4	0
Teacher grade 5	2	4	2
Teacher grade 6	3	3	0
Total	13	15	2

Figure 50: Post-test results and gains from the pre-test results of the drawings of the elementary teachers

Unfortunately the number of the elementary students and teachers for each school is too small to get a significant difference between the elementary schools using a statistical test.

Gain

Students

Despite the fact that Sneek students could give more correct answers, the gain of the elementary students from Amsterdam students is higher as can be seen in figure 47. Comparing the total number of correct answers in the pre-test and the total number of correct answers in the post-test of figure 47, it shows that more students from Amsterdam changed their minds after participating in the Mission Moon project. After the Mission Moon project 89 more correct answers were given by the Amsterdam students compared to the total number of correct answers in the pre-test. Enormous increase in the correct answer can be seen in the post-test results of both schools were students had to arrange the celestial objects the sun, the earth and the moon starting from the smallest celestial object, were the students had to point out the moon in a solar system picture and in the question 'does the earth move around the sun or does the sun move around the earth?'.
An extreme increase in the correct answer can be seen in the post-test results of the Amsterdam students to the question 'how is it possible that we see the moon at night?'. This question was before the Mission Moon project correctly answered by 2 Amsterdam students and after the Mission Moon project 18 students from Amsterdam were able to answer this question correctly. The increase in correct answers of the Amsterdam students is also notable when the students had to point out the earth in the solar system picture. 12 students from Sneek could point out the earth before the Mission Moon project and after the Mission Moon project this number increased to 21. An increase of 7 students who gave a correct answer after the Mission Moon project can be seen when the students

had to explain the moon phases.
In spite of the fact that more students from Amsterdam changed their minds and gave the correct answer after the Mission Moon project, two enormous increases in the post-test results of the Sneek students can be seen. After the students participated in the Mission Moon project more students were able to answer the following questions correclty: 'how long does it take the moon to orbit the earth once?' and 'does the earth orbit the sun or does the sun orbit the earth?'. The latter question was only answered correctly by 11 Sneek students before the Mission Moon project while after the Mission Moon project 21 out of 23 Sneek students (1 student was ill during the post-test) answered this question correctly.

Drawings
Increase in the number of scientific drawings can be seen in Figure 48. 5^{th} grade Sneek students drew after the Mission Moon project 6 more scientific lunar phases while the 5^{th} grade students from Amsterdam drew 1 more scientific lunar phase compared to the pre-test results. A better improvement of the Amsterdam students can be seen in the post-test results of the 6^{th} grade students from Amsterdam. The number of scientific drawings after the Mission Moon project increased with 3 compared to the number of scientific drawings before the Mission Moon project. The number of scientific drawings of the 6^{th} grade students from Sneek on the other hand show no improvement.

Teachers

Figure 49 shows the total number of correct answers of the Sneek teachers slightly increased after they participated in the Mission Moon project. Due to the small number of interviewed teachers it is impossible to see extreme differences between the pre-test results and the post-test results. Slight increases however are seen when the Sneek teachers were asked to explain the day/night cycle and to the question 'do we always see the same side of the moon?'. A small decrease on the contrary can be seen in the results of the question 'does someone in Africa see the same shape of the moon as someone in the Netherlands?'.
The number of correct answers given by the teachers from Amsterdam on the other hand stayed constant. Good to see is the increase in correct answers to the question 'what happens during a lunar eclipse?'. Small decreases however can be seen in the questions where the teachers were asked to explain the day/night cycle and the moon's appearance ('why can we see the moon at night?').

Drawings
Figure 50 show the number of scientific drawings made by the teachers. Comparing the total number of scientific drawings of the lunar phases before and after the Mission Moon project, it can be seen that the Sneek teachers drew 5 more scientific drawings and the Amsterdam teachers 3 more drawings. Luckily, the number of names of the lunar phases increased for both schools after the Mission Moon project. Before the Mission Moon project the Sneek teachers could only label 3 moon phases (excluding the full moon) and the Amsterdam teachers 5 whereas after the Mission Moon project the number of names of the lunar phases increased with 3 names for both elementary schools.

To support the quanitative comparisons between the pre-test results and the post-test results of the students (the number of interviewed teachers is too small to obtain a significant difference), a paired samples t-test was used to examine the numbers of students who increased their scientific understanding of astronomical concepts. Due to the small amount of students, I could only use a paired samples t-test for all the students to get a significance < 0.05. The paired samples t-test compares the means of the pre- and post-test results and computes the difference between the two results for each case, and tests to see if the average difference is significantly different from zero. The paired samples t-test shows that there is positive correlation (=0,546) and that there is an improved knowledge of astronomical concepts. (t = 8,569, p=0.000).

The questions of the questionnaire can be divided into 5 different subjects: factual questions, gravity questions, movement questions, questions of the lunar phases and the eclipse questions. Figure 51 show the t-test results for each subject. The t-test results reveal that all the subjects had significant gains from pre-test to post-test with the exception of the gravity questions those did not show a significant difference between the pre- and post-test results of the students.

	N	T	Sig. (2-tailed)
Factual	47	5,952	,000
Gravity	47	,489	,627
Movements	47	3,261	,002
Lunar Phases	47	5,430	,000
Eclipses	47	,385	,045

Figure 51: T-test results of the elementary students for each astronomical subject.

The quanitative comparisons of the amount of scientific drawings before and after the Mission Moon project (see figure 48) show a slight shift in content knowledge from alternative or scientific drawings from pre- to the post-test. The paired samples t-test examined the development of the scientific drawings from the pre- to the post-test and show a significant difference in the pre- and post-test results of the scientific drawings (t=2,121, p=0,045). This was done by comparing the total number of scientific drawings made before and after the Mission Moon project.

The teachers did not show significant difference (t=1,109, p=0,310) between the pre- and post-test results what demonstrates that the teachers had similar knowledge of the astronomical concepts before participating the Mission Moon project.

Conclusions and implications for teaching

This study investigated students and their teachers conception of astronomical concepts before and after the Mission Moon project. The instrument of this investigation consisted of interviews which were audio taped and were transcribed verbatim. The interview questions have been used in an earlier study. (Vosniadou, 1989; Vosniadou & Brewer, 1990) and the results of this study are consistent with results reviewed in the literature.

The Mission Moon project was an organized project due to the international year of astronomy. The elementary school in Amsterdam spread the project over 3 weeks whereas the elementary school in Sneek completed the project in 1 week. It is however difficult to conclude what is more effective, because the Sneek students could answer more questions correctly compared to the Amsterdam students but the number of Amsterdam students who positively changed their minds is larger than the number of Sneek students.

The post-test results of both elementary schools have shown increase in the correct answer. The enormous increases can be seen in the following subjects:

- Sizes of the celestial objects: the sun, the earth, the moon.
- Pointing out the earth and the moon in a solar system picture.
- Movement of the earth around the sun
- The appearance of the moon is due to the fact of the sunlight reflecting on the surface of the moon.

After the Mission Moon project the Sneek students have shown an enormous increase in the correct answer in the question 'how long does it take the moon to orbit the earth once?'. The post-test results of the Amsterdam students on the other hand have shown an enormous increase in the correct answer in the question about the lunar phases.

In general could the elementary students from Sneek answer more questions correctly compared to the students from Amsterdam. The notable differences between the elementary students of both schools can be seen in the post-test result of the question 'how long does it take the moon to orbit the earth once?'.

The paired samples t-test of the students' results confirm that the Mission Moon project had a positive effect, especially the factual questions, the motion questions and the lunar phase questions show a significant improvement after the Mission Moon project. Students were however wrestling with the gravity questions especially the connection of gravity with air or the earths atmosphere. Students also have to be aware that some astronomical terms can be misleading. Students were confused drawing and labelling the phases of the moon. Students often drew a first quarter and labelled it as half moon, thinking the moon completed the half of its orbit. (Dove, 2002).

The positive post-test results of this study reflects an increase in the elementary

students' understanding of astronomical concepts and therefore I would recommend to organize a Mission Moon project or a similar project each year to stimulate elementary students for science and astronomy and improve students' understanding of astronomical concepts. Despite the fact that a significant difference can be seen between the pre-test and post-test results I would recommend to limit the lesson material, which elementary schools receive at the time of registration, only to lunar based material. Otherwise students become overwhelmed with information and the lessons are less effective.

This study also showed that beside elementary student also their teachers have alternative ideas about astronomical concepts after the Mission Moon project. Most elementary teachers often avoid teaching and discussing astronomical topics with their students, because they do not have a scientific idea about astronomical topics themselves. For student learning to be effective, elementary teachers should have a good and most important a scientific understanding of astronomical concepts and to deal with alternative ideas in astronomy and science in general I would recommend (pre-service) elementary teachers to participate in the VTB Pro (Broadening Technical Education in Primary Education) programme. The VTB Pro Programme is designed to help primary schools integrate science and technology into their teaching and provides teachers with training and guidance on how to integrate science and technology into their lessons. In this way teachers obtain a scientific idea about science and technology and are more capable to help their students with alternative ideas in science. Minstrell and Smith (1983) recommended further that teachers should ask their students for their ideas, listen respectfully to the ideas students have and guide the students into developing experiments or experiences that will change their ideas. I think elementary teachers have to apply these recommendations to increase the students understanding of scientific concepts, like astronomical concepts.

In a further research the number of students and teachers has to increase to not only see a significant difference between the pre-test results and the post-test results but also to see a significant difference between the students and their teachers of the two different elementary schools.

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Appendix A

Questionnaire for 3^{th} and 4^{th} grade students.

Factual Questions:

1. What is the shape of the earth?
   - flat
   - circle
   - round
   - oval
   - sphere, like a ball
2. What is the shape of the moon?
   - flat
   - circle
   - round
   - oval
   - sphere, like a ball
3. Arrange the earth, the moon and the sun from the smallest object to the largest object.
4. Could you in the following picture point out the earth? (See figure 52)
5. Could you in the following picture point out the moon? (See figure 52)

   Gravity Questions:

6. (See figure 53) This person standing on the earth has a ball in his hands and drops it, where would the ball go?
7. (See figure 54) This person standing on the moon has a ball in his hands and drops it, where would the ball go?

   Questions about the motions of the celestial objects:

8. Does the earth move around the moon? Or does the moon move around the earth?
9. Does the earth move around the sun? Or does the sun move around the earth?
10. Where is the sun at night?
11. How is it possible that we have day and night?
12. How long does it takes the moon to orbit the earth once?

- about 1 hour
- about 1 day
- about 1 month
- about 1 year.

Questions about lunar phases:

13. Does the moon shine? How is it possible that we see the moon?
14. How is it possible that the moon changes its shape every night?

Additional questions for 5^{th} and 6^{th} grade students:

Drawing lunar phases:

15. Could you draw the different shapes of the moon?

Questions about lunar phases:

16. If I am standing in the Netherlands and I am seeing a full moon, does someone in Africa also see a full moon?
17. If we observe the moon, do we always see the same side?

Questions about the eclipses:

18. What happens during a lunar eclipse?
19. What happens during a solar eclipse?

Questionnaire for the elementary teachers.

Questions about the motions of the celestial objects:

1. Does the earth move around the moon? Or does the moon move around the earth?
2. Does the earth move around the sun? Or does the sun move around the earth?
3. Where is the sun at night?
4. How is it possible that we have day and night?
5. How long does it takes the moon to orbit the earth once?
   - about 1 hour
   - about 1 day
   - about 1 month
   - about 1 year.

   Questions about lunar phases:

6. Does the moon shine? Why? How is it possible that we see the moon?
7. How is it possible that the moon changes its shape every night?

   Drawing lunar phases:

8. Could you draw the different shapes of the moon?

   Questions about lunar phases:

9. If I am standing in the Netherlands and I am seeing a full moon, does someone in Africa also see a full moon?
10. If we observe the moon, do we always see the same side?

    Questions about the eclipses:

11. What happens during a lunar eclipse?
12. What happens during a solar eclipse?

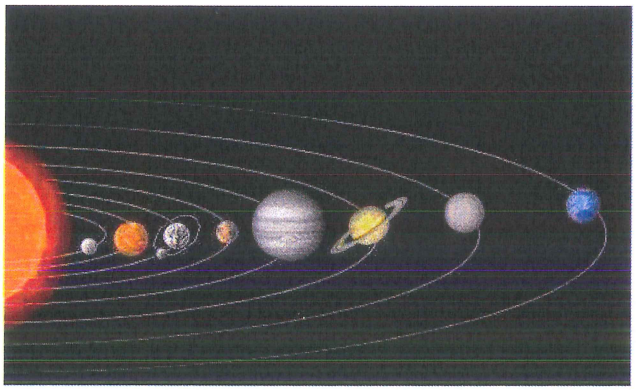

Figure 52: Solar system.

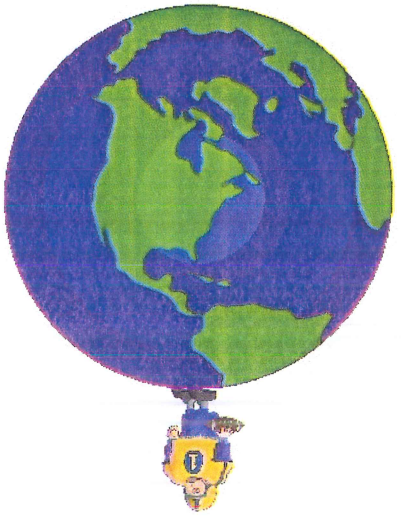

Figure 53: Gravity on the earth.

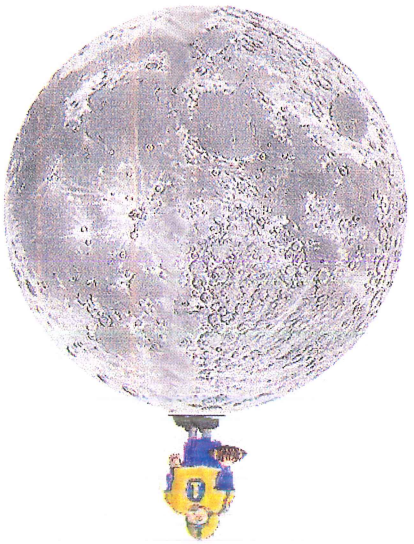

Figure 54: Gravity on the moon.