

Drawing based modeling and simulation in primary school science education - The impact on
students' attitude towards science and domain specific knowledge

Hanna Schmalz
s1023381
University of Twente

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Abstract

Thirty-one German students (grade 5 and 6) participated in a study which aims at finding out if animation of drawn models contributes to the understanding of complex planetary movements and to a positive attitude towards science. They worked with SimSketch, a modeling tool that gives learners the opportunity to create drawings of phenomena they study and simulate them afterwards. Their task was the model construction of the solar system in which the Venus orbit and the Earth's perspective of Venus' retrograde movement were emphasized. The students had to answer special questions before and after the use of SimSketch to enable the measurement of the treatment's effects. Results indicate that animation of drawn models contributes to the understanding of complex planetary movements and to a positive attitude towards science although gender differences were found. Male students improved their attitude towards science after the use of SimSketch whereas females did not. The female students in return increased their general planetary knowledge after the treatment which contrasts with the results of male students.

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1. Introduction

Education is a big issue with regard to the future society. The importance of children's learning aptitude is therefore recognized during the last decades. The programme for International Student Assessment (PISA) in 2000 for example aimed to evaluate educational systems worldwide by testing the students' skills of knowledge in participating countries. PISA uses tests, which are designed to evaluate student's ability to apply their knowledge to real-life situations. According to this program the importance of science education is the preparation of students for participation in society (OECD Programme for International Student Assessment (PISA)). Some of the participating countries like for example Germany were placed below the average in all tested subjects (Grek, 2009) which leads to a big challenge for politicians and scientists to find out how educational systems can improve children's learning aptitude and arrange an effective acquirement of new knowledge.

The cognitive view of learning suggests that one of the most important elements in the learning process is how much prior knowledge someone brings to new learning situations and for this reason knowledge is more than the end product of previous learning; it also guides new learning (Woolfolk, Hughes & Walkup, 2008). One important way by which learners can guide their own learning capacities is the use of learning strategies. Especially cognitive learning strategies which describe skills in rehearsing learning contents or organizing it into a main topic, are thought to affect comprehension (Leopold & Leutner, 2012). Model-based learning is one form of cognitive learning strategies. According to Gobert (2000) it describes the construction of mental models and the subsequent elaboration and revision.

Mental models are internal cognitive representations used to generate external representations. Prior knowledge for example is one form of a mental model that influences our perceptions of phenomena and our understanding of representations (Buckley, 2000). Mental models can be revised or elaborated after an evaluation of their accuracy. Model revision describes the process by which parts of an existing model are modified and model elaboration describes the process of adding something to an existing model or combining existing models. In this context *learning* describes the continuous adaption of mental models (Gobert, 2000).

Models in general can be defined as simplified representations of a system focusing on the specific aspects of this system (Ingham & Gilbert, 1991). The creation of models allows to

reflect on certain aspects of phenomena. It is important to use models to formulate hypotheses and to describe scientific phenomena and for that reason models are an essential component to build scientific knowledge. Modification and evaluation of models are, furthermore, important for a scientific world view, because they illustrate the way scientists work (Penner, 2000). It seems obvious that models are of interest for educational research and in the past decades the value of models to science education has therefore been increasingly recognized among the science education reform movements (Gobert, 2000).

Current views on science education further underline the significance of getting students engaged in scientific inquiry activities. The aim is to improve the students understanding of science contents and scientific practices (Sins, Savelsbergh, van Joolingen & van Hout-Wolters, 2010). Inquiry learning is an approach to offer authentic experience by engaging learners in a knowledge construction process (Löhner, van Joolingen, Savelsbergh & van Hout-Wolters, 2005). It can be described as “an educational activity in which students individually or collectively investigate a set of phenomena – virtual or real – and draw conclusions about it” (Kuhn, Black, Keselman, & Kaplan, 2000). Gobert and Pallant (2004) suggest that students’ engagement in authentic scientific inquiry is an excellent pedagogical approach to support their content learning, inquiry skill development and understanding of the nature of science and of scientific models. Authentic scientific inquiry can be made in different ways, but it definitely presumes active engagement of the students. Drawing is one of those activities which require active engagement.

When reporting their discoveries scientists do not limit themselves to words, but rely on diagrams, graphs and similar images to illustrate their results. The same applies to students who understand a scientific text better when they are asked to visualize or draw the content instead of engaging in text-focused processing (Leopold & Leutner, 2012). Leopold & Leutner (2012) have shown that the ability to transfer acquired knowledge to new situations has been increased through drawing activity whereas students who were asked to summarize the acquired knowledge were less able to transfer the content to new situations.

According to van Joolingen, Bollen & Leenaars (2010) drawing can form a bridge between initial ideas and the formal model of a system. A drawing helps identifying the main components that need to be included in a model and that need to be represented as one or more variables. Van Joolingen, Bollen, Leenaars & Kenbeek (2010) had two approaches how to construct a model: drawing to prepare the model and drawing the model itself. Drawing to

prepare the model contains three steps: drawing, defining of variables and the transfer of everything into a computer model. Van Joolingen, Bollen, Leenaars & Kenbeek (2010) found out that models that have been constructed by students in those three steps help with activating prior knowledge and with constructing the model itself based on the drawn elements. This kind of drawing guides learners in making their views on a domain more specific. For that reason SimSketch (van Joolingen, Bollen, Leenaars, & Kenbeek, 2010) works with several steps to create a final model. Students have to draw each single part of the model first, give them names in a second step and tell them at the end how to move. SimSketch is one modeling tool that gives learners the opportunity to create drawings of phenomena they study and simulate them afterwards. If they draw for example the earth and the sun, they can arrange the fact that the earth rotates about its own axis and orbits the sun in a simulation. Another feature of SimSketch is the possibility to change the viewpoint within the simulation and adjust velocity and size to perfect the students' own construction. That gives the student the chance to inspect the self-constructed model from every perspective and to acquire a deeper understanding of the topic. Simulation in general could be defined as an imitation of a system, which can be used to explore domain-specific knowledge (Penner, 2000). The term *computer simulation* describes "programs that contain a model of a system (natural or artificial, e.g., equipment), or process" (de Jong, & van Joolingen, 1998).

Van Joolingen, Bollen and Leenaars (2010) emphasize that simulation based on knowledge - which is used by SimSketch - can have a positive effects on learning processes. Learners will be confronted with the consequences of their own ideas and will be able to adjust these ideas based on this confrontation. Chung, Harmon and Baker (2001) agree with that idea and specify that simulation-based learning is effective in improving students' skills in dealing with complex projects, linking theory to real-world application and improving their problem-solving performance. The use of simulations may, therefore, also be a good tool to give students an understanding of complex structures occurring in science education.

Especially primary and high school students "perceive science largely as a passive process of observing and recording events" (Penner, 2000) and if they have to choose their most disliked subject, it is often science (Osborne & Collins, 2003). Duran, Toral, Martinez-Torres and Barrero (2007) found out that computer simulations have positive effects on the students' satisfaction, participation and initiative. That leads to the question whether the image that students have of science can be improved through computer simulation and

modeling and whether students can develop a positive attitude towards science and maybe perceive science as something more active and interesting due to the use of computer simulations.

The approach is an experimental study in which students are faced with the task of drawing a model of the solar system using SimSketch. They are directed to assign behavior to elements in the drawing and ultimately to simulate the self-constructed model. The emphasis will be the Venus orbit and the earth's perspective of Venus' movements, because if someone on earth watches Venus for a couple of days he or she will recognize loop-like movements. The main research question is whether animation of drawn models contributes to the understanding of complex planetary movements and to a positive attitude towards science. It is expected that students who construct models and animate them afterwards expand their domain specific knowledge and understand the complex planetary movements better than before the model construction and animation (Hypothesis 1). Furthermore it is expected that students who construct models and animate them afterwards get a more positive attitude towards science (Hypothesis 2).

Research has shown that girls outperform boys on planning and attention (Naglieri & Rojahn, 2001) and that boys in contrast have in general more positive attitudes towards science and greater levels of scientific knowledge than females (von Rotten, 2004). Due to these findings it is suggested that there are also differences between boys and girls with regard to the effects of modeling and simulation. It is in question if there are significant differences between male and female students regarding the understanding of complex planetary movements and the creation of a positive attitude towards science after the animation of self-drawn models (subquestion).

2. Method

2.1 Participants

The participants were 31 German students that attend classes five or six of a secondary school in Bocholt. There were 48,4 % female and 51,6 % male students taking part in the study with an average age of 11,39 years and a standard deviation of 0,67. In order to participate the students had to sign up in a list because the number of students that could participate at the same time was limited to ten. There were seven fixed dates to take part in the

study and at each date there was a different number of participants, between one and eight students.

2.2 Material

In this study SimSketch (van Joolingen, Bollen, Leenaars, & Kenbeek, 2010) is used as it allows simulation of constructed models. The modeling process consists of two tasks which require the students to model the solar system and animate it afterwards, heliocentrically at first and geocentrically (from the earth's perspective) second. The computers of the participating school are to run SimSketch and their screens are projected to touch-screens by Wacom (model: DTZ - 1200W). The projection of the computer-screen onto the Wacom touch-screen enables the students to simultaneously draw something and watch the drawing in progress. The tablets allow the students to draw on it with proper pens, but do not react on tangency of fingers or palms.

By providing two questionnaires, one before and one after the use of SimSketch, the simulations' effects on domain specific knowledge and attitudes towards science is measured. The first questionnaire contains items regarding the general planetary knowledge and the attitude towards science. General planetary knowledge is measured by seven multiple choice questions whereas "1" stands for a right and "0" for a wrong answer. The attitude towards science on the other hand is measured by seven four-point-likert-scale items whereas "1" means a very negative attitude and "4" a very positive attitude towards science.

The second questionnaire consists of the same items as the first one plus additional questions regarding Venus. As domain specific knowledge about Venus' orbit is not expected before the treatment, there is no pretest. There are two multiple choice and two open questions measuring Venus knowledge after the treatment. One open question asked the students to describe the retrograde movement of Venus in own words and the second to make a drawing of it. In all four questions "1" stands for a right and "0" a wrong answer. In a second step the two open questions are encoded in another way. There are three criteria for both questions which could be stated respectively drawn by the students. "0" stands for the situation in which the student provides no criteria and "3" means that the student provides all three criteria.

The last point within the second questionnaire is the students' opinion on SimSketch. The students evaluate SimSketch by filling out a table with opposing adjectives. Their

answers are given on a five-point Likert scale. The score “1” stands for the students’ judgement that the more negative adjective is totally appropriate to describe SimSketch and the score “5” stands for the opposite judgment. Ten statements were, furthermore, given to find out how the students think about the use of SimSketch. The students are to react on these statements by giving or not giving their consent. They respond on a four-point Likert scale whereas “1” means that they totally disagree and “4” that they perfectly agree.

2.3 Procedure

After a short introduction to the experiment, SimSketch and the use of the Wacom-tablets, the students filled out the first questionnaire. When they were finished they got the instruction to run the tutorial of SimSketch and work on the modeling tasks (see Figure 1) before filling out the second questionnaire. The students were allowed to ask questions regarding the use of SimSketch and the understanding of the questionnaires at any time.

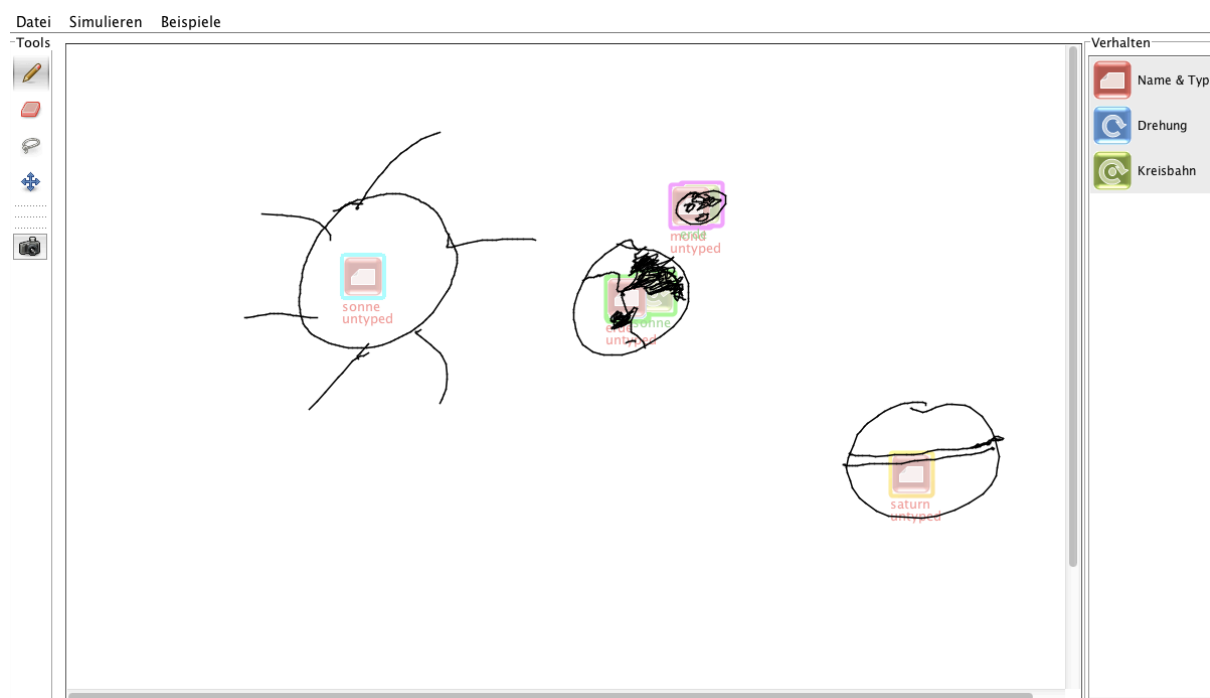


Figure 1. One student's drawing of the first task within the modeling program SimSketch

3. Results

The aim of this paper is to investigate the effects on students’ attitude towards science and domain specific knowledge initiated by the use of SimSketch. The testing procedure begins with the identification of the variables’ normal distribution by the Kolmogorov-Smirnov-Test. In case of normal distributed variables T-Tests are used to determine the

differences of the scores before and after the use of SimSketch. When there was no normal distribution the Wilcoxon Signed-Rank-Test is used. This section is split into five subsections. The first four thematize the main research question and the subquestion, and the last one gives information about the students' work with and their opinions on SimSketch.

3.1 Attitude towards science

A one-sided Paired-Sample T-Test (see Table 1) is used to determine the differences between the measured attitude towards science before ($M=3,152$; $SD=0,329$) and after the treatment ($M=3,309$; $SD=0,401$). It turns out that the attitude's mean after the use of SimSketch is significantly higher than before, $T(31)=2,672$; $P=0,006$.

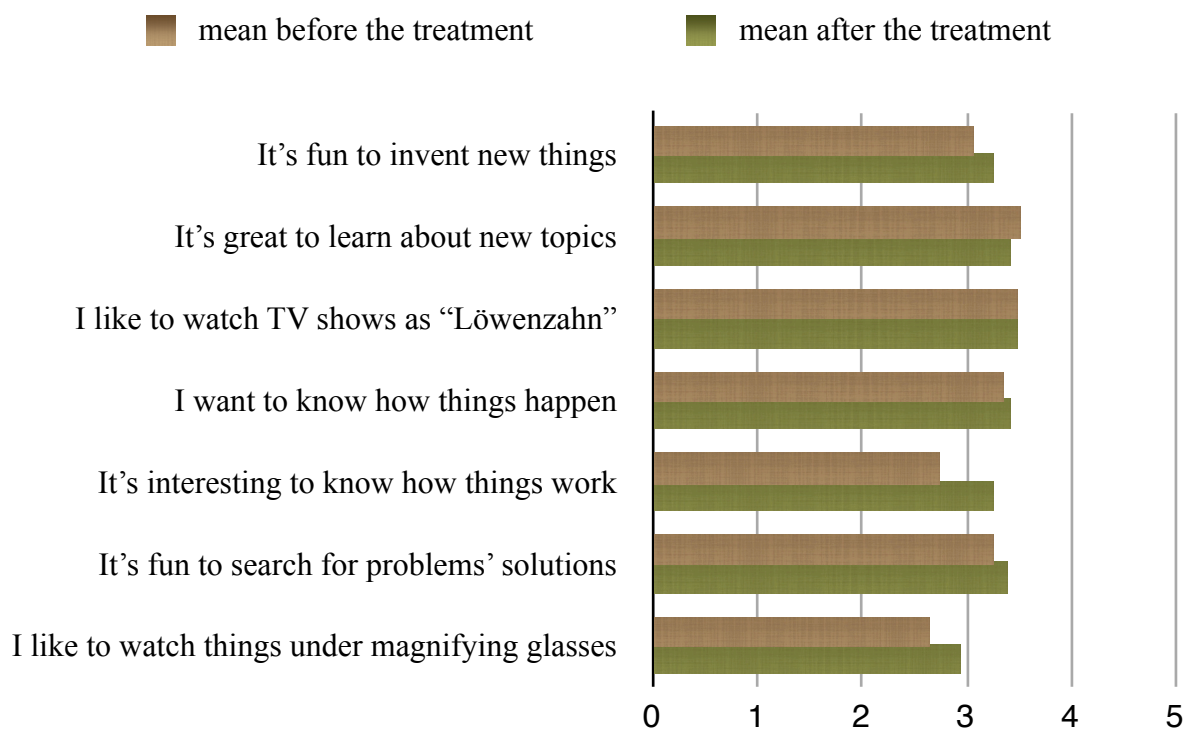


Figure 1. *Mean-values before and after the use of SimSketch for every single item concerning the attitude towards science*

Concerning the mean-values of the single items with regard to the attitude towards science (see Figure 1), it is striking that the item "It's interesting to know how things work" achieves remarkably more positive consent after the use of SimSketch than before. The item "It's great to learn about new topics" in contrast is evaluated as less adequate after the treatment in comparison to the anterior evaluation.

3.2 General planetary knowledge

The one-sided non-parametric Wilcoxon Signed-Rank-Test (see Table 2) is used to find out if students have significantly more planetary knowledge after the use of SimSketch. It turns out that the distribution of measured general planetary knowledge after the treatment ($M=0,862$; $SD=0,145$) shows systematically higher values than the measured general planetary knowledge before the treatment ($M= 0,806$; $SD=0,175$); $P=0,031$.

There are some questions for which remarkably many students did not know the right answer before the treatment. 22,6% did not know what a solar system actually is, 25,8% had no idea how, respectively if the sun is moving and 35,5% did not give the right answer to the question why the sun cannot always be seen at the same position in the sky. After the use of SimSketch the percentages of wrong answers regarding the mentioned questions generally decreased, but exceptionally in case of the first question. After the treatment only one student (3,2%) did not know the right answer to the question what the solar system actually is.

3.3 Knowledge of the retrograde movement of Venus

Table 3. *Mean, standard deviation and T value of a one-sided One-Sample T-Test on the knowledge of the retrograde movement of Venus after the use of SimSketch*

	N	M	SD	T	d.f.	P
Knowledge of Venus	31	0,516	0,376	7,642	30	0,000

A one-sided One-Sample T-Test (see Table 3) is used to determine if the knowledge of the retrograde movement of Venus after the treatment is significantly higher than the no-knowledge expectation before the treatment. It can be ascertained that the knowledge after the treatment ($M=0,516$, $SD=0,376$) is significantly higher than zero, $T(31)=7,642$; $P=0,000$.

Table 4. *Mean, standard deviation and T value of a one-sided Paired-Sample T-Test on the students' ability to reflect knowledge of the retrograde movement of Venus in a written and a drawn way*

	N	Drawn		Written		P
		M	SD	M	SD	
Venus knowledge	31	1,193	1,077	0,581	0,807	0,006

The aim of the following test is to find out if the students do better in representing their new knowledge in a drawing or in describing it in own words. The one-sided non-parametric Wilcoxon Signed-Rank-Test is used to compare the distribution of the items (see Table 4). It turns out that the distribution of the variable concerning drawn Venus knowledge ($M=1,193$; $SD=1,077$) has values which are systematically higher than values of the variable concerning written Venus knowledge ($M=0,581$; $SD=0,807$); $P=0,009$.

3.4 gender differences

This section thematizes the treatment's effect on the attitude towards science, general planetary knowledge and knowledge of the retrograde movement of Venus, but for each sex separately due to a file-splitting of the sex-variable. Regarding the attitude towards science it is possible to compare the mean values using a one-sided Paired-Sample T-Test for female as well as for male participants, as according to the Kolmogorov-Smirnov-Test all populations have a normal distribution.

Table 5. *Mean, standard deviation and T value of one-sided Paired-Sample T-Tests for each sex on the attitude towards science and general planetary knowledge before and after the use of SimSketch*

	After treatment		Before treatment		T	df	P	
	N	M	SD	M				SD
Attitude towards science (female)	15	3,352	0,319	3,257	0,236	1,375	14	0,095
Attitude towards science (male)	16	3,268	0,472	3,0536	0,379	2,301	15	0,018
Knowledge (female)	15	0,857	0,153	0,800	0,169	1,702	14	0,05
Knowledge (male)	16	0,866	0,142	0,812	0,186	1,307	15	0,105

Paired-Sample T-Tests (see Table 5) are performed for both sexes and it can be ascertained that only the male students' attitude towards science is significantly higher after the use of SimSketch, $T(16)=2,301$; $P=0,018$. Furthermore, it is tested if the attitude towards science before respectively after the treatment is equal among both sexes. Two-sided independent T-Tests are used and it emerges that the females' prior attitude towards science ($M=3,257$; $SD=0,236$) does not significantly differ from the males' prior attitude ($M=3,305$;

SD=0,379); $T(31)=1,778$, $P=0,086$. For the attitude towards science after the treatment the findings are similar, the females' posterior attitude towards science ($M=3,352$; $SD=0,319$) does not significantly differ from the males' posterior attitude ($M=3,268$; $SD=0,472$); $T(31)=0,580$, $P=0,566$.

Regarding the general planetary knowledge the means are compared by the use of a one-sided Paired-Sample T-Test (see Table 5) for female as well as for male participants, because again the populations are normal distributed. It turns out that only the female students scored after the use of SimSketch significantly higher on questions regarding general planetary knowledge, $T(15)=1,702$; $P=0,05$. There was additionally tested if the general planetary knowledge before respectively after the treatment is equal among both sexes. Two-sided independent T-Tests are used and it emerges that the females' prior knowledge ($M=0,800$; $SD=0,169$) does not significantly differ from the males' prior knowledge ($M=0,8125$; $SD=0,186$); $T(31)=0,192$, $P=0,849$. For the general planetary knowledge after the treatment the findings are similar, the females' posterior knowledge ($M=0,857$; $SD=0,153$) does not significantly differ from the males' posterior knowledge ($M=0,866$; $SD=0,142$); $T(31)=0,168$, $P=0,867$.

Table 6. *Mean, standard deviation and T value of one-sided One-Sample T-Tests for each sex on the knowledge of the retrograde movement of Venus after the use of SimSketch*

	N	M	SD	T	d.f.	P
Knowledge of Venus (female)	15	0,567	0,319	6,859	14	0,000
Knowledge of Venus (male)	16	0,469	0,427	4,392	15	0,000

The knowledge of the retrograde movement of Venus is also tested in both sexes separately. A one-sided One-Sample T-Test is used (see Table 6) and it turns out that after the treatment male ($T(16)=4,392$; $P=0,000$) as well as female ($T(15)=6,859$; $P=0,000$) students' knowledge of Venus' movements is significantly higher than the no-knowledge expectation before the treatment.

3.5 Use of SimSketch

Table 9. *Minimum, maximum, mean and standard deviation of the students' evaluation of opposing adjectives describing SimSketch*

	N	Minimum	Maximum	M	SD
Boring - exciting	31	3,0	5,0	4,484	0,724
Uninspired - creative	30	3,0	5,0	4,667	0,606
Familiar - new	29	1,0	5,0	4,345	1,078
Impractical - useful	30	1,0	5,0	3,967	1,245
Needless - valuable	29	2,0	5,0	3,759	0,912
Confusing - well arranged	30	1,0	5,0	3,300	0,915
Difficult - easy	30	1,0	5,0	3,467	1,137
Technical - human	30	1,0	5,0	2,400	1,037
Not nice - nice	31	3,0	5,0	4,484	0,724
Bad - good	30	2,0	5,0	4,433	0,774

It is striking that the mean-scores of half the items regarding opposing adjectives are above “4” and therefore very positive. Only for the item by which the students had to choose between the more negative adjective “technical” and the more positive one “human” the evaluation’s mean was remarkably lower (see Table 9). In comparison to the other adjectives, “confusing - well arranged” (M=3,300; SD=0,915) and “difficult - easy” (M=3,467; SD=1,137) have quite low mean-values as well, but in this case the students still evaluate the more positive adjective as more appropriate. Concerning the students’ evaluation of opposing adjectives it is additionally noticeable that there are three items having a minimum score of “3”. This implies that there are no students evaluating the negative adjective as more appropriate: “boring -exciting”, “uninspired - creative” and “not nice - nice”.

Table 10. *Minimum, maximum, mean and standard deviation of the students' consent to statements concerning the use of SimSketch*

	N	Minimum	Maximum	M	SD
I have frequently worked with such programs	31	1,0	4,0	1,774	0,920
I found the tasks interesting	31	2,0	4,0	3,419	0,672
I liked to think about the solar system	31	2,0	4,0	3,129	0,619
I enjoyed to work with SimSketch	31	1,0	4,0	3,516	0,724
I found it difficult to work with SimSketch	31	1,0	4,0	2,258	0,893
I think that my drawings are well done	31	1,0	4,0	2,806	0,749
The drawing helped to understand the solar system	31	1,0	4,0	3,193	0,792
I liked to see my own drawings moving	31	1,0	4,0	3,452	0,723
It was difficult to discover how it is possible to make the drawing move	31	1,0	4,0	2,484	0,962
The drawing's movements helped me to understand the solar system	30	2,0	4,0	3,200	0,714

By analyzing mean-values of the statements concerning SimSketch, it is striking that six out of ten items have a mean-value higher than “3” (see Table 10). The only statements which do not get wide approval are “I have frequently worked with such programs” (M=1,774; SD=0,920), “I found it difficult to work with SimSketch” (M=2,258; SD=0,893), “I think that my drawings are well done” (M=2,806; SD=0,749) and “It was difficult to discover how it is possible to make the drawing move” (M=2,484; SD=0,962).

After the modeling and simulation process the students got to know what the orbits of the solar system really look like. They were asked to note the differences of their self-constructed models and the models of the real world. The most common difference was caused by a mistake during the modeling process. The students had to separate the components of their model by use of a special feature (“lasso”). This feature enabled the attribution of movements to single objects of the drawing. 41,9% of the students have not done this correctly and the simulation did not work as expected. 19,3% forget to name the

single objects and 6,4% of the students do not even remember giving the objects instructions what to do. This mistake resulted in the situation that the simulation could not move at all.

Concerning the simulation's correctness 32,3% of the students forget to show that the earth rotates about its own axis, 25,8% let the moon go around the sun and 22,6% of the students do not remember to coordinate Venus' movements around the sun. 6,5% of the students even simulated a geocentric world view where everything goes around the earth. Furthermore, it was noticeable that 48,4% of the students made mistakes in their model construction although they have answered the pretest's questions regarding those phenomena rightly.

Discussion

With respect to the research question whether animation of drawn models contributes to the understanding of complex planetary movements and to a positive attitude towards science it was found that students significantly benefit from the animation of drawn models in both areas. Additionally, it was discovered that there are gender differences regarding the research question. Male students significantly improved their attitude towards science after the use of SimSketch whereas females did not. The female students in return increased their general planetary knowledge significantly after the treatment which contrasts with the results of male students. This research additionally demonstrated the differences between the reproduction of knowledge by means of drawings and descriptions in own words. It emerged that students significantly better reproduce their knowledge of the retrograde movement of Venus by means of drawings than by the use of own words.

These results suggest that simulation of drawn models has a positive effect on students' learning aptitude. According to Chung, Harmon and Baker (2001) simulation-based learning is effective in improving students' skills in dealing with complex projects, linking theory to real-world application and improving their problem-solving performance. In pursuance to the present results they attain a deeper understanding of the whole topic, but also a more positive attitude towards science. Modeling and simulation is one very active way of learning. Students do not just read or listen to someone teaching ex-cathedra, they actively create something and experience the contents they are learning. The students' interaction with the learning contents is thought to cause the positive effect concerning the attitude towards science. With SimSketch students actively work with contents by drawing and modifying

their own models. They adjust the simulations' perspective, the velocity and the size to perfect their own construction and therefore attain a deeper understanding of the topic. Kahle & Lakes (1983) argued that "lack of experience in science leads to a lack of understanding of science and contributes to negative attitudes towards science". With SimSketch students experience science very actively and, therefore, attain a more positive attitude towards it.

A possible explanation for the students' improved understanding of complex planetary movements is the visual stimulation of the students' attention by the use of the modeling tool SimSketch. They do not just read something and try to remember the content in words; they remember the learning contents by use of their self-constructed drawings they look at during the modeling process. These self-drawn pictures can support comprehension and remembrance; they may help to build mental models as for example prior knowledge (Glenberg & Langston, 1992) which can be used to guide new learning (Woolfolk, Hughes & Walkup, 2008).

Gender differences may occur due to the fact that girls outperform boys on planning and attention (Naglieri & Rojahn, 2001). That explains the significant improvement of the females' general planetary knowledge after the treatment. They use their attention to fully concentrate on the tasks and learn from it. Boys in contrast have in general more positive attitudes towards science than girls (Osborne & Collins, 2003; von Rotten, 2004) which is also in accordance with the results of the present study.

Compared to findings of other researchers there are similar but also contradictory results. The outcome that students' abilities increase after model construction is in accordance with several other researchers (Ainsworth, 2006; van Joolingen, Bollen & Leenaars, 2010; Rutten, van Joolingen, & van der Veen, 2012). Ainsworth (2006) found that students' performances can be enhanced by the interaction with appropriate presentations. The results of the present research are comparable because all students got to see the right animation of the solar system and after the treatment their performances regarding the general planetary knowledge improved. Another research (Rutten, van Joolingen, & van der Veen 2012) has shown that students who use computer simulations in addition to traditional instructions achieve significantly higher results on their tasks. In the present study simulation is not only an additional tool but the results are similar because the students improve their abilities after the use of modeling and simulation as well. Van Joolingen, Bollen & Leenaars (2010) also agree with with these findings. They ascertained that the process of generating a simulation

based on knowledge can have a positive effect on the students' learning abilities. Learners will be confronted with the consequences of their own ideas and will be able to adapt these ideas based on this confrontation.

It was, however, striking that many students were able to answer questions regarding the solar system even before the treatment, but they had difficulties with relating this prior knowledge to the computer model they were to construct. This result is consistent with findings of Sins et al (2005). They brought to light that students often fail to perform model behavior successfully because they do not use their prior knowledge. The present research additionally found out that students are better in reproducing acquired knowledge by means of drawings rather than by the use of own words. That is in accordance with findings of Leopold and Leutner (2012). They have shown that the ability to transfer acquired knowledge to new situations can be increased by drawing activity whereas students who are asked to summarize acquired knowledge are less able to transfer the content to new situations. In the present research there was no transfer to new situations but even the reproduction of acquired knowledge appeared to be easier in a drawn way.

Apart from many similarities to results of other researchers, there are still some points of the present study which conflict with other findings. According to von Rotten (2004) males have a more positive attitude towards science and greater levels of scientific knowledge than females. In the present study there is, however, no proof for a significant gender difference neither before nor after the treatment. Furthermore, it is found that drawing to prepare a model - drawing, defining of variables and the transfer of everything into a computer model - helps with activating prior knowledge and with constructing the model itself based on the drawn elements (van Joolingen, Bollen, Leenaars & Kenbeek, 2010). The present results do not agree with that suggestion. Although the students had to draw each single part of the model first, give them names in a second step and tell them at the end how to move, 48,4% of the students made mistakes in the model construction although they answered the pretest's questions regarding those phenomena rightly. These contrary results occur due to some limitations of the experiment which should be addressed.

One of those limitations was the special target group for the experiments. Only German students attending class five and six of one school in Bocholt and consequentially one school in the whole country were part of the present study. For this reason the chance to get a large data pool was quite low from the very first and that led to the most critical

limitation: the small group of participants. The students' enrollment was even lower than expected due to some critical circumstances. The fixed dates for the experiments were distributed over five weeks and many students forgot their registration for the experiment at the end of this period. Another point which could have limited the potentiality of the experiment was the bounded number of possible participants at the same time. Seven fixed dates had to be arranged to execute the study with an acceptable number of students. For that reason students who took part in one of the first experiments were able to talk to their classmates about the tasks and contents. If these classmates participated in the study at a later point of time, they were prepared and got an improved starting condition. They may get better results and that could have caused a negative effect on the study's reliability.

Due to a different number of participants on each date (between one and a group of eight), some students got a better assistance than others. When there are only one or two students taking part in an experiment it is much easier to take care of all questions and problems that occur than in a situation where eight students try to communicate with the researcher. So it has to be stated that the conditions during the experiment were not equal for all participants. Because of these inequalities of treatment it is hard to draw conclusions and not definitely possible to generalize the results to other situations.

After the pilot study it was expected that the students need about 45 minutes to run through the tasks and complete the questionnaire and for that reason the experiments' duration was limited to one hour. Unfortunately some students needed an unexpected amount of time and so at the end they had to hurry. It was not possible to allow them more time, because the school's computer room was always booked in the lesson after and the participants had to leave on time. The last point which could have limited the potentiality of the experiment was the weather condition at the second and third fixed date of the study. The temperature was over 30 degrees in the shade and the air condition in the computer room was not easy to sustain. The students had problems to focus, asked questions more than once and hardly dealt with their tasks. Their results might have been different if the experimental conditions had been more neutral.

In spite of all those limitations the present results still have expressiveness by reason of the great accordance with researchers of other studies as mentioned before. The biggest value of these results is the possible application in primary and high schools. Students from those age-groups "perceive science largely as a passive process of observing and recording

events” (Penner, 2000) and that is why educational systems require an improvement in their ability to teach science. When students were asked which subjects they do like least, the most disliked subject was science (Osborne & Collins, 2003) and that is a fact which may be enhanced by means of the present results. Educational systems could be guided in the direction of active science experiences by use of modeling and simulation programs as SimSketch. Students may have more fun with sciences, develop a more positive attitude towards it and improve their abilities and their knowledge in areas of science. Nevertheless, it has to be said that further research is needed to bring education to perfection. However, the present results can be used to develop follow-up-studies and so they have already established a foundation for a great series of further investigations.

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Appendix

questionnaire

Mai, 2012

Liebe Jungs und Mädchen,

Ihr seid dabei an einer Untersuchung der Universität Twente teil zu nehmen. Dafür schon einmal herzlichen Dank!

Die Untersuchung besteht aus mehreren Teilen, bei denen Ihr Fragen beantworten und zwei Zeichnungen erstellen sollt. Insgesamt wird die Untersuchung ungefähr eine halbe Stunde in Anspruch nehmen.

Seid bei allen Fragen so ehrlich wie es geht, denn ihr müsst keine Angst haben etwas falsch zu machen. Wenn ihr euer Bestes gebt, reicht das voll und ganz!

Ganz viel Spaß!

Untersuchungsleitung

Hanna Schmalz

TEIL 1: Fragen

Du bist ...

- männlich
 weiblich

Wie alt bist du?

- 10 Jahre
 11 Jahre
 12 Jahre Anders

Hier werden einige Behauptungen aufgestellt, die sich darauf beziehen welche Einstellung du zur Wissenschaft hast. Gib hierbei immer an, inwiefern du damit übereinstimmst oder auch nicht. Kreuze einfach das Kästchen mit der Aussage an, die am besten zu dir passt.

1. Ich habe Spaß daran mir immerzu neue Dinge auszudenken, die mir helfen könnten meine Umwelt besser zu verstehen.

- Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

2. Ich finde es toll etwas über neue Themengebiete zu lernen.

- Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

3. Ich schaue gerne Fernsehsendungen wie "Quarks & Co", "Löwenzahn" oder „Galileo“.

- Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

4. Ich bin neugierig und will immer genau wissen wie oder warum etwas passiert. (Zum Beispiel: Wie entsteht Wind).

- Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

5. Ich finde es uninteressant zu wissen wie Dinge, mit denen ich mich beschäftige funktionieren (wie zum Beispiel ein Computer).

- Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

6. Es macht mir Spaß ständig nach Lösungen für Probleme zu suchen.

- Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

7. Gegenstände unter einer Lupe anzusehen oder Mikroskope zu benutzen, interessiert mich nicht besonders.

- Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

Fragen über das Sonnensystem

Hier findest du einige Fragen über das Sonnensystem. Für jede Frage werden vier mögliche Antworten gegeben, wovon jedoch immer nur *eine* richtig ist. Markiere die richtige Antwort mit einem Kreis. Versuche die Fragen so gut es geht auszufüllen und wenn du eine Antwort nicht weißt, kreise trotzdem eine der vier Möglichkeiten ein.

1. Woraus besteht ein Sonnensystem?

- A. Aus allen Sternen die es gibt.
- B. Aus einer Sonne und aus Planeten, die sich um die Sonne drehen.
- C. Aus Sonne, Mond und Erde.
- D. Aus einigen Sonnen.

2. Was ist die Erde?

- A. Ein Planet.
- B. Ein Stern.
- C. Ein Mond.
- D. Eine kleine Sonne.

3. Um was dreht sich die Erde?

- A. Die Erde dreht sich um die Sonne.
- B. Die Erde dreht sich um den Mond.
- C. Die Erde dreht sich um nichts herum, aber der Mond und die Sonne drehen sich um die Erde.
- D. Die Erde dreht sich um nichts herum, aber die Sonne dreht sich um die Erde.

4. Was ist die Sonne?

- A. Ein Satellit.
- B. Ein Planet.
- C. Ein Mond.
- D. Ein Stern.

5. Um was dreht sich die Sonne?

- A. Die Sonne dreht sich um die Planeten.
- B. Die Sonne dreht sich um die Erde.
- C. Die Sonne dreht sich zusammen mit dem Mond um die Erde.
- D. Die Sonne dreht sich nicht.

6. Wo ist die Sonne in der Nacht?

- A. Die Sonne steht in der Nacht hinter dem Mond.
- B. Die Sonne ist in der Nacht auf der anderen Seite der Erde.
- C. Wolken verdecken in der Nacht die Sonne.
- D. Die Sterne stehen in der Nacht vor der Sonne.

7. Wie kann das sein, dass man die Sonne von der Erde aus gesehen immer an einer anderen Stelle sieht?

- A. Weil die Erde sich um ihre eigene Achse dreht.
- B. Weil die Sonne sich bewegt.
- C. Weil die Erde sich um die Sonne dreht.
- D. Weil die Sonne sich um ihre eigene Achse dreht.

TEIL 2: Zeichnen

Du wirst gleich mit den Zeichenaufgaben beginnen, aber vorher wollen wir dir erst erklären, wie das Computerprogramm genau funktioniert. Um die Bedienungsanleitung zu öffnen musst du mit der Maus auf “Beispiele” klicken und dann “Tutorial” auswählen. Wenn du fertig bist, mit den Beispielen, fang mit der Zeichenaufgabe an.

Lies die Aufgaben gründlich durch bevor du mit dem Zeichnen beginnst.

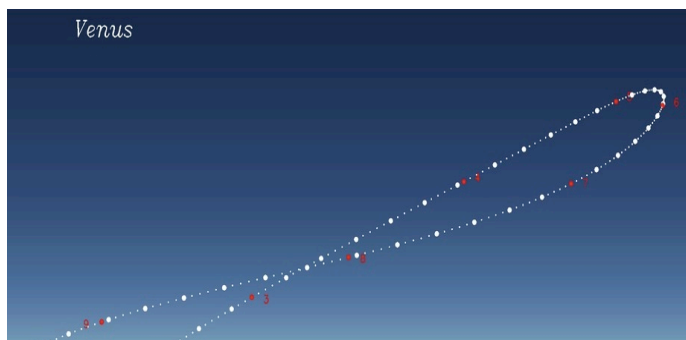
Zeichnung 1: Sonnensystem

Wir leben alle zusammen auf der Erde und wenn wir tagsüber nach draußen schauen, dann sehen wir die Sonne. Am Abend sehen wir keine Sonne mehr, aber den Mond und die Sterne. Die Erde, die Sonne und der Mond befinden sich alle in unserem Sonnensystem genau wie viele andere Planeten auch.

1. Stelle durch eine Zeichnung dar, wie unser Sonnensystem aussieht. Zeichne hierzu auf jeden Fall die Sonne, die Erde und den Mond und einen anderen Planeten.
2. Beschreibe durch die Anbringung von “Stickers” wie die Sonne, der Mond und die Erde sich relativ zueinander bewegen.
3. Wenn du fertig bist, klicke auf “Modelle” und dann auf “Simulation beginnen”, so dass sich deine Zeichnung bewegen kann.

Zeichnung 2: Umlaufbahn der Venus

Die Venus ist nach Merkur der Planet, der der Sonne am nächsten steht. Wenn man von der Erde aus in den Himmel schaut und ganz genau auf die Position der Venus achtet, fällt innerhalb einiger Wochen auf, dass sie sich nicht in einer geraden Linie, sondern in einer Schleifenform bewegt. Hier ist ein Foto von dieser Schleifenform.



1. Stelle durch eine Zeichnung dar wie die Schleifen zu Stande kommen. Du darfst deine vorherige Zeichnung benutzen und anpassen, wenn das nötig ist. Zeichne auf jeden Fall die Erde, die Venus und die Sonne.
2. Beschreibe durch die Anbringung von “Stickers” wie die Sonne, die Erde und die Venus sich relativ zueinander bewegen.
3. Wenn du fertig bist, klicke auf “Modelle” und dann auf “Simulation beginnen”, so dass sich deine Zeichnung bewegen kann. Versuche die Schleifen der Venus von der Perspektive der Erde aus zu simulieren.

TEIL 2: Fragen

In der folgenden Tabelle kannst du angeben welches Wort das angewendete Computerprogramm SimSketch deiner Meinung nach am besten beschreibt. Mach in jeder Reihe ein Kreuz in der Nähe von dem Wort, das am besten passt. Wenn du das Kreuz in die Mitte setzt, bedeutet das, dass du beide Wörter gleichermaßen passend findest.

Arbeiten mit dem Computerprogramm SimSketch war...

Langweilig	Spannend
Phantasielos	Kreativ
Neu	Schon bekannt
Praktisch	Unpraktisch
Unnötig	Wertvoll
Verwirrend	Übersichtlich
Einfach	Schwer
Menschlich	Technisch
Schön	Nicht schön
Gut	Schlecht

Mit den folgenden Fragen möchten wir herausfinden, wie du die Zeichenaufgaben und das Computerprogramm gefunden hast. Gib einfach an inwiefern du mit den Behauptungen übereinstimmst oder nicht. Es gibt hierbei keine richtigen oder falschen Antworten, denn es geht nur um deine Meinung. Es ist wichtig, dass du pro Zeile nur ein Kästchen ankreuzt.

1. Ich habe schon öfter mit solchen Programmen gearbeitet.

Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

2. Ich fand die Zeichenaufgabe interessant.

Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

3. Ich fand es toll über das Sonnensystem nachzudenken.

Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

4. Ich fand es toll mit dem Computerprogramm zu arbeiten.

Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

5. Ich fand es schwierig mit dem Computerprogramm zu arbeiten.

Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

6. Ich denke, dass ich die Zeichnungen gut gemacht habe.

Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

7. Das Zeichnen und Simulieren hat mir geholfen das Sonnensystem besser zu begreifen.

- Ich stimme überhaupt nicht zu
 Ich stimme nicht zu
 Ich stimme zu
 Ich stimme voll zu

8. Ich fand es toll zu sehen wie die Zeichnungen sich bewegen.

- Ich stimme überhaupt nicht zu
 Ich stimme nicht zu
 Ich stimme zu
 Ich stimme voll zu

9. Ich fand es schwer herauszufinden wie die Zeichnungen sich bewegen.

- Ich stimme überhaupt nicht zu
 Ich stimme nicht zu
 Ich stimme zu
 Ich stimme voll zu

10. Die Zeichnungen zu bewegen hat mir geholfen das Sonnensystem zu verstehen.

- Ich stimme überhaupt nicht zu
 Ich stimme nicht zu
 Ich stimme zu
 Ich stimme voll zu

Die richtige Zeichnung

Wir zeigen dir jetzt in SimSketch die richtige Zeichnung vom Sonnensystem und von der Venus Umlaufbahn. Geh auf Simulation und drücke dann auf der Tastatur CTRL-O um die Zeichnung des Sonnensystems zu sehen und dann simuliere es mit „Simulieren – Starte Simulation“ und der Play-Taste.

1. Was ist der Unterschied zwischen dem Sonnensystem, das du gezeichnet hast und der richtigen Zeichnung? Schildere kurz die Unterschiede.

.....

Schau dir auch die richtige Simulation von der Umlaufbahn der Venus an indem du jetzt die Perspektive veränderst. Wähle „Erde“ als Mittelpunkt. Wenn du jetzt auf den roten Punkt drückst, werden die Schleifen der Venus richtig deutlich.

2. Was ist der Unterschied zwischen der Umlaufbahn der Venus, die du gezeichnet hast und der richtigen Zeichnung? Schildere kurz die Unterschiede.

.....

TEIL 2: Fragen über das Sonnensystem

Hier findest du noch einmal einige Fragen über das Sonnensystem. Für jede Frage werden vier mögliche Antworten gegeben, wovon jedoch immer nur *eine* richtig ist. Markiere die richtige Antwort mit einem Kreis. Versuche die Fragen so gut es geht auszufüllen und wenn du eine Antwort nicht weißt, kreise trotzdem eine der vier Möglichkeiten ein. Lass dich nicht von der Wiederholung einiger Fragen verunsichern.

1. Woraus besteht ein Sonnensystem?

- A. Aus allen Sternen die es gibt.
- B. Aus einer Sonne und aus Planeten, die sich um die Sonne drehen.
- C. Aus Sonne, Mond und Erde.
- D. Aus einigen Sonnen.

2. Durch welche Begebenheiten sehen wir die Bewegung der Venus manchmal in Schleifenform?

- A. Die Umlaufbahn der Venus hat eine spezielle Form.
- B. Die Venus dreht sich um die Sonne; die Erde um sich selbst und die Sonne. Auf der Erde haben wir daher eine spezielle Perspektive um die Schleifen sehen zu können.
- C. Die Venus hat keine echte Umlaufbahn und bewegt sich darum manchmal zufällig schleifenförmig.
- D. Die Venus dreht sich sehr langsam um den Mond und bewegt sich darum von der Erde aus gesehen in Schleifenform.

3. Was ist die Erde?

- A. Ein Planet.
- B. Ein Stern.
- C. Ein Mond
- D. Eine kleine Sonne.

4. Um was dreht sich die Erde?

- A. Die Erde dreht sich um die Sonne.
- B. Die Erde dreht sich um den Mond.
- C. Die Erde dreht sich um nichts herum, aber der Mond und die Sonne drehen sich um die Erde.
- D. Die Erde dreht sich um nichts herum, aber die Sonne dreht sich um die Erde.

5. Zeichne die Umlaufbahn der Venus aus der Perspektive der Erde.**6. Was ist die Sonne?**

- A. Ein Satellit.
- B. Ein Planet.
- C. Ein Mond.
- D. Ein Stern.

7. Um was dreht sich die Sonne?

- A. Die Sonne dreht sich um die Planeten.
- B. Die Sonne dreht sich um die Erde.
- C. Die Sonne dreht sich zusammen mit dem Mond um die Erde.
- D. Die Sonne dreht sich nicht.

8. Wo ist die Sonne in der Nacht?

- A. Die Sonne steht in der Nacht hinter dem Mond.
- B. Die Sonne ist in der Nacht auf der anderen Seite der Erde.
- C. Wolken verdecken in der Nacht die Sonne.
- D. Die Sterne stehen in der Nacht vor der Sonne.

9. Wie kann das sein, dass man die Sonne von der Erde aus gesehen immer an einer anderen Stelle sieht?

- A. Weil die Erde sich um ihre eigene Achse dreht.
- B. Weil die Sonne sich bewegt.
- C. Weil die Erde sich um die Sonne dreht.
- D. Weil die Sonne sich um ihre eigene Achse dreht.

10. Um was dreht sich die Venus?

- A. Die Venus dreht sich um die Sonne.
- B. Die Venus dreht sich um die Erde.
- C. Die Venus dreht sich um den Mond.
- D. Die Venus dreht sich um nichts, aber die Sonne dreht sich um die Venus.

11. Beschreibe in eigenen Worten durch welche Begebenheiten die Schleifenbewegung der Venus zustande kommt.

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Hier werden einige Behauptungen aufgestellt, die sich darauf beziehen welche Einstellung du zur Wissenschaft hast. Gib hierbei immer an, inwiefern du damit übereinstimmst oder auch nicht. Kreuze einfach das Kästchen mit der Aussage an, die am besten zu dir passt.

1. Ich schaue gerne Fernsehsendungen wie "Quarks & Co", "Löwenzahn" oder „Galileo“.

- Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

2. Ich finde es uninteressant zu wissen wie Dinge, mit denen ich mich beschäftige funktionieren (wie zum Beispiel ein Computer).

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3. Ich habe Spaß daran mir immerzu neue Dinge auszudenken, die mir helfen könnten meine Umwelt besser zu verstehen.

- Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

4. Gegenstände unter einer Lupe anzusehen oder Mikroskope zu benutzen, interessiert mich nicht besonders.

- Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

5. Ich finde es toll etwas über neue Themengebiete zu lernen.

- Ich stimme überhaupt nicht zu Ich stimme nicht zu Ich stimme zu Ich stimme voll zu

6. Es macht mir Spaß ständig nach Lösungen für Probleme zu suchen.

- Ich stimme überhaupt nicht zu
 Ich stimme nicht zu
 Ich stimme zu
 Ich stimme voll zu

7. Ich bin neugierig und will immer genau wissen wie oder warum etwas passiert. (Zum Beispiel: Wie entsteht Wind).

- Ich stimme überhaupt nicht zu
 Ich stimme nicht zu
 Ich stimme zu
 Ich stimme voll zu

Willst du noch etwas zu der Untersuchung anmerken?

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Das ist das Ende der Untersuchung.

Ich möchte dich bitten deinen Klassenkameraden nicht zu erzählen, was du in dieser Untersuchung genau gemacht hast. Es würde meine Ergebnisse verfälschen, wenn jeder Schüler informiert wäre und von vornherein über das Phänomen der Venus und der Nutzung von SimSketch bescheid wüsste.

Herzlichen Dank, dass du mitgemacht hast!