The Use of a Drawing-based Simulation for Modeling the Solar System

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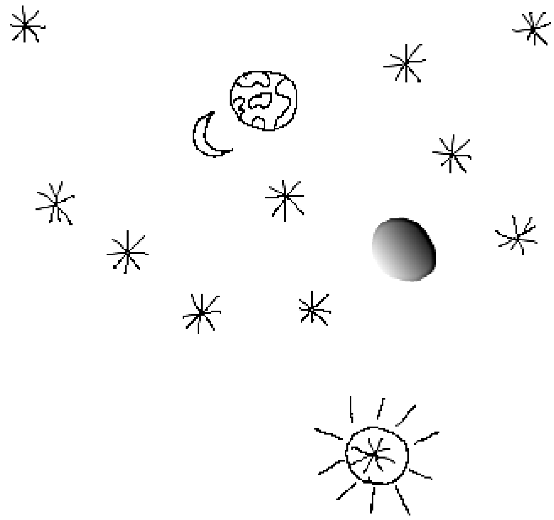

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An experimental study among children in the SimSketch learning environment

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Abstract

Learning science is hard for many students. Modeling is a teaching tool in learning science that enables students to create models of scientific phenomena. This study attempts to bring modeling within the reach of young children by using the SimSketch modeling environment, which is based on freehand drawings that can be converted to simulations. 249 children in the age range from 7 to 18 participated in the study and used SimSketch to create a drawing-based model of the solar system. Participants showed significant differences in pre-and posttest. Young children (7-9 years) showed a significant better score in posttest. Modeling contributed independently to the knowledge acquisition, since the quality of the model influenced the score of the posttest, with the pretest as control variable. The study shows that the drawings-based modeling approach SimSketch has potential to contribute to learning and the understanding of scientific phenomena, especially in young children.

Keywords: *Science education, Drawing, Modeling, Simulation, SimSketch, Young Children*

1. Introduction

1.1 Science Education

Learning to understand science is hard for many students, given that science is a complex and multifaceted activity in an effort to explain natural phenomena (Louca & Zacharia, 2011). Science is not only focusing on formulas and facts, it is a process and the practice of trying to make sense of the world (Penner, 2001). It is important to give students an authentic view of doing science. Science education starts with the basic understanding of the world around us. This understanding is about ideas, concepts and theories used to interpret the world (Driver & Bell, 1986). For a better understanding of difficult scientific theories, a certain way of thinking has to be developed, which is generally referred to as scientific thinking. Students need requisite skills to engage in scientific thinking (Zimmerman, 2005). The scientific thinking skills can be related to formal and informal thinking skills (Zimmerman, 2005). According to Zimmerman (2007), scientific thinking includes the skills involved in inquiry, experimentation, evidence evaluation, and inference that are done in the service of conceptual change or scientific understanding. Schauble, Glaser, Duschl, Schulze and John (1995) emphasize the authentic practice of science in scientific thinking, which focuses on performing and interpreting experiments for the specific purpose to the theories they hold.

Zimmerman (2007) argues that the formation and modification are essential parts of the development of learning science. Scientific thinking and reasoning can support the formation and modification of the concepts and theories about the natural and social world. Scientific reasoning can give direction to students how to generalize components and relations of the phenomena. It can encourage students to reflect on the process of knowledge acquisition and change (Wilkening & Sodian, 2005). Therefore scientific thinking should be supported and trained for science learning.

1.2 Young children and science learning

Involving students in learning science from an early age can encourage the development of scientific thinking (Penner, 2001). Holt (1977) argues that young children are naturally active and curious; they want to discover, explore, learn and create something new. This is also recognized by Eshach and Fried (2005), who state that naturally children enjoy observing and thinking about nature. Carson (1984) agrees and states that relatively young children are already intrigued in the how and why of things around them. Carson (1984) refers to this as the sense of wonder. Children's innate curiosity creates an intrinsic motivation to explore the world (Eshach and Fried, 2005). This curiosity of children can pique them to learn and explore. On these observations several authors argue that science learning is engaging for young children since they are biologically prepared to learn about the world around them (Carson, 1984; Eshach & Fried, 2005; French, 2004).

In a study of Poland, van Oers and Terwel (2010) it is shown that from the age of seven years children will change from abstract to concrete reasoning. Children aged seven start to think logically and try to make connections and relations (Eccles, 1999). However, young children still find it hard to represent these connections in words or in symbols (Ginsburg & Golbeck, 2004). It is important for them to find strategies to obtain skills that will contribute to better scientific thinking. An example of such a strategy is schematizing. Schematizing is constructing an external representation (Poland et al., 2010) and organizing own thinking and knowledge (Davydov, 1988). This schematizing can be used in solving problems and improving symbolic representations. If children are actively engaged in the learning content, they do not only reproduce the material, they will also restructure their own understanding of the material. This results in positive learning outcomes and deeper understanding of the learning content. According to Poland et al. (2010) drawing and visualization can support schematizing. Visualization and drawing may be an important step to the development and the use of more scientific concepts. It can assist young children in their shift from every day, or spontaneous concepts, to more scientific concepts (Brooks, 2009). These visualizations can be dynamic or static. Dynamic visualizations or drawings offer the possibility to display transformations, changes and actions. Static visualizations lack these additional display possibilities (Poland et al., 2010). Dynamic visualizations invoke insight into the key relations and transformation in a certain knowledge domain, therefore they are especially suited for young children. Eccles (1999) states that dynamic visualizations help children to understand complex structures and relations. Insight in these complex and abstract relations is an important part of scientific thinking. Gopnik (2011) discovered that young children transform their representations on the basis of concrete experiences and are able to learn in complex and sophisticated ways. Gopnik, Sobel, Schulz and Glymour (2001) demonstrated that very young children, from two to four years old, can make accurate causal inferences on the basis of patterns of variation and covariation. They argue that even very young children can learn about the causal structure in theories, even with remarkable speed and accuracy.

Considering that young children demonstrate scientific thinking skills (Gopnik, 2011) and display a sense of wonder (Carson, 1984), in conceiving scientific phenomena it seems important to start science education at an early age. The American Association for the Advancement of Science (2001) also suggests that the acquisition of basic science concepts in early childhood is an essential foundation for understanding more advanced concepts at a latter stage. Therefore opportunities have to be created for young children in which they can invent, design and discover to learn science. Practicing scientific thinking skills could help children to become better science students (Holt, 1977) and prepare them for academic performance.

Exposing young children to science activities might enhance their motivation and their further natural interest (Eshach & Fried, 2005). Introducing stimulating and active science activities that enhance children’s natural curiosity and enthusiasm will have a positive effect on children's attitude toward science in later life (Arnold, Fisher, Doctoroff & Dobbs, 2002). This positive attitude towards science can provide the acceptance of scientific enquiry as a way of thought among others, the enjoyment of science learning experiences, the development of interests in science and the development of an interest in pursuing a career in science or science related work (Klopfer, 1971). Attitude towards science is a multifaceted construct consisting of a number of elements, including motivation towards science, value of science and enjoyment of science (Gardner, 1975; Piburn, 1993).

1.3 Motivation

The motivation of students seems to be an important component in learning contexts (Pintrich, 2003; Pintrich & De Groot, 1990; Sins, Van Joolingen, Savelsbergh & Van Hout-Wolters, 2008). The goal of science education is to increase students' scientific thinking skills as well as their knowledge about scientific concepts. In addition, students must be motivated to learn science. Motivation is not only important for the acquisition of scientific thinking skills and knowledge, also for the willingness of students to increase knowledge of science (Tuan, Chin & Shieh, 2005). This willingness is a component of motivation. Eccles, Wigfield and Schiefele (1998) argue that, motivational theories focus primarily on individuals' cognitions and beliefs about themselves, the tasks and the academic context. Based on the study of Eccles et al. (1998), Patrick, Mantzicopoulos, Samarapunga & French (2008) looked for patterns of children's motivation for science. They figured out what the motivational beliefs of children are. The motivational beliefs, relevant for this study, are self-competence and value or liking of learning (Eccles et al., 1998; Patrick et al., 2008; Wigfield & Eccles, 2002).

Competence. Personal competence is an important type of belief, common to motivational theories (Pintrich, 2003). Students who believe they are competent, who are expecting success and are confident about their abilities, will expend greater effort, take more challenges and persist longer before giving up compared to students with less confidence and belief in their competence, even when the prior knowledge is equal (Patrick et al., 2008; Wigfield & Eccles, 2002).

Value or liking. Another important motivational belief is ‘liking’. If students have a positive attitude towards the learning subject, think the task is interesting and value a task as important or useful (Patrick et al., 2008) and like to learn about the object (Osborne, Simon & Collins, 2003) they are more motivated to learn.

As previously discussed, opportunities for better scientific thinking should be created. Besides the enhancement of motivation to engage children in scientific thinking, several strategies could be used. For example, visualizations or schematizing could be made in order to provide support in science education (Ainsworth, Prain & Tytler, 2011). An important strategy is modeling. Modeling can support the teaching and learning of science (Penner, 2001).

1.4 Modeling & Drawing

Since recent years the importance of models and modeling in science education is increased (Coll, France & Taylor, 2005; Gobert & Buckley, 2000; Harrison & Treagust, 1998; Sins, Savelsbergh & van Joolingen, 2005). The process of building a model is called modeling. Scientists make use of modeling to develop a theory or to test ideas and elaborate their knowledge by creating models. With modeling, scientists can represent difficult and abstract phenomena (Harrison & Treagust, 1998). Teachers can use modeling in the classroom to explain students how some phenomenon works. Modeling can play an essential role in acquiring and processing new information. That is why modeling is crucial for science education. Students can use modeling by themselves to externalize their ideas about a specific domain (Sins et al., 2005). It can support thoughts and structure problem solving processes. However, creating models by students is not yet widely used in the classroom.

Models created by students are examples of self-generated external representations. Zhang (1997) defines external representations as “the knowledge and structure in the environment, as physical symbols, objects, or dimensions, and as external rules, constraints, or relations embedded in physical configurations” (p.180). A representation can thus be shown as schematizing, a model, diagram, graph, system, idea or process. In this study the focus is on creating a physical, expressive model. Schwarz and White (2005) define a model as "a set of representations, rules and reasoning structures that allow one to generate predictions and explanations" (p.166). In expressive models students construct their own model of a domain (Löhner, van Joolingen, Savelsbergh, van Hout-Wolbers, 2004). Building an expressive model involves of students’ own contribution and creativity, however this can also be a model on the basis of formulas. Physical models are models that require an external representation that capture the conceptualization of students of natural phenomena (Papert, 1991). Penner (2001) argues that physical models play a specific role in education, as he concludes it is supporting sense making. In this combination of an expressive and physical model, students create their own model on the basis of their conceptualization or idea. In these models properties and processes are shown and these models identify how relations and variables are interrelated (Clement, 1989; Bliss, 1994).

According to Hestenes (1987), creating models can benefit to education, since students can create models by themselves to learn science. Penner (2001) discussed that when a student develops a model to learn science, some specific and critical components must be addressed. He focused on three important ideas. In the first idea the role of building physical models is helping students to improve their understanding of the natural world. Second is typical for science education, students design their own representations in order to express phenomena. The third importance is that students have to reflect on their own thinking and doing.

When implementing modeling in science education, the learning environment and the modeling-tool must be taken into consideration (Hestenes, 1987). It is essential that modeling tools will help students to externalize their ideas. Drawings can be a bridge between ideas and a formal model (Van Joolingen, Bollen and Leenaars, 2010). Forming a formal model can be difficult for students. Formal models require knowledge of the elements and relations in the domain, and it also requires knowledge of the notation and syntax of system dynamics (Van Joolingen et al., 2010). It is easier for students to show their ideas with drawings instead of forming a formal model. Students can draw in learning science to make their knowledge explicit. Students can externalize their ideas and show their understanding of the domain with a freehand drawing. Van Meter & Garner (2005) argue that drawing can help to identify the important elements, which have to be included in a model. However, static and two-dimensional drawings may not show dynamic processes. Riley (1990) argues that static drawings are difficult to understand without the representation of flows and the changing in the dynamic systems. Dynamic processes ensure the relations in the drawing. To translate the drawing more into a formal model, the drawing has to be dynamic. Hestenes (1987) emphasizes the role of computers in dynamic modeling. Hestenes (1987) states: "The computer environment can be exceptionally engaging and versatile" (p.2.). Computers and tools can help students to understand science. According to Hewson (2004) computers can give support that allows children to learn complex scientific concepts that is difficult to learn on their own.

1.5 Computer simulations for creating models

The computer is taking a central role in the process of modeling. Computers enable students to create models of scientific phenomena. In a model students are forced to make their knowledge about concepts and interactions explicit (Löhner et al., 2005). Computer tools can support sense making that allow students to reify their conception of the world (Orhun, 1995). Computer applications using visualization, modeling, and simulation have been proven to be powerful tools for teaching scientific concepts (Roschelle, Pea, Hoadley, Gordin & Means, 2000). Learning in the environment of these computer applications can ensure deep and meaningful understanding by students, as they will process scientific content in an active, constructive, and authentic way (Manlove, Lazonder & de Jong, 2006). Computer simulations are examples of learning environments in which visualizations are important. The term simulation can be used in different ways. Ord-Smith and Stephenson (1975) defines a simulation as: "the technique by which understanding the behavior of a physical system is obtained by making measurements or observations of the behavior of a model representing that system" (p.3). According to De Jong & Van Joolingen (1998) a computer simulation is a program that contains a model of a system or a process. In the context of computer supported learning, computer simulations are applications designed to facilitate science instruction and learning through improved visualization and interactivity with models of natural phenomena (De Jong & Van Joolingen, 1998). Simulations allow students to draw and develop their own model into a computer program and let it run. In the running simulation students can show their idea of the real world, and they can decide which elements of reality to include and exclude for the process they want to simulate. The simulation can be used for dynamic processes and can be deployed to learn complex science concepts.

In this research students worked in a computer simulation environment called SimSketch (Van Joolingen, Bollen & Leenaars, n.d.).

1.6 SimSketch as computer simulation environment

SimSketch is a program that provides the drawing and modeling of features that results in a simulation. It is software in which models are specified as drawings, rather than as computer codes or mathematical formulas (Van Joolingen, Bollen & Leenaars, n.d.). In this environment students do not have to form a formal model. SimSketch provides no numerical input and does not requires mathematical knowledge of students, because it is based on drawings. In SimSketch students have the possibility to make a drawing with different elements of a phenomena. In this drawing students can visualize and express their ideas. After drawing, students can assign a behavior to the elements in their drawing. In SimSketch there are different behaviors, like rotation, replication, movement and so on. The software has to know which elements students create, that is why elements have to be segmented and labeled. In this label the student can give the element a name and a type. When the model is created, SimSketch simulates the phenomenon, or compute how it will behave according to the rules, specified by the student.

There are several domains suitable for SimSketch. The solar system is a domain that can be processed by SimSketch. Learning about the solar system makes an important contribution to the development of scientific thinking and understanding science (Percy, 1996). In the solar system it is important to show elements, and their interrelations. In the solar system dynamics are very important. Especially, conceptual understanding in this domain requires understanding of the spatial and static information as well as understanding the causal and dynamic movements within the solar system (Gobert & Clement, 1999). In SimSketch, students can see their elements move in relation to each other.

Lunetta & Hofstein (1981) argue that appropriate simulations can make science learning more interesting and relevant to students and increase motivation. A simulation can help in promoting essential goals in science learning. It is important for Simsketch to be appropriate for students. Software possesses both pragmatic and hedonic quality (Hassenzahl, Kekez and Burmester, 2002). Whether software with a high pragmatic or hedonic quality is experienced and judged as appealing may depend on the activity and goal it is used for.

1.7 Present study

This study was performed in Science Center Nemo in Amsterdam. In this study, students drew and simulated the solar system in SimSketch. Children were invited to create drawings on the process of the solar system. The aim of this study is to investigate how properly students make their drawing and if this drawing and simulating contributes to a better understanding of the solar system. In this study the modeling process will be illustrated and how learning is evolved in this context.

The broader purpose of this study is to gain insight in the relation between the knowledge acquisition of the participants in the drawing environment and their age. The variable of age will be used to determine whether young children benefit more from drawing in SimSketch for their knowledge acquisition than older children. Literature has shown that children are able to learn science from an early age. Nevertheless for young children it is difficult to understand and create formal models. The drawing-based simulation SimSketch could enhance science learning with freehand drawings.

Besides measuring the knowledge acquisition by drawing in SimSketch, in relation with age, the study also determines whether motivation can contribute to the knowledge acquisition. Motivation seems to be an essential component in learning contexts. The motivation is composed of the perceived competence of the students and the valuing and liking of the task by the student. The attitude of students is towards the software program SimSketch.

As discussed above, the importance of drawing, simulation and motivation in science learning has been shown in several studies. If these components are important, it has to be considered to what extent students are facilitated in knowledge acquisition of the solar system by drawing in SimSketch, what role knowledge and motivation can play and whether these components are affected by age.

The main question in this research is:

> ***"To what extent can modeling in SimSketch facilitate knowledge acquisition concerning the solar system and how is this related to age and motivation?"***

The sub questions in this research are:

- To what extent is the quality of modeling in SimSketch related to knowledge acquisition concerning the solar system?
- To what extent is the quality of modeling in SimSketch related to the different ages of the children?
- To what extent differences occur between ages of children in knowledge acquisition concerning the solar system?
- To what extent does motivation play a role in modeling quality and facilitation of knowledge acquisition concerning the solar system?

2. Method

2.1 Participants

A total of 288 children was recruited in Science Center Nemo, Amsterdam. Children from 7 to 18 years were asked while they were visiting the museum, if they wanted to participate in this experiment for the University of Twente. Participation in the study was on a voluntary basis. Of the 288 participants, 39 students were omitted from the data analysis, because they did not complete the entire test, due to technical difficulties with the computers or the software, or learning disabilities. This resulted in 249 participants (128 girls and 121 boys). Children were from primary (n = 193) and secondary school (n = 55), one participant had not entered a school type. Table 1 gives an overview of the distribution of participants.

Table 1. Ages and gender of the participants (n=249)

	7 years	8 years	9 years	10 years	11 years	12 years	13 years	14 years	15 years	18 years	Total
Boy	2	20	19	16	24	17	14	7	2	0	121
Girl	2	15	26	32	18	15	8	7	4	1	128
Total	4	35	45	48	42	32	22	14	6	1	249

2.2 Materials

2.2.1 Learning environment

During the modeling assignments participants worked with a computer and a drawing tablet in an integrated drawing and simulation environment that was created specifically for this study. This drawing tablet was a Cintiq LCD monitor with a touch screen pencil. The drawing and simulation environment is called SimSketch and was developed by Van Joolingen, Bollen, and Leenaars (2010). The environment offered an integrated tutorial, which taught participants to use the drawing tablet and the software SimSketch. A screenshot of the SimSketch learning environment is provided in Figure 1. Detailed logs of all the user's interactions with the software were automatically saved online at a server that was located at the University of Twente.

2.2.2 Learning domain

In the present study participants engaged in drawing and modeling activities concerning the solar system. According to Barnett, Barah and Hay (2001) students find it hard to understand basic astronomical phenomena, because these phenomena are far out of reach for students. Education in astronomy, therefore, has make a transition from an emphasis on delivering content through lectures to a focus on supporting students reasoning about the solar system in authentic learning tasks that involve the construction of scientific models (Barab, Hay, Barnett and Keating, 2000). Simulations allow students to enact basic astronomy concepts into dynamic models.

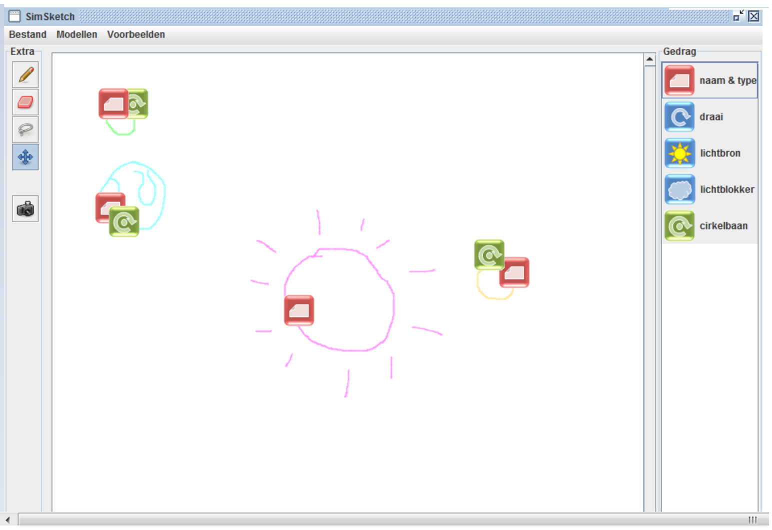

Figure 1: Software environment SimSketch (Van Joolingen, Bollen, Leenaars, 2010)

2.2.3 Learning tasks

Modeling assignment. During the modeling assignment participants were working with the drawing tablet. Participants completed a tutorial that introduced them to the important features of tablet and the software. After this short tutorial, participants were instructed to start the assignment. The actual drawing and modeling task assignment consisted of two tasks and was followed by a feedback assessment task. During the feedback assessment students had to compare their own model with an expert model.

In the *first* task participants were instructed to draw our solar system, including at least the sun, the earth, the moon and one other planet. They had to name and label the different elements in the drawing. Subsequently, participants had to show how these objects were moving relatively to each other by assigning specific behaviors (like ‘rotate’ and ‘circular orbit’) to objects in their drawing. After students assigned these specific behaviors to the objects they could simulate their model. Between drawing and simulating it was possible to adjust their model by removing or changing. In the *second* task participants had to show how a solar eclipse would occur in their model. It was not necessary to create a new drawing. In the software they could use behaviors like 'Light resource' and 'Light reflector' to show the beam of light. When participants were simulating their model they had to make a screenshot on the exact moment the eclipse occurred. If participants did not know how to show the eclipse in their model, they could skip making the screenshot.

Feedback. The feedback assessment consisted of comparison questions. In this assessment participants were asked to compare their own model to an expert model that was provided by the SimSketch learning environment. The goal of the feedback assessment was to stimulate the participants to think and learn about the solar system and the solar eclipse. Therefore 'thinking questions' were added to stimulate independent thinking of the participants (Van der Plas and De Roos, 1977). Participants were asked to construct their response based on a comparison of their own model with the expert model. When participants had to answer the question to what extent their model looked like the expert version, they had to consciously think about it. The first question requested children to compare their drawing of the solar system with the solar system in the simulation and write down the differences they observed. The second question focused on a comparison between students' own representation of a solar eclipse and the expert version.

2.2.4 Tests

Domain knowledge test. The domain knowledge test consisted of eight multiple choice questions. The questions were based on the work of Vosniadou and Brewer (1990), who composed a list of typical misconceptions children have about solar system. Their results showed that children conceptualized that the earth was located in the middle of the solar system and that the day and night cycle is caused of the movement by the sun and the moon. They also mentioned that children conceptualized the clouds cover up the sun at night. Children also assumed that the sun was a planet, instead of a star (Vosniadou & Brewer, 1990; 1994). The questions and alternative answers in this study are established on the basis of these formed misconceptions of children about the solar system and addressed. The domain knowledge test was administered as a pre- and posttest. The pre- and posttest version of the test consisted of the same items, but with different orders for the items and the answer alternatives.

2.2.5 Questionnaire

To gain insight in children's motivation as well as their attitude towards the software a questionnaire was constructed that included items that focused on children's motivation as well as their attitude. See appendix A for the tasks, tests and questionnaire.

Motivational items. In this part of the questionnaire participants had to answer twelve questions. These questions were about their competence and whether they found the task interesting and valued the task as useful. The questions were part of the motivation of the participants, which consists of perceived competence and valuing. The affective questions were measured with the Likert Scale (Likert, 1932). In this study the Likert-scale had four equal interval scales.

Questions about software attitude. Students' attitude towards the software was measured by a semantic differential. This semantic differential has been used to measure the connotative meaning of concepts (Hassenzahl, kekez & Burmester, 2002; Osgood, Suci & Tannenbaum, 1957). In table 2. an overview of the concepts is presented. The semantic differential consisted of ten contradictory variables. Participants could score on a five-point-scale.

Table 2. Overview of the concepts

Boring	-	Exciting
Little fantasy	-	Creative
New	-	Already known
Impractical	-	Practical
Not useful	-	Valuable
Confusing	-	Clearly arranged
Difficult	-	Easy
Technical	-	Human
Not beautiful	-	Beautiful
Bad	-	Good

NB. Items were translated from Dutch

2.3 Procedure

The session took place in a computer lab under the guidance of the experiment leader and an experiment assistant. In the computer lab eight participants could work at the same time. Posters and public assistants in the museum informed visitors about the experiment. Visitors could enroll the experiment when there was a free spot in the computer lab and the experiment leader or assistant was available for the first brief instructions. Parents of participants were informed about the study, by a letter (See appendix B). Before the participants entered the learning environment, they received a brief instruction about the experiment and more specifically the tests and questionnaires and the SimSketch login procedure.

After this brief instruction, the participants could start the questionnaires, tests and experiment. Participants started with the domain knowledge pretest. Before starting the modeling assignment they were considered to complete a SimSketch tutorial. The tutorial took ten minutes and explained how students could navigate through the SimSketch learning environment and could operate the available tools. By following each step in this tutorial, every part of SimSketch was explained. The experiment leader and assistant helped participants who did not understand the tutorial. See appendix D for the tutorial.

After this tutorial the real experiment could start, the modeling assignment. During the modeling assignment, the experiment leader and assistant offered help when there were problems with understanding the assignment or linguistic problems within the assignment. The participants were told not to talk to each other during the experiment, but that they could ask questions by raising their hand at any time. The participants were given no help in the content of the assignment. The modeling assignment took approximately 15 minutes. After the modeling assignment the participants could start the second session, with the last questionnaires. Participating in the study lasted approximately a total of 45 minutes.

2.4 Coding and scoring

The pre- and posttest consisted of eight items. Scores were computed by awarding a correct answer with one point, incorrect answers yielded no points. In the modeling assignment participants could score on different elements in their model. The solar system consisted of nine items and the solar eclipse consisted of five items. The total score of the model was fourteen points, in table 3. there is a overview of the static and dynamic elements in which participants could score. The experiment leader only scored static elements in the models which were given a name by the participant. If participants put multiple circular orbits on their elements, the experiment leader did not score them.

Table 3. Score for modeling with static elements and dynamic processes, one point for each element in the model

Static elements	**Dynamic processes**
Sun	Earth rotates on its axis
Earth	Planet rotates on its axis
Moon	Moon orbits around earth
Other planet	Earth orbits around sun
Lightblocker earth	Planet orbits around sun
Lightblocker moon	Solar eclipse
Lightblocker planet	
Light source sun	

2.5 Analysis

To compute the inter-rater reliability for the scores on the modeling assignment, a second coder received a protocol and coded the scores of twenty models independently. The inter-rater reliability of the models was measured by Cohen's Kappa. Cohen’s kappa = 0.661, which is considered good.

Indicators of the reliability of the pretest was reasonable ($\alpha = 0.698$). The indicator of the reliability of the posttest was good ($\alpha = 0.721$). A univariate analysis was used to explore the extent to which the pre-and posttest differ. The differences were measured for age and gender, with post hoc comparison (Bonferroni). To find out whether there was a difference between the overall scores of participants in the pre- and posttest, the scores were entered into a repeated measured ANOVA. The different scores for the modeling assignment were also measured. In a univariate analysis, with post hoc comparison (Bonferroni), the differences in ages could be measured on scores. Regression analyses and correlations could show relations between knowledge acquisition and modeling quality. Knowledge acquisition could be measured by a partial correlation, whereas the influence of modeling on the posttest could be analyzed with control variable by pretest. In table 4. the mean scores of the tests and models are viewed.

Table 4. Mean scores and standard deviations for scores on the quality of the model and pre- and posttest

	N	Max. score	Mean (SD)
Score Model	235	14	7.25 (3.317)
Score Pretest	246	8	5.73 (1.947)
Score Posttest	241	8	5.95 (1.938)

The constructs of motivation questions were formed by using a reliability analysis. There are two constructs formed within the motivational questions, 'valuing' and 'perceived competence'. The construct 'valuing' measured to what extent participants like the assignment about the solar system and to what extent they enjoyed working with the computer. The construct 'perceived competence' measure to what extent participants better understand the solar system by modeling and simulating. In table 5. the items within the constructs are shown. Item 1, 5, 6 and 9 were removed by an insufficiently reliability. These items were not used in the results. The reliability of 'valuing' is reasonable (α=0.604). The reliability of construct 'perceived competence' is good (α=0.774). The attitude of SimSketch consisted of all nine items within the semantic scale and the reliability is reasonable (α=0.650). To explore the extent to which the constructs within motivation differ a univariate analysis was used. The differences were measured for age and gender, with a post hoc comparison (Bonferroni). Also for the attitude of SimSketch the differences were measured by a univariate analysis.

Table 5. Constructs measuring Motivation with items

Construct	Item	Question
Valuing	2	I think the drawing assignment was interesting
	3	I did not like to think about the solar system (Rescaled)
	4	I enjoyed working with the computer
	8	I liked to see how the drawings were moving
Competence	7	The drawing helped me to better understand the solar system
	10	I have a better understanding of the solar system, because I've watched the right version of the drawings
	11	I think the computer can help to understand things better
	12	The simulation of the drawing has helped me to a better understanding the solar system

3. Results

3.1. Modeling in SimSketch

The modeling assignment was executed by 235 participants. The scores on the different elements and processes in the model is presented in figure 2.

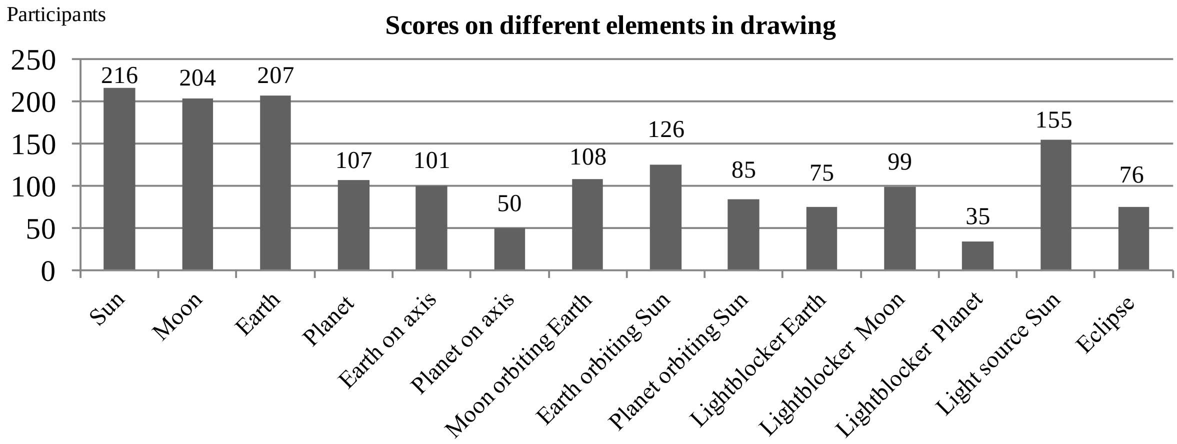

Figure 2. The results of the different elements and the number of participants

In table 6. the mean scores are presented for the score of static elements and dynamic processes. The static elements were drawn by 235 participants (M = 4.93, SD = 1.987) and the maximum score was 8 points. The dynamic processes were also shown by 235 participants (M = 2.32, SD = 1.797) and the maximum score was 6 points.

Table 6. The scores for dynamic processes and static elements in modeling

		Model	
		Static	**Dynamic**
	n =	*M (SD)*	M (SD)
Age (in years)			
7 - 9	78	4.81(2.007)	1.91(1.707)
10 - 11	85	4.71(1.950)	2.22(1.734)
>12	72	5.32(1.978)	2.89(1.797)
Gender			
Boys	114	4.83(1.815)	2.53(1.815)
Girls	121	5.04(2.157)	2.13(1.765)
Boys and age (in years)			
7 - 9	37	4.70(2.414)	1.95(1.747)
10 - 11	39	5.00(1.747)	2.51(1.636)
> 12	38	5.39(2.273)	3.11(1.815)
Girls and age (in years)			
7 -9	41	4.90(1.578)	1.88(1.691)
10 - 11	46	4.46(2.094)	1.98(1.795)
> 12	34	5.24(1.615)	2.65(1.756)

Note. Static elements with a max of 8 points and dynamic processes with a max of 6 points

In order to analyze the influence of age on the static elements and dynamic processes, participants were divided into three age groups. The scores for the dynamic processes were significant different between ages ($F(2,232) = 6.006$, $p = .003$, $\eta^2 = .049$). A post hoc (Bonferroni) showed that >12 year old participants have significant ($p = .002$) higher scores of dynamic modeling than 7-9 year old participants. The boys of >12 years scored significant better on dynamic processes than 7-9 year old boys ($p = .016$).

Each model of the participant was evaluated for correctness. A score was computed for the solar system (M = 5.38, SD = 2.303), the solar eclipse (M = 1.87, SD =1.447) and the total score (M = 7.25, SD = 3.317). The regression analysis showed that the pretest (prior knowledge) had influence on the score of the model. Prior knowledge influenced the score at the solar system ($R^2 = .072$, F (1,230) = 17,733, $p <.001$), the solar eclipse ($R^2 = .068$, F (1,230) = 16,896, $p < .001$) and the total score of the model ($R^2 = .090$, F (1,230) = 22,708, $p < .001$).

Table 7. Mean scores and standard deviation of ages and gender at scores of the models

	Solar system		**Solar eclipse**		**Total model**	
	n =	*M (SD)*	*n =*	*M (SD)*	*n =*	*M (SD)*
Age (in years)						
7 - 9	85	5.05(2.250)	85	1.67(1.345)	85	6.72(3.133)
10 - 11	90	5.24(2.250)	90	1.69(1.431)	90	6.93(3.258)
>12	72	5.90(2.363)	72	2.31(1.498)	72	8.21(3.419)
Gender						
Boys	114	5.45(2.399)	114	2.11(1.515)	114	7.56(3.597)
Girls	121	5.31(2.217)	121	1.64(1.347)	121	6.96(3.015)
Boys and age (in years)						
7 - 9	37	4.92(2.532)	37	1.73(1.484)	37	6.65(3.683)
10 - 11	39	5.54(2.011)	39	1.97(1.347)	39	7.51(3.051)
>12	38	5.87(2.591)	38	2.63(1.601)	38	8.50(3.875)
Girls and age (in years)						
7 - 9	41	5.17(1.986)	41	1.61(1.222)	41	6.78(2.584)
10 - 11	46	4.98(2.427)	46	1.46(1.471)	46	6.43(3.377)
>12	34	5.94(2.117)	34	1.94(1.301)	34	7.88(2.847)

Note. Score solar system max. 9 points. Score solar eclipse max. 5 points. Total score model max. 14 points.

A univariate analysis of variance showed a significant difference between ages and the total score of the model ($F(2,232) = 4.539$, $p = .012$, $\eta^2 = .038$). A post hoc comparison (Bonferroni) revealed that there were significant differences for the total scores of the models between 7-9 year and >12 year old participants ($p = .017$), and even between 10-11 year and

>12 year old participants (p = .046). The scores for the solar eclipse between ages were significant as well (F (2, 232) = 4.809, p = .009, η^2 = .040). The post hoc (Bonferroni) showed significant differences between 7-9 year and >12 year (p = .020), and between 10-11 year and >12 year old participants (p = .024). Table 7. specifies the mean scores and standard definitions for gender and age.

3.2. Knowledge acquisition

With a repeated measure ANOVA can be shown whether there are differences between pretest (M = 5.73, SD = 1.947) and posttest (M = 5.95, SD = 1.938). The repeated measures ANOVA with a Greenhouse-Geisser correction determined that the averages of pretest and posttest differed significantly between time points (F(1, 238) = 5.035, p = .026). The knowledge concerning the solar system was higher in the posttest.

To further explore the extent to which the pre-and posttest differ, the data were divided according to gender and age. It appeared that girls have significant differences between pre- and posttest scores (t(126) = -2.201, p =.03), which means that girls had a significantly higher posttest score than pretest score. The boys showed no significant differences (t (113) = -.86, p = .391) between the pre- and posttest scores.

Table 8. Mean scores and standard deviation for pretest and posttest

	Pretest		**Posttest**	
	n =	*M (SD)*	*n =*	*M (SD)*
Age (in years)				
7 - 9	82	4.72(1.958)	82	5.09(2.156)
10 - 11	89	5.92 (1.785)	85	6.16(1.580)
>12	75	6.60 (1.619)	74	6.66(1.706)
Gender				
Boys	119	6.19(1.859)	114	6.28(1.868)
Girls	127	5.36(1.937)	127	5.63(1.959)
Boys and age (in years)				
7 - 9	40	4.98(1.901)	39	5.21(2.080)
10 - 11	39	6.49(1.684)	36	6.86(1.334)
>12	40	6.98(1.423)	39	6.87(1.592)
Girls and age (in years)				
7 - 9	42	4.48(2.003)	43	4.98(2.241)
10 - 11	50	5.48(1.752)	49	5.65(1.562)
>12	35	6.17(1.740)	35	6.43(1.820)

Note. Domain knowledge questions with a minimum of 0 points and maximum of 8 points.

Table 8. gives the average number of correct items for the pre- and posttests in different groups. In order to analyze the influence of age on pre- and posttest, participants were divided into three age groups. A univariate analysis of variance showed a significant difference in the pretest between ages ($F(2,243) = 22.25$, $p < .001$, $\eta^2 = .155$). A post-hoc comparison (Bonferroni) showed that the score in pretest between 7-9 year and 10-11 year old participants was significantly different ($p < .001$). The participants from 7-9 year and >12 year differed significant in pretest ($p < 0.001$). The 10-11 year and >12 year old participants revealed also a significant difference ($p = .05$). The score of the posttest between ages demonstrated a significant difference score too ($F(2,238) = 15.310$, $p < .001$, $\eta^2 = .114$). The post-hoc comparison (Bonferroni) showed a significant difference between 7-9 year and 10-11 year old participants ($p = .001$) and 7-9 year and >12 year old participants ($p < .001$). In figure 3. the differences between pre- and posttest of the three age groups and gender are presented.

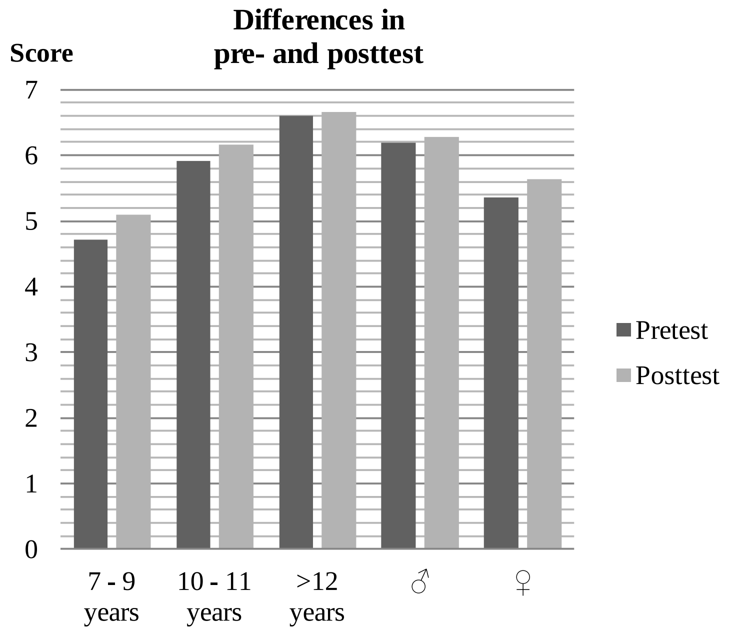

Figure 3. Different scores in pre- and posttest for three age groups and gender

3.3. Quality of modeling and knowledge acquisition

In this study the hypothesis assumed that the quality of modeling facilitates knowledge acquisition concerning the solar system. To measure the possible facilitation of knowledge a partial correlation was performed to analyze if the scores of models influence the posttest, with pretest as control variable. The score of modeling the solar system had a moderated correlation with the posttest ($r(222) = .286$, $p = .005$). Also the total score of the models correlated with the posttest ($r(222) = .186$, $p = .005$).

3.4. Motivation

Motivation consisted of perceived competence (M = 2.90, SD = 0.596) and valuing (M = 3.29, SD = 0.480). The score for the pretest was a predictor for the score on perceived competence ($R^2 = .046$, $F(1,242) = 11.615$, $p = .001$). Competence as an independent variable had a predictive value for the score on the posttest ($R^2 = .051$, $F(1,237) = 12.643$, $p < .001$). In a bivariate correlation, perceived competence have a negative relation ($r(239) = -.225$, $p = .01$) with score of the posttest. There was no significant bivariate correlation between valuing and the score of the posttest.

A univariate analysis of variance showed a significant difference between the age groups and the score of competence ($F(2,44) = 6.781$, $p < .001$, $\eta^2 = .053$). A post hoc comparison (Bonferroni) showed only a significant difference between the 7-9 year and >12 year old participants ($p < .001$). There were no significant differences between ages and valuing. In table 9. the mean scores and standard definition were presented for valuing and competence. There were no influences or relations from perceived competence and valuing for the score at the total models, solar system and solar eclipse.

Table 9. Mean scores and standard deviation of ages and gender at Valuing/Competence

	Valuing		**Competence**	
	n =	*M (SD)*	*n =*	*M (SD)*
Age (in years)				
7 - 9	83	3.36(0.521)	84	3.05(0.566)
10 - 11	90	3.30(0.435)	89	2.91(0.626)
>12	75	3.21(0.479)	74	2.71(0.544)
Gender				
Boys	120	3.32(0.512)	120	2.85(0.647)
Girls	128	3.28(0.448)	127	2.94(0.542)
Boys and age (in years)				
7 - 9	40	3.32(0.558)	41	3.03(0.681)
10 - 11	40	3.37(0.456)	39	2.83(0.689)
>12	40	3.28(0.526)	40	2.68(0.525)
Girls and age (in years)				
7 - 9	43	3.40(0.489)	43	3.07(0.438)
10 - 11	50	3.25(0.413)	50	2.98(0.572)
>12	35	3.14(0.413)	34	2.74(0.572)

Note. Agreement was scored on a four-point scale ranging from "totally disagree" (1) to "totally agree" (4).

3.5. Attitude towards SimSketch

The majority of all participants rated SimSketch as entertaining (91%). The participants thought SimSketch was good (85.4%) and found it beautiful (81.3%). Participants also judged SimSketch as creative (84.1%), and more than the half judged SimSketch as a technical program (59.8%). The half of the participants found SimSketch organized (51.4%) and practical (56.5%). Some participants thought working with SimSketch was quite difficult (32.7%). For most of the children (85.4%) it was the first time to work with such a program. Nevertheless, children evaluated SimSketch as a valuable program (71.5%).

The semantic questions formed the attitude for SimSketch (M = 3.23, SD = 0.425). The scores of attitude SimSketch were reasonable similar. The different scores between age and gender were not significant. In table 10. averages and standard definitions are presented for gender and age.

Table 10. The mean scores and standard deviation for Attitude Simsketch

	Attitude SimSketch	
	n =	*M (SD)*
Age (in years)		
7 - 9	82	3.24(0.344)
10 - 11	86	3.21(0.494)
>12	75	3.26(0.424)
Gender		
Boys	119	3.28(0.401)
Girls	124	3.19(0.445)
Boys and age (in years)		
7 - 9	40	3.24(0.358)
10 - 11	39	3.27(0.431)
>12	40	3.33(0.416)
Girls and age (in years)		
7 - 9	42	3.24(0.333)
10 - 11	47	3.16(0.541)
>12	35	3.18(0.427)

Note. Agreement for attitude SimSketch was scored on a five-point semantic scale from negative (1) to positive (5). The mid-point (3) was neutral.

4. Conclusion & Discussion

From the results of modeling, it appeared that drawing static elements is easier for children than displaying dynamic processes. Children of >12 year scored significant better on dynamic modeling than children of 7-9 years. These results demonstrate that older children could better modeled dynamic processes. As noted in the literature, apparently young children still find it difficult to show dynamic processes in their model (Eccles, 1999). In certain cases children needed support during modeling. Providing support for cognitive and dynamic processes has proven to be effective in computer environments (van Joolingen & De Jong, 2003; Saab, 2005).

The results indicate that the prior knowledge measured by pretest, influenced the quality of modeling. Learners construct concepts from prior knowledge (Novak, 1990). It is plausible that prior knowledge contributes to the quality of modeling, since it is then easier to draw. However, to mention an effect of a pretest measure, it is necessary to evaluate the initial situation of the participants (Bos, Terlouw & Pilot, 2007). In this study there was no baseline measurement, with regard to time pressure in the museum an effect of pretest cannot be sorted.

The first research question examined whether quality of modeling is related to knowledge acquisition. The score of modeling weakly relates to knowledge acquisition. It is a statement that there is a (small) effect visible that modeling contributed knowledge acquisition, whereby a correction of the pretest is used. However, it can be considered that during the experiment participants already learned due the process of the experiment. It is possible that there are other alternatives in the process of modeling which could have led to better quality (Dooley, 2001). This may explain why modeling moderated influenced the knowledge acquisition. A possible explanation is retesting of participants after pretest and the possibility that the experiment may already have influenced their behavior and thus the posttest. Also, the duration of the experiment can play a role in the relationship between knowledge and the experiment. The modeling assignment was of short duration, because there was a limit set by the museum, which makes it difficult to determine whether they really learned something. Participants could have had different treatments due to the situation. The crowds of the museum, and parents who (un)conscious urged children to hurry.

The second research question questioned whether the quality of modeling is related to age. It seems that the quality of modeling is different between ages. The older children have a significantly better total model. Also the solar eclipse was modeled better by older children.

This can be explained because young children have yet more difficulty with showing dynamic processes and moving elements; it takes less effort for older children. It can be declared by the fact that SimSketch was quite new for participants, and they had no or little experience with computer modeling. The results showed a tendency that younger children had less often worked with a program like SimSketch. It is possible when these younger children build more experience and practice with SimSketch, they find it more easy to draw.

The third research question stated whether differences occur in knowledge acquisition between the different ages. The results show that there were significant differences between the scores on the pre- and posttest. The greatest differences were noticeable among younger children. The younger children (7-9 year old) scored in the posttest significantly higher than in the pretest. The results also demonstrate differences between boys and girls. Girls took in the posttest significantly higher scores than in the pretest. However, there may be a ceiling effect among older children and boys. This ceiling effect occurs when participants in the posttest are no longer able to score much higher than in the pretest. The entry level of young children and girls is lower, which allows more gain in knowledge acquisition. This could be a possible explanation for these differences. Still it can be assumed that for young children and girls it is evidently more beneficial, since they learn more.

According to Mayer (2001) there are two main goals of meaningful learning: understanding and remembering. Understanding means that learners build a coherent mental representation. During the modeling assignment participants had to build a coherent mental representation of the solar system. Participants had to understand the complex and multifaceted activity, with the help of modeling and feedback with the expert model. Mayer (2001) calls this the transfer test to understanding. Remembering refers to being able to reproduce the subject matter and is measured in a retention test. The retention test is not used in this study, because the study could only take place within the museum. There were practical limitations that made it difficult to take a retention test. Therefore it cannot be determined whether the (young) participants have learned meaningful.

The fourth research question considered whether motivation, consisting of perceived competence and valuing, plays a role in the quality of modeling and the knowledge acquisition. A significant difference was found in the score of competence among the ages of children. Young children (7-9 years old) scored higher in perceived competence than older children (>12 years old). Young children have indicated that drawing could help them for a better understand of the solar system and that it can contribute to their knowledge. This also corresponds to the results of the knowledge acquisition. Young children actually score higher in knowledge acquisition. They could have felt like modeling helped them in the experiment. It was also shown that the competence affects the score of the posttest. A negative correlation was found between perceived competence and posttest. Compared to the older children, the posttest score of young children is lower and young children have a higher score of competence. This can be explained by the lower entry level of younger children. There were no significant results found in the valuing of children, nevertheless the results show a tendency in the score of valuing. Young children have a predominantly higher score in valuing, than older children. As Eshach and Fried (2005) mentioned in the introduction, young children enjoy observing and thinking about nature. This is in line with the tendency of a higher score in valuing by young children.

To summarize, the results show that young children have less (prior) knowledge about the solar system and are not that good in modeling dynamic processes as older children. For young children there is much profit to achieve in the quality of modeling. The results show a tendency that young children have a higher valuing than older children, which means that they found it interesting to think about the solar system and liked working with SimSketch. The fact that young children acquire more knowledge while modeling in SimSketch is in line with the theory of science learning in young children, as mentioned in the introduction. Young children are willing to learn a lot and prefer an active way (Holt, 1977). It is important that young children will be involved early in science learning and will be encouraged to development scientific thinking.

The present study makes a contribution to the scientific literature on young children's ability to learn science, the importance of modeling and simulating, and children’s effective use of SimSketch to obtain knowledge concerning the solar system. Other studies already showed that modeling and simulating which are based on drawings, can be effective for learning science (Löhner et al, 2004; Leenaars et al, 2012; Sins et al, 2005), or that young children are able to learn science (Eshach & Fried, 2005; Holt, 1977; Wilkening & Sodian, 2005). However there is little research in the use of modeling and simulation for science learning in relation with the ages of children. Therefore this study is useful, given that it proves that modeling and simulation can contribute to the acquisition of science knowledge in young children.

To conclude, this study advocates that using a drawing-based simulation like SimSketch should be introduced in educational settings, given that it can provide a fundamental contribution to knowledge acquisition. There may even occur a learning progression when young children are trained in the use of this methodology. In addition working with SimSketch can give a boost into motivation and technical skills. This technique consists of practicing and getting experience with making a model, whereas drawing will support this. It may be useful that schools and teachers will let students work with SimSketch. It can be used as teaching methodology, especially in courses like mathematics, chemistry and physics. Then modeling has a main role in acquiring and processing new information, instead of getting content through lectures. When students draw to explore and justify understandings in science, they are more motivated to learn than from conventional teaching (Ainsworth, Prain & Tytler, 2011). A drawing-based simulation as SimSketch can help children within education to gain knowledge in a different and authentic way. For young children, it offers the opportunity to develop within science learning. By starting at an early age, becoming familiar with drawing the models, and gain experience in making a qualitative model, it can make great leaps in learning science and scientific thinking.

Future

Over the last years, computer technology has assumed an increasingly role within the school environment (Chan et al., 2006; Dooling, 2000; Harris & Straker, 2000). The use of touch screen computers, tablets and interactive whiteboards in schools can support children in developing computer technology skills and encourage them to learn. For example, more and more schools have computers and interactive whiteboards. Lewin, Somekh & Steadman (2008) argue that computer technologies can supports visualizations. It can explain difficult concepts or demonstrating skills to students. By these developments in school children are becoming more convenient with computer technologies and gain more skills. This provides opportunities for the drawing-based simulation SimSketch in the future. When (young) children are more familiar with touch screen computers and the simulation SimSketch, they will be better able to model and it allows them to develop their knowledge. For an improved market position, the software of SimSketch could also be implemented in smart phone technology and tablets.

Several domains are suitable for SimSketch, however an important question is in which domains children can use the drawing based simulation SimSketch for learning science and whether it can be successful in every domain. It is possible that some domains are too difficult to draw. In further research should be examined to what other domains SimSketch could be used to learn science.

In this study children participated when they visited Science Center Nemo. These children are probably already more interested in science. In further research should be conducted to determine whether this drawing-based simulation can also be effective in other conditions. Children need also more time to perform on the modeling assignment, because time pressure could obstruct children to draw extensive. Including a retention test to measure if children afterwards remember the domain knowledge by modeling in SimSketch. In this study the focus was on different age groups. In future research other variables can be investigated. This could include science curiosity, intelligence/level and demographic variables.

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Appendix

A. Questionnaires

B. Letter for parents

C. Extra information for parents

D. Tutorial

A. Questionnaires

Maart, 2012
Inlognaam: ………………….

Beste jongen of meisje,

Je staat op het punt om mee te doen aan een onderzoek voor de Universiteit Twente. Alvast super bedankt hiervoor!
Het onderzoek waar je aan mee gaat doen bestaat uit meerdere onderdelen. Je gaat vragen beantwoorden en je mag twee tekeningen gaan maken op het scherm dat voor je staat. Het zal ongeveer een half uur duren.
Wees bij alle vragen zo eerlijk mogelijk en wees niet bang om iets fout te doen. Als jij je best doet, dan gaat het helemaal goed komen.

Heel veel plezier & natuurlijk succes!

Onderzoeksleider
Annika Aukes

UNIVERSITEIT TWENTE.

- Deel 1-

Algemene vragen

Ben je een meisje of een jongen?

- ☐ meisje
- ☐ jongen

Op welke school zit je?

- ☐ Basisschool
- ☐ Middelbare school

Hoe oud ben je?

☐ 6 jaar	☐ 11 jaar
☐ 7 jaar	☐ 12 jaar
☐ 8 jaar	☐ 13 jaar
☐ 9 jaar	☐ 14 jaar
☐ 10 jaar	☐ Anders namelijk ……………………

Vragenlijst Zonnestelsel

Hieronder staan een aantal vragen over het zonnestelsel. Bij elke vraag worden meerdere antwoorden gegeven. Er is altijd maar *één antwoord* goed. Probeer de vragenlijst zo goed mogelijk in te vullen. Omcirkel bij elke vraag een antwoord ook als je het antwoord niet weet.

1. Waar bestaat ons zonnestelsel uit?

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.

Tekenen
Je gaat zo beginnen met de tekenopdrachten. Voordat je gaat starten, gaan we je uitleggen hoe het computerprogramma werkt. Je mag op het beeldscherm SimSketch aanklikken om het programma te openen. *Vervolgens vul je de inlognaam in die op de eerste pagina staat.*

Ga om de handleiding te openen met je pen naar ‘voorbeelden’ en klik op ‘tutorial’. In de handleiding hoef je niet heel mooi te tekenen, het gaat er om dat je begrijpt hoe het programma werkt. Besteed dus niet teveel tijd aan de handleiding! Als je klaar bent met de handleiding, ga dan verder met de tekenopdracht.

Tekenopdracht 1
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. Maak een tekening van ons zonnestelsel. Teken hierbij de zon, de aarde, de maan en één andere planeet.

2. Omcirkel de zon, de aarde, de maan en de planeet met de lasso en geef ze vervolgens allemaal een naam en type. Geef met de ‘gedragsstickers’ aan hoe de zon, aarde, planeet en maan ten opzichte van elkaar bewegen.

3. Als je de tekening hebt gemaakt, ga dan naar ‘Modellen’ en ‘Start Simulatie’. Je kan dan de tekening laten bewegen.

Tekenopdracht 2
Een keer in de zoveel tijd is er een verduistering van de zon, dan wordt het helemaal donker op aarde. Dit noemen we een zonsverduistering.

1. Laat in je tekening zien hoe een zonsverduistering werkt.

2. Geef met de ‘ gedragsstickers’ aan hoe de zon, aarde en maan ten opzichte van elkaar bewegen en hoe er een verduistering van de zon plaats vindt. Vergeet niet de lichtbron en de lichtblokker te gebruiken.

3. Als je de tekening gemaakt hebt, ga dan naar ‘Modellen’ en ‘Start Simulatie’, zodat je de tekening kunt laten bewegen. Om een soort foto te maken van het beeldscherm, kun je het screenshot gebruiken. Dat staat rechts bovenin bij het Simulatie venster. Maak een Screenshot precies op het moment wanneer jij denkt dat er een zonsverduistering plaatsvindt .

- Deel 2 -

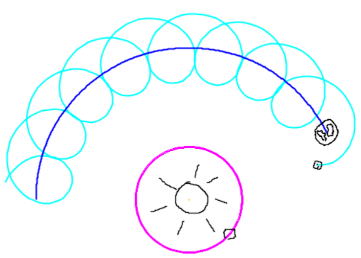
<u>Simsketch</u>
In de volgende tabel kun je in iedere rij aangeven welk woord het best beschrijft wat je van SimSketch, het computerprogramma, vindt. Zet in iedere rij een kruisje, meer naar links of naar rechts om aan te geven welk woord het beste past. Als je een kruisje in het midden zet, geef je aan dat de twee woorden even goed passen.

Werken met het computerprogramma SimSketch was...

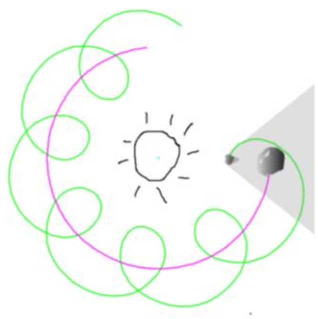
Saai	☐	☐	☐	☐	☐	Leuk
Weinig fantasie	☐	☐	☐	☐	☐	Creatief
Nieuw	☐	☐	☐	☐	☐	Al bekend
Praktisch	☐	☐	☐	☐	☐	Onpraktisch
Niet nuttig	☐	☐	☐	☐	☐	Waardevol
Verwarrend	☐	☐	☐	☐	☐	Overzichtelijk
Makkelijk	☐	☐	☐	☐	☐	Moeilijk
Menselijk	☐	☐	☐	☐	☐	Technisch
Mooi	☐	☐	☐	☐	☐	Niet mooi
Goed	☐	☐	☐	☐	☐	Slecht

<u>De juiste tekening</u>
Je krijgt nu in SimSketch de juiste tekening te zien van het zonnestelsel en van een zonsverduistering. Klik met je pen op 'Bestand' en druk op het toetsenbord op CTRL-O om het zonnestelsel te kunnen zien. Laat de tekening bewegen.

1. Wat zijn de verschillen of overeenkomsten met het zonnestelsel dat jij getekend had en de goede tekening? Geef een kort antwoord:..
   ....
   ....



Zonnestelsel



Zonsverduistering

Kijk daarna ook naar de juiste tekening van de zonsverduistering, druk op het toetsenbord op CTRL-P en laat de tekening bewegen.

2. Wat zijn de verschillen of overeenkomsten met de zonsverduistering die jij getekend had en de goede tekening? Geef een kort antwoord:..
   ....
   ....

Vragenlijst tekenvragen en SimSketch

Geef hieronder aan in hoeverre je het oneens of eens bent met deze stellingen. Er zijn geen goede of foute antwoorden. Per stelling mag je maar één hokje aankruisen!

1. Ik heb al vaker gewerkt met dit soort computerprogramma's

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

2. Ik vond de tekenopdracht interessant

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

3. Ik vond het niet leuk om over het zonnestelsel na te denken

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

4. Ik vond het leuk om met het computerprogramma te werken

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

5. Ik vond het moeilijk om met het computerprogramma te werken

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

6. Ik denk dat ik de tekeningen goed heb gemaakt

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

7. Het tekenen heeft mij geholpen om het zonnestelsel beter te leren begrijpen

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

8. Ik vond het leuk om te zien hoe de tekeningen gingen bewegen

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

9. Ik vond het moeilijk om de tekeningen te laten bewegen

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

10. Ik begrijp het zonnestelsel beter, doordat ik de juiste tekeningen heb bekeken

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

11. Ik denk dat het computerprogramma kan helpen om dingen beter te begrijpen

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

12. Het laten bewegen van de tekening heeft mij geholpen bij het begrijpen van het zonnestelsel

☐ Helemaal niet mee eens ☐ Niet mee eens ☐ Mee eens ☐ Helemaal mee eens

Vragenlijst zonnestelsel
Hieronder staan weer een aantal vragen over het zonnestelsel. Bij elke vraag worden meerdere antwoorden gegeven, maar er is altijd maar *één antwoord* goed. Probeer de vragenlijst zo goed mogelijk in te vullen. Ook als je het juiste antwoord niet weet, omcirkel dan alsnog een antwoord.

1. Waar bestaat ons zonnestelsel uit?
A. Zon, maan en aarde.
B. Een zon met planeten die daar omheen draaien.
C. Een aantal zonnen bij elkaar.
D. Alle sterren gezamenlijk.

2. Waar draait de aarde omheen?
A. De aarde draait nergens omheen, maar de zon draait om de aarde.
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 om de zon heen.

3. Wat is de aarde?
A. Een maan.
B. Een ster.
C. Een kleine zon.
D. Een planeet.

4. Wat is de zon?
A. Een maan.
B. Een satelliet.
C. Een ster.
D. Een planeet.

5. Waar is de zon 's nachts?
A. De sterren staan dan voor de zon.
B. Wolken dekken de zon af.
C. De zon zit dan achter de maan.
D. De zon is dan aan de andere kant van de aarde.

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

7. Wat gebeurt er bij een zonsverduistering?
A. Een planeet staat dan precies tussen de aarde en de zon in, de schaduw van die planeet valt dan over de aarde heen.
B. Dan is de zon aan de andere kant van de aarde.
C. Dan verdwijnt de zon achter de wolken.
D. De schaduw van de maan valt dan over de aarde heen, de maan staat dan precies tussen de aarde en de zon in.

8. Hoe kan het dat de zon steeds op een andere plaats staat, gezien vanuit de aarde?
A. Omdat de zon beweegt.
B. Omdat de aarde om haar eigen as draait.
C. Omdat de zon om haar eigen as draait.
D. Omdat de aarde om de zon draait.

Wil je nog iets zeggen over dit onderzoek?
…………………………………………………………………………………………………..
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Dit is het einde van het onderzoek.
Heel erg bedankt dat je hebt meegedaan!

B. Letter for Parents

INFORMATIE OVER HET ONDERZOEK

Als je een ingewikkeld probleem aanpakt, zoals hoe het zonnestelsel in elkaar zit, helpt het vaak om een tekening te maken. Met zo'n tekening kan je aangeven wat belangrijk is en hoe onderdelen met elkaar verbonden zijn, zoals de maan die rond de aarde draait. Het kan nog beter helpen als de tekening kan laten zien hoe de planeten ten opzichte van elkaar bewegen. *SimSketch* kan dat. Met SimSketch kun je een tekening maken van iets dat je interessant vindt, aangeven hoe de onderdelen van je tekening moeten bewegen, en vervolgens laat SimSketch ze daadwerkelijk bewegen. Op die manier maak je met SimSketch *modellen*. Modellen zijn een belangrijk instrument in de wetenschap.

De afgelopen jaren is de belangstelling voor modellen als didactisch hulpmiddel in het onderwijsleerproces toegenomen. Modellen kunnen het denken en het probleemoplossingsproces ondersteunen en structuren. Met SimSketch kun je dus modellen maken op basis van een tekening.

Aan de Universiteit Twente doen we onderzoek naar het maken van modellen door leerlingen, van basisonderwijs tot aan de Universiteit. We vinden het belangrijk dat mensen leren wat modellen zijn, hoe ze worden gebruikt en wat hun beperkingen zijn. Als een econoom een uitspraak doet over zijn verwachtingen over de economie doet hij dat op basis van een model. Net als bij weersvoorspellingen kan zo'n modelgebaseerde uitspraak uitkomen of niet. Als je geleerd hebt wat modellen zijn en hoe ze werken kun je dergelijke uitspraken beter op waarde schatten.

In dit onderzoek bij NEMO laten we kinderen modellen maken van het zonnestelsel. We denken dat je door te beginnen met een tekening kinderen al jong met modellen kennis kunt laten maken en over het zonnestelsel kunt laten leren. We onderzoeken hoe goed kinderen het zonnestelsel kunnen modelleren, en we vragen of ze het leuk en interessant vinden. Daarbij kijken we naar het verband met de leeftijd: vanaf welke leeftijd kunnen kinderen een goede tekening maken.

Meer informatie over SimSketch en onze andere modelleeractiviteiten kun je vinden op www.modeldrawing.eu. Daar kun je SimSketch ook zelf uitproberen.

C. Extra information for parents

ONS ZONNESTELSEL

Het blijkt dat kinderen veel misconcepties hebben over het zonnestelsel. Hieronder een rijtje met de opvattingen die kinderen hebben over het zonnestelsel.

Wat sommige kinderen denken over het zonnestelsel…

- Sterren en sterrenbeelden staan elke nacht op dezelfde plek aan de hemel.
- De aarde is het centrum van het zonnestelsel. (De planeten, zon en maan draaien rond de aarde.)
- De maan kan alleen ’s nachts gezien worden.
- De aarde is het grootste object in het zonnestelsel.
- Het zonnestelsel bevat alleen de zon, planeten en de maan.
- Alle sterren zijn op dezelfde afstand van de aarde.
- Sterren worden gelijkmatig verdeeld over het heelal.
- De helderheid van een ster hangt alleen af van de afstand tot de aarde.
- De aarde staat ergens op.
- De aarde is groter dan de zon.
- De zon verdwijnt in de nacht.
- De aarde is rond als een pannenkoek.
- Wij wonen op het vlakke midden van de aardbol.
- Planeten kunnen niet gezien worden met het blote oog.
- De zon zal nooit opbranden.
- De zon is niet een ster.

Een korte uitleg over ons zonnestelsel

De zon is het middelpunt van ons zonnestelsel. De aarde draait om de zon, net als de 8 andere planeten van ons zonnestelsel. De tijd die een planeet erover doet om één rondje om de zon te draaien, noemen we de omlooptijd van die planeet. De omlooptijd van een planeet hangt af van de omtrek van de planeetbaan en ook van de snelheid waarmee de planeet beweegt. Hoe dichter een planeet bij de zon staat, hoe sneller de planeet om de zon draait. Dit komt door de aantrekkingskracht van de zon. De aarde doet ongeveer 365 dagen over één rondje rond de zon

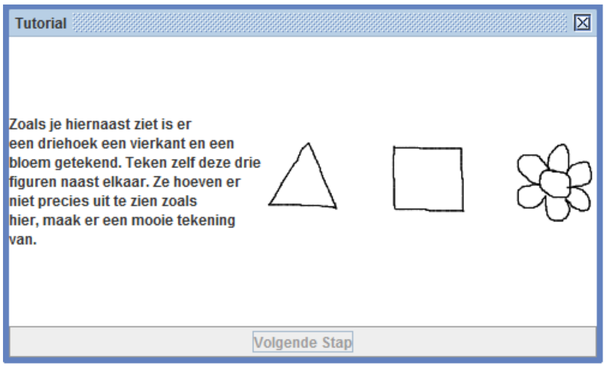
De planeten draaien niet alleen om de zon, maar draaien ook om hun eigen as. Elke planeet heeft zijn eigen omwentelingstijd. Dit is de tijd waarin een planeet één keer om zijn as draait. De draaias van de aarde is een denkbeeldige lijn die door de Noord- en Zuidpool loopt. De aarde draait in bijna 24 uur om zijn as. Dat noemen we een etmaal.

De maan is het dichtstbijzijnde hemellichaam van de aarde en het enige natuurlijke object dat in een stabiele baan om de aarde draait. Zelf straalt ze geen licht uit, maar voor ons is ze wel zichtbaar omdat ze zonlicht in de richting van de aarde weerkaatst . De maan is merkelijk kleiner dan de aarde. De maan draait om zijn eigen as in ongeveer 28 dagen en maakt een omwenteling om de aarde in ongeveer 28 dagen.

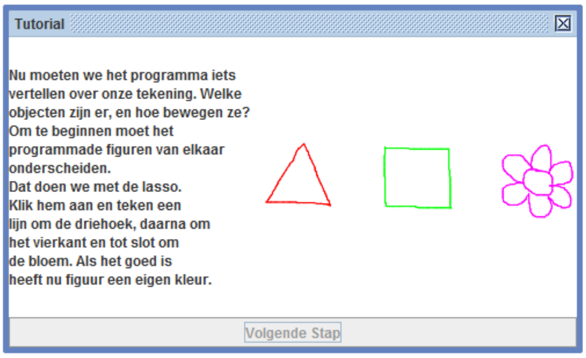
D. Tutorial SimSketch

1.

2.

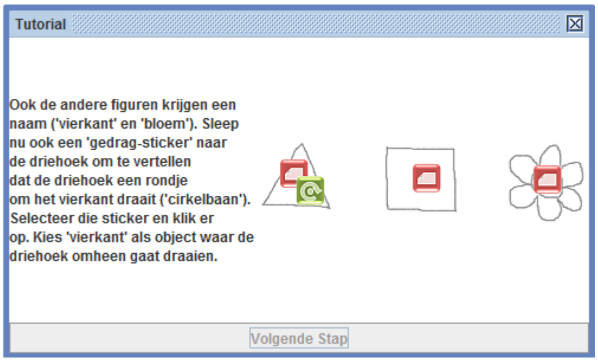


3.



4.

5.



6.

7.

8.

9.


Tutorial
SimSketch
Bestand
Modellen
Voorbeelden
Extra
groeperen Strg-F
start simulatie Strg-R
Nu is alles klaar.
Druk op 'Modellen - start simulatie'.
Druk op play om de tekening te laten bewegen.
Simulatie
start simulatie
Volgende Stap

10.


Tutorial
SimSketch
Bestand
Modellen
Voorbeelden
nieuw Strg-N
open... Strg-L
opslaan as... Strg-S
afsluiten Strg-N
Als alles lukt klik op 'Bestand - nieuw' en dan beginnen we nu met een tekening van ons zonnestelsel.
Einde.