

Drawing based modeling and simulating in primary school science education

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Abstract

Forty-three eight graders of two intact classrooms of one elementary school participated in a study investigating the extent to which simulating learner created drawings are effective towards the acquisition of domain knowledge, attitude towards science, scientific attitude and self-efficacy in science. Students used SimSketch to model a part of the solar system as a drawing. In the control group students only drew; in the experimental group it was possible to simulate the drawings of the solar system. Domain knowledge, attitude towards science, scientific attitude and self-efficacy were measured. The study showed a positive trend towards above variables between pre- and post-tests and differences between the scores of the control- and experimental group. Only scientific attitude showed a significant improvement between the pre- and post-test. Furthermore, children sometimes showed some misconceptions regarding the solar system. On the whole, the experiences of children working with SimSketch were very positive.

1. Introduction

1.1 Science in primary schools

Good science education at primary schools is very important. Current research would suggest that there are four shared rationales for science education. First, the economic argument entails the view that we must ensure an adequate supply of scientifically trained individuals to sustain and develop an advanced industrial society. The second argument, the utilitarian argument concerns the view that knowledge of science is practically useful to everyone. Third, the cultural argument concerns that science and technology are one, if not the greatest, achievement of contemporary society, and that knowledge thereof is an essential prerequisite for the educated individual. Finally, the democratic argument states that many of the political and moral dilemmas posed by contemporary society are of a scientific nature and educated citizens need a minimum of scientific knowledge to participate in debate about such dilemmas (Osborne & Hennessy, 2003).

The economic argument is most frequently presented in the theory. Also Kind, Jones and Barmby (2007), believed the main problem is a gap between needs and reality for the discipline of science. The reality is a falling number of students choosing to follow the study of science. There is mounting evidence of a decline in the interest of young people in pursuing scientific careers (Smither & Robinson, 1988). This problem is a worry for governments all over the world and questions have been raised about what should be done to increase students' interest in science.

The primary school curriculum ensures students a basic level of science gain. Besides learning the contents of the domain, it is important that students have a positive attitude towards science and gain insight into how science works. Developing a positive attitude towards technology is important because the chance of choosing a technical or scientific discipline in secondary education will increase. Even if a child does not make the choice of further technical education, a positive attitude plays an important role in the pleasure experienced in science (Dawson, 2000).

Therefore teachers need to develop an educational environment that emphasizes understanding about memorization, inquiry learning, creating positive beliefs and attitudes towards science and learning and allowing students some control over their learning. This can be designed in different ways. In the current study, we implemented the method of experiential learning in order to educate children.

The theory is called “Experiential Learning” to underline the central role that experience played in the learning process. The term “experiential” is used therefore to differentiate experiential learning from cognitive learning theories, which tend to emphasize cognition over affect, and behavioral learning theories that deny any role for subjective experience in the learning process. Experiential learning theory defines learning as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb 1984, p. 41). The Experiential Learning Theory has been generally accepted as a useful framework for learning centered educational innovation, including instructional design, curriculum development and life-long learning.

In this study an example of experiential learning will be used namely, modeling and simulating of drawings. In this way students are actively engaged with the material and gain more insight into how a phenomenon works.

1.2 Modeling in science education

Within science education modeling is an important way to implement experiential learning. Researchers have presented models and the process of scientific modeling as core components of science education because the heart of learning in science is the construction and use of models of natural phenomena (Justi & Gilbert, 2002; Redish & Wilson, 1993; Sherin, 1996; White & Frederiksen, 1998; Wilensky & Resnick, 1999). Science is the practice of trying to make sense of the world around us.

According to Mayer (2011), there are different modes of models/modeling in learning and teaching. First, you can *learn with models*; the second mode includes *learning to model* and the third concerns *learning by modeling*. In this study we investigated learning by modeling. This is the case that combines learning with and to model(s) to gain deeper insights in complex phenomena by active participation in constructive processes. The focus of this study is on the phenomenon ‘solar system’.

In different studies, like social studies, recommendations are offered for using drawings to direct learners’ attention to illustrations, stimulate the use of imagery and visualization, and increase content area knowledge (van Meter & Garner, 2005). The visual qualities of a model are useful in making an explanation better understood and more easily remembered. It can also contribute to the understanding of it and it can help the modeler think more deeply about the domain (Sins, van Joolingen, Savelsbergh & van Hout-Wolters, 2007). Physical models played a special role in education they support sense making (Penner, 2001).

The most promising educational modeling tools that appear in literature are computer-based (Kurtz dos Santos & Ogborn, 1994; Louca, 2004; Redish & Wilson, 1993; Sherin, 1996; White & Fredriksen, 1998; Wilensky & Resnick, 1999). The argument is made that such tools allow students to use their current knowledge to express and construct their own models (Penner, 2001).

Krajcik and Sutherland (2010) found in their research that the ability to make sense of models, maps, diagrams, simulations and graphs is an important aspect of developing literacy in science because many scientific ideas are very complex. In computer modeling, students create their own executable external representations of a domain or subject.

1.3 Simulating in science education

Computer-based modeling can be a tool for students to understand their own way of thinking (Doerr, 1995). Through modeling students can look at a dynamic simulation of their own mental models, giving them insight in complex phenomena, helping them to coordinate and integrate facts and scientific theory (Hestenes, 1987), and giving them a more integrated and coherent view of science (Doerr, 1995; Hestenes, 1987).

Findings of research of Smetana and Bell (2012) suggest that simulations can be as effective, and in many ways more effective, than traditional (i.e. lecture-based, textbook-based) instructional practices in promoting science content knowledge, developing process skills, and enabling conceptual change.

Computer simulations have the potential to make instruction more interactive and authentic and make learning abstract concepts more concrete (Ramasundarm, Grunwald, Mangeot, Comerford, & Bliss, 2005). They allow students to confront their own beliefs by working with and receiving immediate feedback about and making personalized problem-solving decisions (Lee, 1999; Rose & Meyer, 2002). This high degree of openness provides students ownership of the learning process.

Simulations are valuable tools for exploring domain-specific topics. For example, White (1993) developed a series of micro world simulations that support students' thinking about such Newtonian concepts such as force and motion. These simulations have proven to be powerful means for helping students develop sophisticated conceptual models.

Additionally, Marbach-Ad, Rotbain and Stavy (2008) compared the effectiveness of computer simulations, textbook illustration activities and traditional lectures in contributing to student achievement in molecular genetics. Multiple-choice assessment results indicated that both the computer simulation and the illustration groups outperformed the control group.

Further results from an open-ended questionnaire, indicated that the simulation group scored significantly higher than both other groups. Also studies of Hounshell and Hill; Lazarowitz and Huppert (as cited in Smetana & Bell, 2012), showed higher academic achievement associated with the use of Computer Assisted Learning (CAL).

One of the main factors in learning science is the attitude of the students. The development of positive attitudes toward science can motivate students' interest in science education and careers in science, Carey & Shavelson; Keeves; Norwich & Duncan (as cited in George, 2006).

As said before, simulations and modeling programs have a role to play in science education. It does not only affect achievement but it can also play an important role in attitude with respect to science. Learning has an affective component and developing positive attitudes is important for students' achievement (Kind et al., 2007). Results from different research offered little support for any strong relationship between attitude and achievement. However, he also cites studies that show no relationship (Gardner, 1975).

Attitude was traditionally seen as one of the main drivers in many processes related to motivation and interest. An early notable influence towards its elaboration was made by Klopfer (as cited in Osborne, 2003), who categorized a set of affective behaviors in science education as:

- the manifestation of favorable attitudes towards science and scientists;
- the acceptance of scientific enquiry as a way of thought;
- the adoption of 'scientific attitudes';
- the enjoyment of science learning experiences;
- the development of interests in science and science-related activities; and
- the development of an interest in pursuing a career in science or science related work.

Further clarity emerged with the drawing of a fundamental and basic distinction by Gardner (1975) between 'attitudes towards science' and 'scientific attitudes'. The latter were in essence the features that might be said to characterize scientific thinking and are cognitive in nature. 'Scientific attitudes' included constructs as rationality, curiosity, open-mindedness and aversion to superstition (Billeh & Zakhariades, 1975). 'Attitudes towards science', are the feelings, beliefs and values held about an object that may be the enterprise of science, school science, the impact of science on society or scientists themselves (Gardner, 1975; Osborne, 2003; Walma van der Molen, van Aalderen-Smeets & Asma, 2011).

Kiboss, Ndirangu and Wekesa (2004), conducted a study in the field of cell theory, in which the control group had to learn through traditional classroom instruction and the

experimental group through computer simulation activities. This study showed that students' involvement in the computer simulation learning activities contributed to the effectiveness of computer simulations in promoting secondary students' academic achievement and positive attitudes toward learning cell theory as compared to the control group.

In addition to an understanding of students' attitude toward learning, measures of self-efficacy have been determined to be very useful in measuring the value of teaching and learning. Bandura (1977) defined "self-efficacy" as the belief that one can successfully perform certain behaviors, such as graphing data. As such, self-efficacy is a belief in one's abilities to accomplish a task, not a measure of those abilities. Self-efficacy mediates behavior, and it also affects outcomes. Students with higher self-efficacy in a particular subject perform better and are more likely to be interested in a career in that field (Pajares, 1997).

Barab and Dede (2007), investigated the relationship between self-efficacy and data gathering behaviors. Results suggest that collaborative simulations may act as a catalyst for change in students' self-efficacy and learning processes.

Baker and White (2003), investigated the effort that was formed to quantitatively measure the impact on students' attitude, self-efficacy and achievement. The control group used a problem based learning (PBL) science unit with paper mapping to support data analysis activities, while the experimental group used a PBL-GIS model. The results of this study showed positive and significant increases in science self-efficacy and technology attitudes, compared to students in the control group.

1.4 Current study

This study refers to the effect of simulating on domain knowledge, attitude and self-efficacy of primary school children. The simulating task relates to the solar system. In addition it is also important to discuss the role of existing misconceptions of the solar system, because these misconceptions caused an effect on the process of modeling and simulating.

Previous research is done by Vosniadou and Brewer (1994), they investigated elementary school children's explanations of the day/night cycle. First, third, and fifth grade children were asked to explain certain phenomena, such as the disappearance of the sun during the night, the apparent movement of the moon, the disappearance of stars during the day and the alteration of day and night.

The results, related to the day/night cycle, showed that children thought the sun is out in the sky during the day, but not during the night. A related observation is that the moon and

stars are in the sky during the night, but not during the day. Most young children are not aware that the moon is sometimes present in the day sky. Many children derive the beliefs that day is caused by the appearance of the sun and the disappearance of the moon and stars; and that night is caused by the disappearance of the sun and the appearance of the moon and stars. If the sun is conceptualized as stationary, children can hypothesize that something else (e.g., clouds, moon, darkness etc.) comes and covers it up. Other misconceptions that emerged from this study is that the sun moves around the earth, the sun goes behind the mountains and the sun switches off at night.

This study also examines the misconceptions that emerged from the multiple-choice test and the drawings. In addition, the drawings were analyzed and the quality of the drawings was assessed. The majority of the study is quantitative in nature and will now be discussed.

The main purpose of this research was to understand the effectiveness of modeling and simulating drawings on domain knowledge, scientific attitude, attitude towards science and self-efficacy towards science.

The main question that this study tries to answer is; *To what extent is simulating drawings effective towards the acquisition of domain knowledge, attitude towards science, scientific attitude and self-efficacy in science?* To answer this main question several hypotheses were prepared, which will be discussed below.

“Simulating drawings leads to more domain knowledge of science than not using simulating drawings.”

Following the results of the study of Marbach-Ad et al; Hounshell and Hill; Lazarowitz and Huppert (as cited in Smetana & Bell, 2012), it is expected that simulating drawings was more effective than just the modeling of drawings because students obtain a better understanding. Simulating drawings gives an extra dimension to the learning process beyond the modeling of drawings. Based on above literature it was supposed that scores on the domain knowledge post-test of the experimental group were higher than the average scores of students in the control group.

“Simulating drawings leads to a more positive scientific attitude, attitude towards science and higher self-efficacy than not simulating drawings.”

Literature showed that learning had an affective component and that developing positive attitudes is important for students' achievement (Kind et al. 2007). It was expected that children enjoy working with SimSketch. Therefore it was assumed that a positive experience with science leads to more confidence and therefore a more positive scientific attitude.

Research of Kiboss et al. (2004) had shown that students' involvement in the computer simulation learning activities contributed to the effectiveness of computer simulations in promoting secondary students' academic achievement and positive attitudes toward learning cell theory. Therefore it was assumed that a positive experience with science leads to a more positive attitude towards science.

Following the results of the study of Baker and White (2003) which pointed out that the PBL-GIS treatment positively affected student science self-efficacy, it was expected that simulating drawings leads to a higher self-efficacy towards science. Therefore it was assumed that a positive experience with science leads to a higher self-efficacy towards science.

2. Method

2.1 Participants

A total of 43 eight graders (26 boys and 17 girls) of two intact classrooms of one elementary school participated in this study. All of the 43 participants completed the pre-tests, experiment and post-tests. The age of the participants ranged from a minimum of eleven years and three months to a maximum of thirteen years and three months, the average was eleven years and ten months (SD= 25,09 month). The children were recruited from an elementary school in Almelo.

2.2 Measurements

This study concerns a pretest-posttest design. Four tests conducted prior to the experiment and five tests after the experiment. The questions of the pre-tests were the same as the post-tests. These questions concerned domain knowledge of the solar system, attitude towards science, scientific attitude and self-efficacy of children towards science, these were the dependent variables of the study. Just listed variables were measured using a paper questionnaire. First, the positions about self-efficacy, attitude towards science and scientific attitude were presented and then questions about the solar system. A bad experience with the multiple-choice test on the solar system, could affect the answers on self-efficacy and attitude tests. Besides in the post-test some questions were asked about their opinion of working with SimSketch.

The domain knowledge questions consisted of eleven multiple-choice questions. All aspects of the attitude towards science, scientific attitude, self-efficacy and their opinion of working with SimSketch were measured using different positions in which pupils were asked to express their views on a scale ranging from 1 to 4 (1 = strongly disagree, 2 = disagree, 3 = agree, 4 = completely agree). Chosen is to work with a four point scale instead of a five point scale, because research of Enochs and Riggs (1990), showed that the middle response 'uncertain' is conceptually different from a middle response option between agree and disagree. This response could also indicate that the respondent does not understand the statement, is not sure about what to answer, or has no opinion on the topic.

The questionnaire and the experiment were developed through extensive pilot work. In collaboration with the supervisor(s) an instruction was made to create a drawing set. Following this, a pilot study took place with about five children and as a result of this, adjustments were made in the instruction.

2.2.1 Domain knowledge test

The students were pre- and post-tested of their knowledge about the solar system. These consisted of eleven multiple-choice questions about the solar system. After the experiment both the experimental- and control group received the multiple-choice questions again. All participants completed the same knowledge test. For the pre-test and the post-test data of the multiple-choice questions, the total possible score was eleven. The original questionnaire is included in Appendix A. The multiple-choice questions in this study were based on the questions in the study of Vosniadou and Brewer (1994).

2.2.2 Attitude towards science test

In the present study, we developed and used attitude scales to measure pupils' attitudes towards science. This study focused primarily on the attitudes towards the solar system instead of science in general. A major justification for using an attitude scale is the use of more than one question to measure the same construct to increase reliability, Gardner (as cited in Kind et al 2007). The positions about attitude towards science in this study were based on the questions in the study of Francis and Greer, 1999; Kind et al. 2007; Walma van der Molen, 2007.

The children were pre- and post-tested on their attitude towards science. Examples of positions about attitude towards science were; 'I think the solar system is interesting' and 'I think it is important that all children learn something about the solar system'. Seven items measuring attitude towards science. The Cronbach's alpha of the pretest was 0.784 and the alpha of the post-test 0.735. The total possible score for attitude towards science was twenty-eight. The original positions of the 'attitude towards science' test are included in Appendix B.

2.2.3 Scientific attitude test

The participants of this study were pre- and post-tested on their scientific attitude. Examples of positions about scientific attitude were; 'I'm curious about things I do not know' and 'I like to think of new things'. Six items measuring scientific attitude. The Cronbach's alpha of the pretest was 0.689 and the Cronbach's alpha of the post-test was 0.778. Both the pre- and post-test of scientific attitude had a total possible score of twenty-four. For measuring the attitude of individual pupils, items of the test were adapted from the research of Kind et al. 2007; Walma van der Molen, 2007. The original positions of the scientific attitude test are included in Appendix C.

2.2.4 Self-efficacy test

The students were pre- and post-tested on their self-efficacy. This test consists of six positions about their self-efficacy towards science. For measuring self-efficacy of individual pupils, items were based on research of Kind et al. 2007; Walma van der Molen, 2007.

Examples of positions about self-efficacy were; 'If I find a school assignment difficult, then I can often think of something to solve it' and 'I'm good at solving school assignments'. Six items measuring self-efficacy. The Cronbach's alpha of the pretest was 0.658 and the Cronbach's alpha of the post-test was 0.689. For the pretest and the post-test data of self-efficacy positions, the total possible score was twenty-four. The original positions of self-efficacy are included in Appendix D.

2.2.5 Opinion of working with SimSketch test

In the post-test a number of positions were asked regarding their opinion about working with the software. The scale consisted of seven statements. Examples of positions about their opinion with the software were; 'I liked it to work with the computer program' and 'The use of a drawing (model) has helped me to better understand our solar system'. Seven items measuring children's opinion about working with Simsketch. The Cronbach's alpha of the post-test was 0.721. For the post-test data of their opinion about working with SimSketch, the total possible score was twenty-eight. The original positions are included in Appendix E.

2.2.6 Activity with Simsketch

The experiment was performed using SimSketch (van Joolingen, 2010). This is software that combines drawing, modeling and simulation features. The user can draw objects, assign behaviors and watch the system being simulated. SimSketch allows students to make drawings of phenomena, behavior attributable to the elements in the drawing and subsequently simulate the drawing. The children in the control- and experimental group received the same drawing-tasks.

They had to make a drawing concerning the 'solar system'. The control group had only drawn the solar system and showed the movement of sun, moon, earth and planets by arrows and/or words and shows how the solar- and lunar eclipse works. The experimental group could simulate the drawing of the solar system and the solar- and lunar eclipse.

The drawings were stored in the system and were subsequently evaluated at certain points. From the log files we extracted all models the students made in the course of the task, and all actions they performed to run either the system simulation or their own models. For each task,

the coding scheme was used to evaluate the inclusion of main points in the drawing. The total possible score for the drawing-exercise was ten points. The original drawing-task is included in Appendix F.

2.3 Design and procedure

As mentioned before, this study involved an experimental study that was organized in a pretest-posttest design. The pre- and post-tests were identical and were given to the students of both the experimental and control group a week before the beginning of the instructional period and immediately after the experiment. Both the pre- and post-tests took about 15 minutes to complete. There was also a post-test for measuring the opinion of children of working with SimSketch.

The students were randomly assigned to the experimental- or control group. Twenty-one children were assigned to the experimental group and twenty-two to the control group. In the experiment the students participated during regular school time. Participation was therefore obligatory. This experiment was carried out in groups of eight children.

The experiment was carried out in a separate room, where individual worked without being disturbed. The experiment per student lasted about 30 minutes. The students worked individually on the task and were told not to communicate with other students about the contents and their findings. The experiment leader briefly introduced herself and the study to the children. The experiment leader also introduced the domain and asked the students to start with the drawing test. After completing the experiment, the participants started with the post-tests.

3. Results

3.1 Data analyses

The data were analyzed using SPSS. First the reliability of the constructs was analyzed using Cronbach's alpha. Based on this, items with low reliability were removed. Second a t-test was performed to see if there are no significant differences between the experimental and control group on the pre-test. The analysis showed that only a significant difference existed in the scientific attitude test, not in the other tests. The results of scientific attitude should therefore be seen in this light.

For the analysis of the data, an overall "repeated measures" is used to analyze these data since it takes into account possible correlations among the four dependent variables. The study showed a positive trend towards above variables between pre- and post-tests and showed differences between the scores of the control- and experimental group (table 1). Only scientific attitude showed a significant improvement between the pre- and post-test ($p=0.018$). Neither a significant multivariate effect, indicating differences between the two groups (i.e., drawing vs. simulating). The children made no significant learning gains by participating in the simulation-based learning environment. Furthermore no significant difference was found between boys and girls.

Table 1:

Group means (M) and standard deviations (SD) of pre-test and post-test scores of the experimental- and control group on the dependent variables

	Experimental group		Control group	
	Pre-test	Post-test	Pre-test	Post-test
	<i>M (s.d.)</i>	<i>M (s.d.)</i>	<i>M (s.d.)</i>	<i>M (s.d.)</i>
Domain knowledge	6.90 (1.64)	7.16 (2.06)	6.86 (1.88)	7.24 (1.45)
Attitude towards science	18.16 (3.92)	19.05 (3.35)	15.90 (4.61)	18.26 (4.17)
Scientific attitude	18.81 (2.06)	20.12 (2.34)	17.59 (3.57)	18.95 (3.10)
Self-efficacy	17.89 (2.21)	18.50 (2.26)	18.30 (3.13)	18.47 (3.22)

3.2 Misconceptions

The analysis of the answers of the multiple-choice test showed that children had certain misconceptions regarding the 'solar system'. Below most of the wrong answers were discussed. The first part refers to the movement of the earth, moon and sun. Three children

believed that the earth orbits around the moon, seven children thought that the moon and the sun rotates around the earth and two children believed that the earth orbits around nothing but that the sun orbits around the earth.

The second part dealt with the misconceptions of the sun. Twenty-nine children knew that the sun orbits around something else in the solar system. Nine children thought the sun is behind the moon at night. Also, twenty-nine children gave the correct answer to the question how the solar eclipse works, however, thirteen children thought that there is another planet exactly between the earth and the sun and the shadow of the planet falls over the sun.

Finally they had some misconceptions about the moon. Eight children thought that the moon orbits around the sun. Answering the question; ‘Where is the moon during the day?’ Nine children gave the right answer, twenty-four children, however, thought the moon is on the other side of the earth during the day. In addition, only eighteen children knew how the lunar eclipse works. Nine children believed that the lunar eclipse is caused by a planet between the sun and moon, and that the shadow of the planet falls over the moon. Fifteen children thought the moon disappears behind the sun. In the drawings, this was also highlighted. Below a drawing of a misconception is shown, explaining the lunar eclipse.

Figure 1

Drawing of a misconception of the lunar eclipse



3.3 Review of drawings

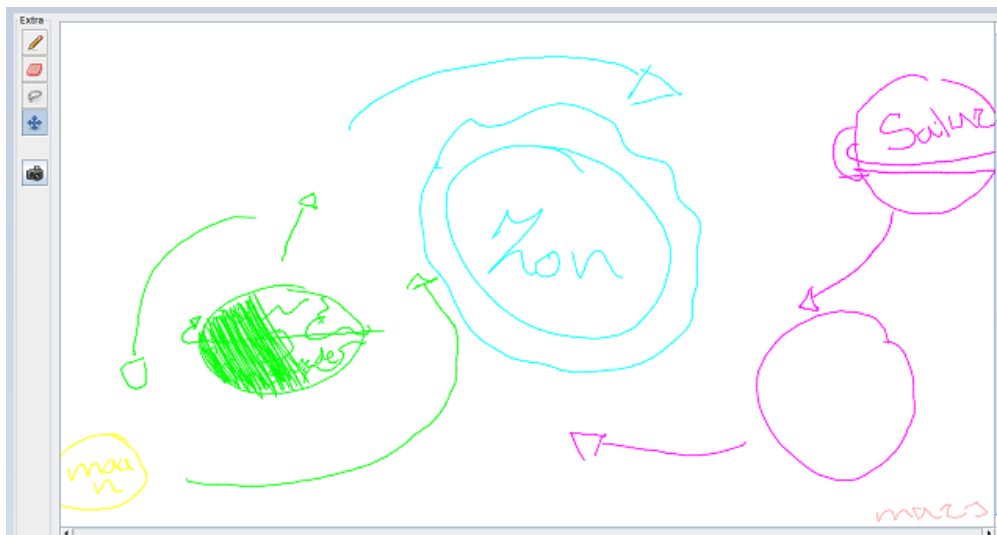
The maximum possible score on the drawings were ten points. The experimental group had a M of 6.14 with a SD of 1.15 and the control group a M of 6.95 and a SD of 1.25, no significant difference was found. From the analysis of the drawings can be inferred that all

children had drawn the sun, moon and earth. However it is striking that in both conditions, few children indicated that the earth orbits around the sun, only 33.33% of the children of the experimental group and 45.45% of the control group. Even fewer children indicated that other planets orbit around the sun. Less than half of the children indicated that the moon orbits around the earth.

Only 33.33% of the experimental group and 68.18% of the control group indicated that the earth rotates around axis. More than 75% of children in both conditions showed correctly how the solar eclipse works. In addition 50% of control group and 76.19% of experimental group showed correctly how the lunar eclipse works.

Figure 2

An example of a good drawing of the solar system



A complete overview of the scores on the drawings can be found in Appendix G. Three striking misconceptions in the drawings showed that five children indicated that the sun orbits around the earth and four children believed that the moon orbits around the sun. Besides, seven children made a drawing of the lunar eclipse, in which the sun covered the moon.

3.4 Opinion of children of working with SimSketch

The observations showed that children working with SimSketch experienced it as really nice. Drawing on a tablet was special for many children. Even the control group, who only drew, were all excited. Furthermore the experimental group found it very interesting to see how the drawings were moving. When they saw that it was not moving as they had intended, they often went right back to work to correct this. An analysis of variance is used to analyze

these data. However, no significant differences were found between the control- and experimental group in the post-test.

The maximum score for each proposition was four points. There were seven positions, so they could achieve up to twenty-eight points. The average total score was 21.14 with a SD of 3.63. This means that the children have usually experienced it as very nice, given the high score. In the statement, 'I liked to see how the drawings were moving' there was an M of 3.76 with a SD of 0.44. In addition by the statement: 'I enjoyed working with the computer program' an M of 3.59 with a SD of 0.74. This means that the average scores are between 'agree' and 'completely agree'. A complete overview of the M-scores and SD-scores in relation to their views about working with SimSketch can be found in Appendix H.

4. Conclusion and discussion

4.1 Conclusion

The main goal of this study was to investigate the effect of simulating on domain knowledge, attitude towards science, scientific attitude and self-efficacy. Based on above the main research question and hypothesis had been formulated. By answering these hypotheses, the main research question could be answered.

With respect to the first hypothesis, namely; *“Simulating drawings leads to more domain knowledge of science than not simulating drawings.”* was found a non-significant result. This research had not demonstrated that simulating drawings leads to higher domain knowledge. These findings are therefore not consistent with previous studies like; Marbach-Ad et al. (2008), which demonstrated that modeling and/or simulating contributes to increased learning gains. Furthermore these findings are not consistent with results of the study of Kiboss et al. (2004) they suggest that involvement in computer simulation learning activities promotes academic achievement. Besides findings of research of Smetana and Bell (2011) suggest that simulations can be as effective, and in many ways more effective, than traditional instructional practices in promoting science content knowledge. Finally, studies of Hounshell and Hill; Lazarowitz and Huppert (as cited in Smetana & Bell, 2012), showed higher academic achievement associated with the use of simulations.

However, the misconceptions of children were similar to the explanations identified in previous research of Vosniadou and Brewer (1994). The results of this study showed misconceptions with respect to the movement of the sun, moon and earth, and also of the day/night cycle. Furthermore there were misconceptions with respect to the lunar eclipse and the solar eclipse.

With respect to the second hypothesis, namely; *“Simulating drawings leads to a more positive scientific attitude, attitude towards science and higher self-efficacy than not simulating drawings”*, no significant effect was found either. This is in contradiction to research of Kiboss et al. (2004), they showed that computer simulations promoted a positive attitude towards learning cell theory. This study showed that there is no significant difference in the scores on self-efficacy between the experimental- and control group. This is in contradiction to the results of Baker and White (2003) which pointed out that the PBL-GIS treatment positively affected student science self-efficacy. Furthermore, research of Barab and Dede (2007) showed that collaborative simulations may act as a catalyst for change in students' self-efficacy and learning processes.

The main research question was; “*To what extent is simulating drawings effective towards the acquisition of domain knowledge, attitude towards science, scientific attitude and self-efficacy in science?*” The main conclusion is that in this study simulating drawings had no positive effect on domain knowledge, scientific attitude, attitude towards science and self-efficacy. The analyses showed a positive trend between the pre- and post-test and also between the conditions. However, no significant trend was obtained. To further clarify the effects of simulating drawings more research had to be done. In the next section, recommendations are given.

4.2 Discussion

As a limitation of this study, it should first be noted that SimSketch did not work optimally. There was an error in the system, because if the drawings had to be simulated than the objects disappeared. As a result nine children of the twenty-one were not able to simulate their drawings. As a consequence of this it could have led to a less positive experience with SimSketch and this could also have influenced the answers given by the post-tests. Moreover, because of the failure of the system it could not be traced if the children used the good ‘name stickers’ and ‘behavior stickers’.

The above problem has also influenced the assessment of the drawings. The average score of the control group was higher than the score of the experimental group; this was probably caused by the failure of the system. It could not always be traced what they had drawn and which behavior stickers they had joined to it, therefore they received fewer points. Besides it was difficult to measure the drawings of the solar- and lunar eclipse. Children could save the image by using the ‘camera button’. They were told to only press the button when they were sure that it was the lunar- or solar eclipse. Though, several children pressed more than once. This made it difficult to measure the images.

However, a follow-up study can be done in a similar way, but with an improved operating system. In which the ‘behavior stickers’ and ‘name stickers’ worked well, the images do not disappear when the drawing is simulated and that only one image can be stored using the ‘camera button’ instead of saving multiple images.

A second limitation concerns the importance of misconceptions regarding the solar system. If children had some misconceptions, how are they adjusted? If they have misconceptions, these are also reflected in the drawing and in the simulation. The results of this study raise the question how these misconceptions can be tackled. Maybe this tool can be useful in other contexts such as in dyads or group discussions with the drawings as the focus for discussion.

A third limitation of this study regards a sample size of 43 participants, which is acceptable but this can be improved in a future study. It might be possible that a larger sample results in significant relationships for the relationships that are now close to significance. Furthermore, when a larger sample size is used, the study will be more reliable and more generalizable.

Another limitation concerns the measurement of attitude towards science. Research of Walma van der Molen (2007) showed that attitude towards science consists of many different dimensions, such as; thoughts, feelings and behavior. This study focused explicitly on the attitudes towards the solar system instead of science in general. However, further research is recommended to measure all the dimensions; in order to get a more reliable measurement of the construct 'attitude towards science '.

Furthermore, modeling and simulating of drawings is very useful for complex phenomena. This study focused on the solar system but there are also other domains imaginable, for example in the field of biology, biochemistry or geography. Besides, this study was conducted only among students in the 8th grade of primary school, this also can be done in secondary education or higher education in order to have more reliable results. SimSketch can make things clearer and provide insight, this is regardless of age.

Finally, it was perhaps a bit too idealistic to expect that self-efficacy, attitude towards science, and scientific attitude would change by an experiment which only lasted 30 minutes. This could be improved by using the software for longer periods of time or working with more assignments. However, whatever influences were involved, things did not seem to have worked out in the way we had hoped.

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Appendix A: Domain knowledge test

MC-vragen

1. Waaruit bestaat ons zonnestelsel?

- A. Alle sterren gezamenlijk.
- B. Een zon met planeten die daar omheen draaien.
- C. Zon, maan en aarde.
- D. Een aantal zonnen bij elkaar.

2. Wat is de aarde?

- A. Een planeet.
- B. Een ster.
- C. Een maan.
- D. Een kleine zon.

3. Waar draait de aarde omheen?

- A. De aarde draait om de zon heen.
- B. De aarde draait om de maan heen.
- C. De aarde draait nergens omheen, maar de maan en zon draaien om de aarde.
- D. De aarde draait nergens omheen, maar de zon draait om de aarde.

4. Wat is de zon?

- A. Een satelliet.
- B. Een planeet.
- C. Een maan.
- D. Een ster.

5. Waar draait de zon omheen?

- A. De zon draait om de planeten heen.
- B. De zon draait om de aarde heen.
- C. De zon draait samen met de maan om de aarde heen.
- D. De zon draait nergens omheen.

6. Waar is de zon 's nachts?

- A. De zon zit dan achter de maan.
- B. De zon is dan aan de andere kant van de aarde.
- C. Wolken dekken de zon af.
- D. De sterren staan dan voor de zon.

7. Hoe kan het dat de zon steeds op een andere plaats staat, gezien vanuit de aarde?

- A. Omdat de aarde om haar eigen as draait.
- B. Omdat de zon beweegt.
- C. Omdat de aarde om de zon draait.
- D. Omdat de zon om haar eigen as draait.

8. Wat gebeurt er bij een zonsverduistering?

- A. Dan verdwijnt de zon achter de wolken.
- B. Een planeet staat dan precies tussen de aarde en de zon in, de schaduw van die planeet valt dan over de aarde heen.
- C. De schaduw van de maan valt dan over de aarde heen, de maan staat dan precies tussen de aarde en de zon in.
- D. Dan is de zon aan de andere kant van de aarde.

9. Waar draait de maan omheen?

- A. De maan draait om de zon heen.
- B. De maan draait om de aarde heen.
- C. De maan staat op een vaste plaats, het lijkt alsof hij beweegt omdat de aarde draait.
- D. De maan draait niet, maar gaat op en neer.

10. Waar is de maan overdag?

- A. De maan zit dan achter de zon.
- B. Je kunt de maan niet zien omdat het dan licht is.
- C. In de lucht, soms kun je de maan overdag zelfs zien.
- D. Aan de andere kant van de aarde.

11. Wat gebeurt er bij een maansverduistering?

- A. Een planeet staat dan precies tussen de zon en maan in, de schaduw van die planeet valt dan op de maan.
- B. Dan verdwijnt de maan achter de zon.
- C. De aarde staat dan precies tussen de zon en maan in, de schaduw van de aarde valt dan op de maan.
- D. Dan is de maan aan de andere kant van de aarde.

Appendix B: Attitude towards science test

	Helemaal niet mee eens	Niet mee eens	Mee eens	Helemaal mee eens
Ik vind het zonnestelstel interessant.	1	2	3	4
Ik vind het zonnestelsel ingewikkeld.	1	2	3	4
Ik wil weten hoe ons zonnestelsel in elkaar zit.	1	2	3	4
Ik vind het belangrijk dat alle kinderen wat over het zonnestelsel leren.	1	2	3	4
Ik denk dat de meeste kinderen het zonnestelsel ingewikkeld vinden.	1	2	3	4
Ik denk dat de meeste kinderen het zonnestelsel interessant vinden.	1	2	3	4
Ik vind het belangrijk dat er genoeg tijd wordt besteed aan het uitleggen van het zonnestelsel.	1	2	3	4

Appendix C: Scientific attitude test

	Helemaal niet mee eens	Niet mee eens	Mee eens	Helemaal mee eens
Ik vind het leuk om nieuwe ideeën te bedenken.	1	2	3	4
Ik vind het leuk om over nieuwe onderwerpen te leren.	1	2	3	4
Ik vind het leuk om zelf dingen te onderzoeken.	1	2	3	4
Ik ben nieuwsgierig naar dingen die ik nog niet weet.	1	2	3	4
Ik verwonder me over dingen om me heen.	1	2	3	4
Als ik iets niet begrijp, dan ga ik door totdat ik het wel begrijp.	1	2	3	4

Appendix D: Self-efficacy test

	Helemaal niet mee eens	Niet mee eens	Mee eens	Helemaal mee eens
Het lukt me meestal wel om een opdracht voor school goed op te lossen, als ik er genoeg moeite voor doe.	1	2	3	4
Als ik een schoolopdracht moeilijk vind, dan kan ik vaak wel iets bedenken om het op te lossen.	1	2	3	4
Ik vind dat ik een goede leerling ben.	1	2	3	4
Ik ben goed in het oplossen van schoolopdrachten.	1	2	3	4
Ook al vind ik een onderwerp op school moeilijk, uiteindelijk kan ik het wel leren.	1	2	3	4
Als het even niet lukt, ga ik aan mezelf twijfelen.	1	2	3	4

Appendix E: Opinion of working with Simsketch

	Helemaal niet mee eens	Niet mee eens	Mee eens	Helemaal mee eens
Ik heb al vaker gewerkt met dit soort computerprogramma's.	1	2	3	4
Ik vond de opdracht interessant.	1	2	3	4
Ik vond het leuk om over ons zonnestelsel na te denken.	1	2	3	4
Ik vond het leuk om met het computerprogramma te werken.	1	2	3	4
Ik vond het moeilijk om met het computerprogramma te werken.	1	2	3	4
Ik denk dat ik de tekening over ons zonnestelsel goed heb gemaakt.	1	2	3	4
Het gebruik maken van een tekening (model) heeft mij geholpen om ons zonnestelsel beter te leren begrijpen.	1	2	3	4

Appendix F: Drawing exercise

Zonnestelsel

Wij leven met zijn allen op de aarde. Als we overdag naar buiten kijken dan zien we soms de zon. In de avond zien we geen zon meer, maar zien we soms een maan en sterren. De aarde, de zon en de maan bevinden zich allemaal in ons zonnestelsel. Ook heeft ons zonnestelsel nog een heleboel andere planeten.

1. *Laat door middel van een tekening zien hoe ons zonnestelsel eruit ziet, teken hierbij in ieder geval de zon, aarde, maan en een andere planeet.*

Zonsverduistering

Het kan gebeuren dat je de zon vanaf de aarde eventjes niet meer kunt zien. Dit noemen wij dan de zonsverduistering. Hieronder staat een plaatje van een zonsverduistering.



2. *Kun je in de tekening aangeven wanneer zich een zonsverduistering voor kan doen. Zet het beeld stop wanneer er volgens jou sprake is van een zonsverduistering. Je kunt het beeld stop zetten door op de 'fototoestel-knop' te drukken.*



'Fototoestel-knop'

Maansverduistering

We hebben één keer in de zoveel tijd ook een maansverduistering, dan kun je de maan even niet meer zien. Hieronder staat een plaatje van een maansverduistering, de maan is hier nog net niet helemaal verduisterd.



3. *Kun je in de tekening aangeven wanneer zich een maansverduistering voor kan doen. Zet het beeld stop wanneer er volgens jou sprake is van een maansverduistering. Je kunt het beeld stop zetten door op de 'fototoestel-knop' te drukken.*

Appendix G: Scores of the drawings

	Experimental group	Control group
	% correct	% correct
Earth	100%	100%
Sun	100%	100%
Moon	100%	100%
Other planet	66,67%	77,27%
Earth orbits around the sun	33,33%	45,45%
Other planet orbits around the sun	19,05%	18,18%
Moon orbits around the earth	38,10%	50,00%
Earth rotates around axis	33,33 %	68,18%
Sun eclipse	76,19%	95,45%
Lunar eclipse	76,19%	50,00%

Appendix H: Overview of the M-scores and SD-scores in relation to their views about working with SimSketch

	N	Mean	SD
Ik heb al vaker gewerkt met dit soort computerprogramma's.	42	1.79	0.95
Ik vond de opdracht interessant.	41	3.51	0.68
Ik vond het leuk om over ons zonnestelsel na te denken.	41	3.34	0.76
Ik vond het leuk om met het computerprogramma te werken.	41	3.59	0.74
Ik vond het moeilijk om met het computerprogramma te werken	39	3.10	0.85
Het gebruik maken van een tekening (model) heeft mij geholpen om ons zonnestelsel beter te leren begrijpen.	42	3.00	0.96
Ik vond het leuk om te zien hoe de tekeningen gingen bewegen.	21	3.76	0.44