LEARNING WITH ANIMATIONS

DOES WORKING WITH DYNAMIC REPRESENTATIONS ENHANCE THE TRANSMISSION OF KNOWLEDGE?

Nabila Lalee
(0194921)

Bachelor of Psychology
FACULTY OF BEHAVIOURAL SCIENCES

EXAMINATION COMMITTEE
Dr. A.H. Gijlers
Dr. L. Bollen

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Summary

In the wake of an ever growing importance of multimedia in education, it is important to investigate the role that animations play in the transfer of new information. Our research focused on the effect that self-created, dynamic representations exhibit on the process of knowledge construction in comparison with self-created, static representations. We let children produce their own animations by providing them with the SimSketch modelling environment. 40 students aged 11-12 participated at our study and created their own dynamic representations to explain certain astronomical phenomena. Working with animations was attempted to stimulate the transmission of new ideas and provide the children with a deeper insight of the dynamic processes of the universe. Our findings suggest the assumption that working with animations does result in a high amount of motivation and positive learning experience, however, further research is needed to identify the actual benefits that dynamic representations can have on knowledge-construction itself.

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1. Introduction

The current trend is to actively engage children in their learning process. Instead of just receiving the information, children construct knowledge for themselves and are given room to explore several ideas and connect new information with already existing one. As every child is seen unique, also their way of learning is unique and current strategies of learning try to support individual ways of knowledge-construction (Smeet, 1996).

In search for supporting active knowledge construction, learning scientist gained interest in computer modelling of dynamic phenomena. The basic assumption is that modelling provides learners with a deeper understanding of the domain, using, and testing computer models (Borkulo, 2009). Based on the idea of active processing of information and the externalization and articulation of knowledge and interrelations several claims have been made concerning the benefit of computer modelling on learning outcomes (de Jong & van Jolingen, 2007). According to Borkulo (2009), these include a better understanding of the behaviour of dynamic systems in general as well as the development of scientific reasoning skills. Moreover, modelling supports the acquisition of domain-specific knowledge by learners.

In my study, I focus on dynamic representations and compare them to static representations. The aim of this study is to reveal, in how far animations influence children's learning process and whether this learning is superior to learning with static-pictures. Within the present study students will work with static or dynamic representations of the solar system. Research indicates that elementary school students have a wide range of misconceptions concerning the universe (Vosniadou & Brewer, 1994). As many of the universe's processes are based on dynamic processes, the solar system is considered a suitable topic for learning with animations.. In the present study we create and evaluate a learning environment that will support children's understanding of the topic to be learned and will deliver important findings that will help to form future education.

1.1. Learning with Animations

1.1.1 External representations

In recent years, animations began to play a more and more important part in education. Learning via computer animations is known to have numerous benefits. External representations have always been applied to enhance learning effects, especially when students have to deal with abstract ideas (de Vries, Dimitriadis & Ainsworth, 2006). External representations are associated with several benefits for the learner. They are said to support different ideas and processes. Diagrams exploit perceptual processes, by grouping together relevant information, and hence make processes such as search and recognition easier (de Vries, Demitriaidis & Ainsworth, 2006). Furthermore, external representations are linked with the effect of constraining interpretations and therefore are said to reduce misconceptions. External representations help learners to perceive complex ideas in a new way and apply them more effectively (de Vries, Demitriaidis & Ainsworth, 2006). Providing learners with various representations may help them to build references across these and hence gain the knowledge to perceive underlying structures. Nevertheless, those representations must be designed with care. Austin (2009) claims that "(…) a poorly designed interface increased the demands on working memory, increased the summative cognitive load, and reduced learning.

Of special advantage to student's learning effects seem to be self-created animations that are said to stimulate active learning. Previous research has shown that students develop a deeper understanding of material they study if they generate explanations to themselves whilst learning (Chi, Bassok, Lewis, Reimann, & Glaser, 1989)." According to Gobert and Clement (1999), students who generated diagrams rather than text summaries whilst reading about of plate tectonics performed significantly better on post-tests as they developed more complex and complete mental models." As stated by Mayer & Sins (1994) in order for information to be transferred and retained, the learner must actively engage in the process of learning by attending to incoming information, organizing it and linking it to previously retained knowledge.

Bonwell and Eison (1991) state that active learning leads students to improved thinking and writing. It can lead to better retention of material, motivating students for further study and developing thinking skills. In 1999, Laws reported on a study that compared students' understanding of basic physics concepts after active-engagement and traditional instruction methods. Outcomes have proven active-engagement learning to be more efficient in teaching children basic physic concepts. "Active learning requires students to do meaningful learning activities and think about what they are doing" (Prince, 2004). According to Prince (2004) learning has to go beyond the mere reception of information. Much more, the essence of active learning lies in the active engagement of the student into the learning process. Learners can take control of their learning themselves; however, the greater amount of independence seems to be connected to certain conditions if wished to be of benefit to be the learner. Especially beginners need to be provided with a structure that supports their more self-navigated way of learning, so they do no loose track of which information to focus on. The learning-environment has to be set up in a way that the learner may take more and more charge of his learning process with time. That will help the learner, to lead his knowledge-construction and information seeking in the right direction (Smeets, 1996). Borsook and Higginbotham-Wheat (1991) even compare the overload of control with giving most students "enough rope to hang themselves with"

1.1.2. Pictures in knowledge construction

With growing importance of multimedia in education, research begins increasingly focuses on the role that pictorial illustrations play in knowledge-construction (Carney & Levin, 2002). According to Neisser (1976) perceptual encoding of pictures takes place by so-called pre-attentive processes. These processes are performed in parallel with unconscious, visual routines (Ullmann, 1984). Furthermore, pictures are said to stimulate a bottom-up encoding of information and are rather independent from prior knowledge and the aim of the individual (Rouet, Levonen & Biardeau, 2001). However, a deeper understanding of a picture calls for higher order cognitive processes, which demand attentiveness from the learner. Those processes are performed consciously and serially in bottom-up and top-down direction, and they are influenced both by prior knowledge and the aims of the individual (Rouet, Levonen & Biardeau, 2001). Learners often underestimate the informational content of pictures and think a short look would be enough for understanding and to extract the relevant information (Mokros & Tinker, 1987). Hence, those learners do not create schemata do analyse the depictive representation, neither do they read off enough information and elaborate it properly. A number of studies have also shown that experts in a knowledge domain have usually more comprehensive and hierarchically organized schemata to read off information from a depictive representation than novices (Lowe, Rouet, Levonen & Biardeau, 2001). Thus, in order to enhance learner's knowledge-gaining, it is crucial for a representation to stimulate an active processing of information. As already indicated in the previous texts different factors can lead to the problem of children not being able to read complex texts.

According to Levin (Carney & Levin, 2002) pictures can serve 5 functions in processing texts. Those are decorational, representational, organizational, interpretational (also called *conventional functions*) and transformational (classified as an *unconventional function)*. These function exhibit different learning effects, as presented in fig. 2.

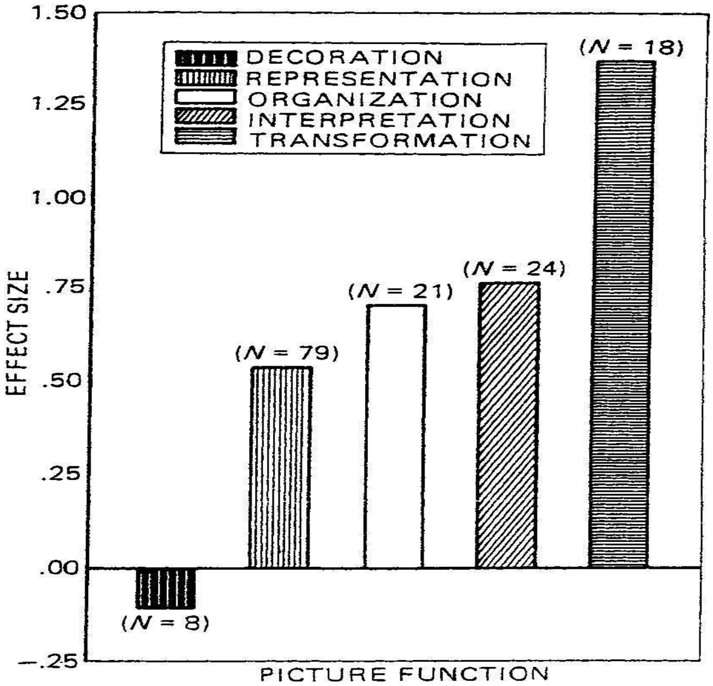

Fig. 2

Pictures and there different functions in processing text (taken from Carney & Levin, 2002)

In some cases pictures can be used to replace a written text as pictures have several advantages. While narrative texts can explain complex processes and operations, pictures can be used to present and relational connections, such as spatial relations (Larkin & Simon, 1987). Pictures can be used to transfer the message of a written text, since they can present the information in a more simple way. Thus, it can be said that pictures reduce the cognitive demands raised by written information. This is especially of benefit when children have to learn about a subject they don't have much knowledge about. (Leutner, Wirth & Schmeck, 2010) formulated the Multimedia-Principle, which claims that presenting a picture combined with a text leads to better learning result than presenting a text alone. That implies, that the text-picture combination must be set up in a “reasonable” way, otherwise know improvement of the learning effect may take place. As already indicated in fig 2, *interpretational pictures* could be classified as set up reasonably, since they deliver great learning effects. Mayer (2001) presents a great example of *interpretational pictures*, as can be seen in fig 3 (Leutner,

Wirth & Schmeck, 2010).

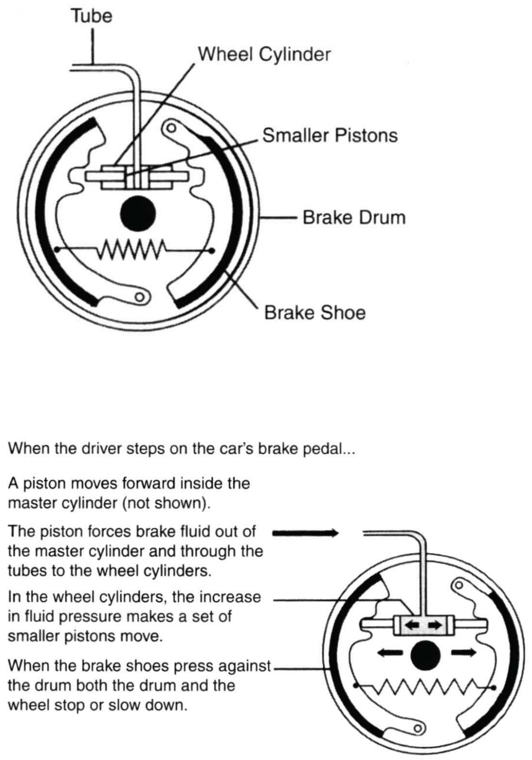

Fig.3

An example of *interpretational pictures* (taken from Leutner, Wirth & Schmeck, 2010).

1.1.3 The benefits of dynamic pictures

Many practitioners believe that a dynamic subject matter is better explained to learners in the form of animations rather than a static picture since the animation presents the respective dynamic directly and realistic (Schnotz & Grondziel, 1996). However these beliefs are questioned by empirical data. Schnotz and Grzondziel (1996) performed a study where learners had to investigate the fact why the earth has different day times and different days on earth. The learners were given a hypertext with verbal information, which either included animated pictures or static pictures. The learners had different possibilities to interact with the animated pictures.

The results showed that the exploratory manipulation lead to a better encoding of detail information in comparison to their static counterparts. However, those having worked with simulations did not show deeper understanding of the learned material. In contrary, they even performed lower in questions that required a corresponding mental simulation.

Rouet, Levonen & Biardeau (2001) offer several possible explanations. Animated pictures shift to a fleeting display of information rather than static. This reduces interaction between descriptive and depictive mental representations, in this case, between representation and mental model. This inhibits a deeper semantic process of the information to be learned. Also watching the simulation might prevent learners from building a corresponding mental model themselves as they simply had to follow the process on the screen. So learning with animations might be easier at first place but sometimes reduces the demands on learner's cognitive processes which can turn out o be a disadvantage to the learner when they have to re-create certain processes themselves.

Also the study performed by Lowe (Rouet, Levonen & Biardeau, 2001) yielded mixed outcomes. Beginning students of environmental science were asked to study animated map materials and to compile an individual set of records that they considered helpful to make predictions from a static weather map. After having worked on the records alone, subjects worked at the computer in pairs and were encouraged to co-operate in their examination of the animation and adopt a highly explorative approach in their extraction of information. Subsequently, researchers analysed the records made by the students to investigate whether the animation influenced the relative attention would give to various aspects of the meteorological pattern. Furthermore, it was examined in how far the subjects could relate the units of information into explanations of the way meteorological patterns change over time. The findings indicated that students mainly detected gross changes in the pattern of meteorological markings. However, the subjects showed the tendency to neglect detailed, yet meteorological significant changes in their records. Moreover, the subject's records lacked sufficient explanations of causal connections between two meteorological features. Possibly, the animated weather map may have been to complex as an information system and thus limited its own instructional effect. Key aspects of the animation that students tended not to report were meteorologically-important multiple relations in which co variation was involved (Lowe, 1999).

Information is processed via selective attention, which is supported by the findings of Höffler & Leitner (2007) that too realistic animations can be contra-productive, because they can include seductive details which distract the learner from the relevant information. Höffler & Leitner (2007) conducted a meta-analysis in which they examined 26 primary studies, yielding 76 pair-wise comparisons dealing with the overall effects of instructional animations compared to static pictures on learning outcomes. These comparisons showed a statistically significant advantage of dynamic pictures. In fact, in 21 pair-wise comparisons animations were superior over static pictures while static pictures yielded better outcomes in only 2 pair-wise comparison. The analysis also showed that another determining factor is the function that an animation has, i.e. whether the animation is representational or decorational. An animation can be called representational when it explicitly depicts the topic to be learned. The study depicted representational animations as superior to representational static pictures while decorational animations do not lead to better learning outcomes than decorational static pictures. Höffler & Leitner also compared in their study which kind of knowledge is best achieved by learning with animations. The different types of knowledge were declarative knowledge, problem-solving knowledge or procedual-motor knowledge (e.g. the reconstruction of a machine gun). Animations seemed to have the most positive effect on learning procedual-motor processes although this result fell short from being significant. On the question, whether animations should be rather highly realistic than schematic, the analysis could not give a clear answer. However, scientists recommend to use schematic animations so the user is not distracted from the crucial aspects of the animations by irrelevant details

(Höffler & Leitner, 2007). Those finding support the belief that it is still a challenging task to create animations that truly benefit learner's effects.

There has been numerous research concerning the effects on dynamic vs. non-dynamic pictures concerning problem-solving. However, the outcomes did not yet draw a clear picture whether dynamic pictures are really more effective than static pictures (Höffler & Leitner, 2007). In addition, the benefits of animations over non-animated pictures might be due to several other factors. For example, computer-based and video-based animations may simply be more realistic than their static equivalent which could lead to different learning results, although highly realistic pictures are not necessarily better for learning than line drawings (Höffler & Leitner, 2007. Furthermore the topic to be learned might determine whether dynamic pictures offer better explanations than non-dynamic ones.

Neither different theories nor studies can explain whether animations are of advantage to the leaner and what factors specifically determine in how far dynamic representations yield better learning outcomes. However, some theories and studies do indicate the promising future of animations in learning science. The wide range of different assumptions and results highlights the importance of further research in this area.

1.2 The working memory

Discussing most efficient strategies of learning, we must turn our focus on working memory as it forms a central aspect in processing and storage of new information. If learning material is to be designed effectively, it is important to know how information is encoded into and maintained in human working memory. It is also important to look closely at how information is presented in working memory. According to the traditional view of human memory, the working memory consists of some structurally separate components through which information is final transferred and stored in the long-term memory (Myake & Akira, 1999). Transformation takes place by i.e. rehearsal. Information cannot be lost once stored in long-term memory, nevertheless its retrieval from it is generally considered more effortful and slower than retrieval from short-term memory (Myake & Akira, 1999). Hence, instructional designs must support both, storage into and retrieval from long-term memory.

While designing instructional pictures, one must consider that working memory is severely limited, according to Baddeley to only about seven items or elements of information at any one time (Kirschner, 2002). Also, it is believed to process only two or three items of information simultaneously. (Kirschner, 2002). These limitations form a challenge to instructional designers as information must be presented in a way that does not exceed the limitations of the working memory. These limits are also addressed by Vekiri (2002), who describes three theories that explain how pictures can facilitate leaning: dual-coding theory, the visual argument hypothesis, and the conjoint retention hypothesis.

1.2.1 Dual-coding theory

The dual-coding theory proposes that information is stored and processed via two different systems: an imagery or non-verbal system for non-verbal information and a verbal system for linguistic information. According to the theory, both systems are functionally and structurally distinct. They differ in function because visual and verbal information are processed separately and independently of each other. Equally, they differ in structure since they store information in representation units that are modality specific, the logogens and the imagens. Imagens correspond to mental images, while logogens refer to verbal codes. Those two are also distinct in organization. Logogens are organized in terms of associations and hierarchies and allows many parts of a mental image to be available to be processed simultaneously. Imagens, on the contrary, are organized in terms of part-whole relationships and only allow sequential processing.

Although those two systems function differently, they still connect the verbal and the visual via associations. (Vekriri, 2002). Vekiri (2002) illustrates this connection with the example of the word "book". People associate the word "book" with an image of a book and thus, hearing this word may generate a mental image of a book.

Hence, visual materials may be used in education to allow the material to be stored both visually and verbally. According to Paivio (1990) this gives the learners more paths to revert to when information must be retrieved from memory. Therefore, visual materials enhance the retention of material as learners are given more ways to memorize information. That goes back to the problem of information from long-term memory being harder to retrieve and highlights the advantage of visual information.

1.2.2 The visual argument theory

The second theory, the visual argument theory, was first formulated by Waller (1981) and describes his visual information can be beneficial over written information. Waller (1981) claims, that graphical representation demand fewer cognitive transformation than does written information and does not exceed the limits of the working memory. Visual information is easier to process since the graphs, diagrams and maps communicate their information through both their individual elements and the way their elements are arranged in space. This also makes it easier to understand inferences about individual elements and their relations (Robinson & Kiewra, 1995) a phenomena called *perceptual enhancement.* Also, graphical representations may help the learner to grasps concepts such as "more" or "better" or illustrate improvement with upward movement or direction (Tversky, 2005). Larkin & Simon (1987) claim that graphic support information search by relying on automatic, perceptual processes. While with written information, users have to search through the whole text for relevant information, graphic displays present all information together and make it easier to locate. This makes information searching less prone to error then searching for information in a text. Finding information by reading through text draws heavily on working memory resources, since the reader has to store important information in his memory while searching for the next relevant piece. The reader has to hold his attention to both the stored information and the text he reads which may lead to an overload of the working memory.

Scaife & Rogers (1996) studied the role of graphic representation in reasoning and problem solving. This research suggested that visual representations do not only function as a mere presenter of information but operate as "external cognition" and thus can influence the nature of cognitive ability (Vekiri, 2002). People can manipulate visual representations instead of carrying out all thinking processes mentally, which facilitates problem solving. As already assumed, this research indicated that graphic representations may reduce working memory load and thus make more cognitive resources available for planning and problem solving. (Vekiri, 2002).Visual representations also may facilitate considering different alternative possibilities as they make alternative states explicit to the viewer. Furthermore, graphic displays may trigger the recall of relevant knowledge that may offer solutions to a problem (Narayanan *et al.,* 1994). .

1.2.3 The conjoint retention hypothesis

The conjoint retention hypothesis was formulated by Kulhavy (1994) and can be seen as an interpretation of the dual-coding theory applied to map learning. It tries to explain how map learning facilitates information processing and rest on two assumptions: the first one refers to the dual-coding theory, claiming that humans posses to different but interconnected memory codes for representing verbal and visual information (Vekiri, 2002). The second assumptions claims that maps contain both information about individual features (such as shape, size and colours) and spatial information among these features (such as distance and boundary relations) and therefore have a significant advantage over written texts. Maps conduct less burden on the working memory, because the map features and their structural relations are simultaneously available. This however, requires that maps provide sufficient structural information. However, these theories try to describe the benefits of visual information in general and do not make a difference between static pictures and those, which are presented dynamically.

1.2.4 Cognitive load

Cognitive load is one of the most intensively studied aspects in the field of learning science (Brünken, Plass & Leutner, 2003). The *Cognitive Load Theory* (CTL) addresses the issue of the limited working memory and how instruction can be designed to deal with those limitations (Kirschner, 2002). CTL is a crucial factor in knowledge construction. Central to the CTL are an overload and understimulation of the working memory, as both can negatively influence the learning process. For a learning instruction to be effective it has to provide an adequate cognitive load to the learner. The more complex the material to be learned, the higher the cognitive load. If the limits of the working memory are exceeded, the learner does not have enough capacities left to retrieve the relevant parts of the information and transfer it into long-term memory. If cognitive load is too low, the learner is not sufficiently engaged into the learning process to make transmissions into long-term memory.

Research has identified two types of cognitive load. *Germane cognitive load* describes the load that is induced by the learner's effort in order to process and understand information (Gerjets & Scheiter, 2003; Renkl & Atkinson, 2003). Cognitive load that is imposed on the working memory by the learning material itself is called *extraneous cognitive load* (Gerjets & Scheiter, 2003; Renkl & Atkinson, 2003). The goal of the design of an instruction should be to reduce *extraneous cognitive load* and optimize *germane cognitive load*.

1.3 Children's conception of the universe

Vosniadou and her colleagues have determined three types of models that people hold to explain astronomical subjects-initial, synthetic and scientific. An initial model is based on personal everyday experience (e.g. seeing the flat surface of the earth). In fact, children form these models long before official instruction as they learn about astronomical phenomena informally in daily life. After children get instructed about astronomical matters, they form synthetic models which form a compromise between their beliefs and the scientific facts they were taught (e.g. the dual Earth, hollow, and flattened sphere). During this phase, children do not fully replace their incorrect beliefs with scientific concepts but tend to reinterpret the new information in accordance with their preliminary models. In the course of adolescence, children from true scientific concepts, viewing the earth as a spherical, unsupported planet, where gravity affects all objects (Vosniadou & Brewer, 1994). The transformation from synthetic to scientific models requires time for discussing both the old and new concepts so the children can fully grasp the new concepts and belief them to be plausible and more useful than their old ideas.

Vosniadou and Brewer (1994) investigated a study regarding elementary school children's explanations of the day night circle. First, third and fifth graders were interviewed about their ideas of certain phenomena, such as the disappearance of the sun during the night, the disappearance of the stars during the day, the apparent movement of the moon and the alteration of day and night. The data Vosniadou and Brewer (1994) gathered showed that while older children hold scientific models to explain these phenomena, younger children tended to form explanations based on everyday experience (e.g., the sun goes down behind mountains, clouds cover up the sun).

2. Methods

2.1 Hypothesis

In line with the theory about the benefits of animations and Cognitive load Theory, two different outcomes could be possibly predicted.

The first hypothesis predicted that children would benefit from the animations and deliver results superior to the non-animation group. It was predicted that working with animations would stimulate the children to a deeper look into the subject to be learned. As a result, the children would gain a better insight in the subject to be learned and achieve higher results at the post-knowledge test than the children from the non-animation group.

It was also predicted that working with animations would result in a slightly increased, optimal level of cognitive load on the children which would turn out to be beneficial for learning.

The second possible outcome was that the animations would impose a too high level of cognitive load which would impede learning. As a result, the children having worked with animations would gain a less deep insight than their static counterpart group. Children reporting the task to be "difficult" or "very difficult" could be an indication of a too high level of cognitive load (see cognitive load measurements)

2.2 Domain and task

In the current study students were engaged in a drawing task on movement in the solar system. Previous research on students' conceptions of the solar system revealed that children face various difficulties in understanding the motion of the planets, the earth's shape and certain astronomical phenomena (as mentioned in Children's concept of the universe') The learning task in the present study focuses on grasping the concept of the planets' movements in regard to each other. The actual learning task was divided into two subtasks. The first subtask focussed on the mere position and circulation of the planets (in regard to each other). The second subtask focussed on applying the knowledge of planets' movements and position to each other in order to explain certain astronomical phenomena. Students were asked to create a representation of the sun, the earth and one other planet in the first subtask. In the second subtask, students were asked to illustrate a solar eclipse.

2.3 Learning Environment and Conditions

Students worked with a computer based drawing environment called SimSketch. This learning environment enables primary and secondary school students to create representations with interactive pen-based input devices. Two versions of the SimSketch environment were developed. The first version enabled students to create a static drawing of the domain. The second version had additional features that enabled students to create a moving animated representation of the domain (SimSketch Ani). In the SimSketch Ani environment students create a drawing of the domain including the key elements and can place ‘stickers’ on their drawing that represent a behavioural primitive, such as certain movements, avoidance, and reproduction. Furthermore, the stickers were able to represent light and shadow. In this way learners are able to create a model by combining learners drawing and the assigned behaviour primitives. The model can be executed and simulated. For our specific domain this meant that students could use the behavioural stickers to make the planets circulating around themselves or another planet. In addition, the behavioural stickers allowed the children to make one planet cast a shadow on another, by determining the sources of light and shadow. Fig. 4 can be consulted for a representation of the second version of the SimSketch drawing environment

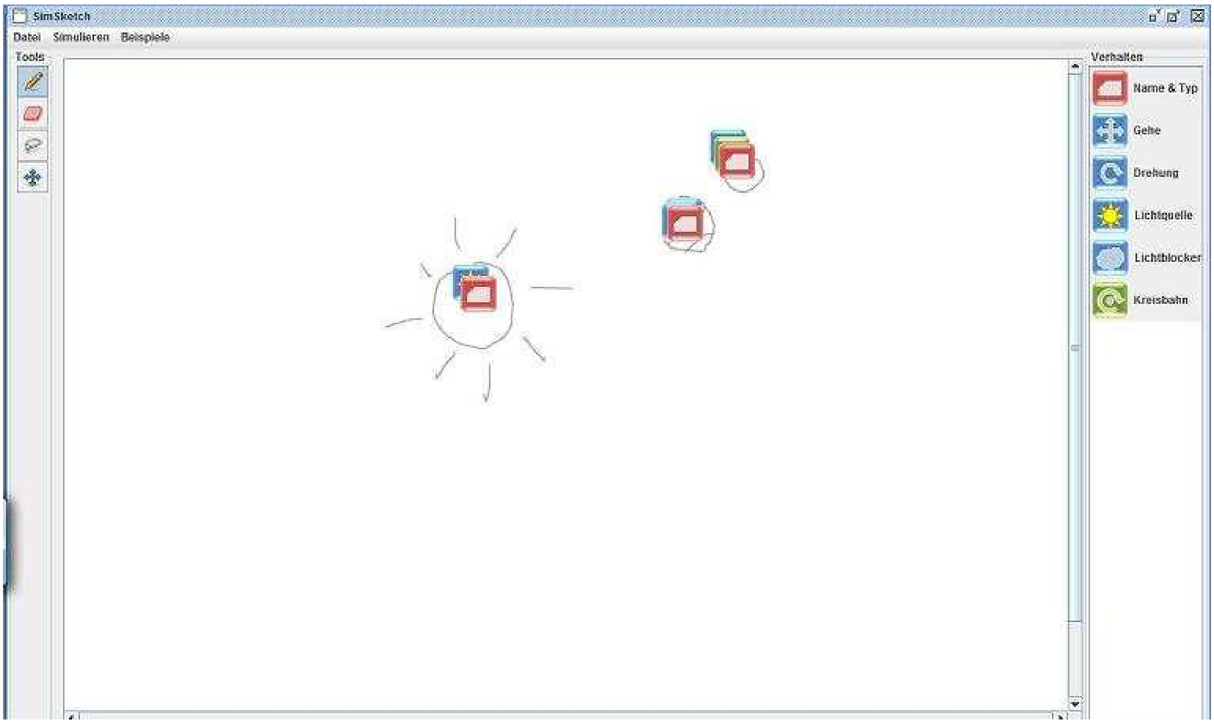

Fig. 4 SimSketch drawing environment with animation function

2.4 Participants

The participants were 40 high school students attending class 6 from a higher school being located in a city area. The subjects were 19 boys and 21 girls, with the average age of 11,5. The subjects were randomly assigned into four groups a 10 children. Group 2 and Group 4 were the animated pictures groups (experimental group) and Group 1 and Group 3 formed the two static pictures groups (control group). All of the participants were native German speakers and shared the same educational background and had no specific background regarding the solar system and the universe.

2.5 Procedure

The actual experiment was consisted of three sessions. The experimental sessions took place in a spare classroom at the school of the participants. Students worked on laptop computers and used a bamboo tablet to create their drawings. All students followed the same sequence of activities. In the first session participants from all conditions completed a pre-test about their knowledge of the solar system. After having completed the test, the cognitive load of the participants was assessed. After the first cognitive load measurement, the four groups directly continued with the completion of the two tasks given to them (being explained in "Domain and task").

Session 1
As mentioned earlier, the two animated pictures group were given two tasks to complete. In the first task, the children had to draw a picture of the sun, the earth and one other planet. With the help of the SimSketch the children had to illustrate the planet's movement. In the second task, the children again had to create their own animation, showing what happens during a solar eclipse. After the first and the second task, the children were measured about their cognitive load the very same way as after the pre-knowledge test.
The two static pictures group had to complete the same tasks as the dynamic pictures group, with the difference that the static pictures group could not make use of animations. They had to draw a static picture of the sun, the earth and one other planet in the first task and a solar eclipse In the second task. As in the experimental groups, the children in the control groups were measured about the cognitive load, the first and the second task put on them. The four groups directly followed one another. The first group to start was the control group, then the experimental group, being followed by the control group and then again by the experimental group. Each group was given 45 minutes time to complete the session.

Session 2
In the second session, the four groups had to complete the very same task as in the first session, with the only difference that the children did not have to complete a knowledge test. Again, all four groups where first measured about the cognitive load and the second task put on them. The children were assigned to the very same group they were assigned to in the first session. The order in which the four groups followed each other was the same as in the first session. Again, all groups had 45 minutes to complete the task.

Session 3
In the third session, the children again were tested about their knowledge of the solar system.

Knowledge tests
Students' knowledge of the solar system and the universe was assessed with a multiple choice pre and post-test.

The pre-test
The pre-test consisted of eight, four answer alternative multiple choice questions. For each question only one answer was correct. The questions addressed basic knowledge about the movement of the earth, the sun and the moon and certain astronomical phenomena such as the solar eclipse. Participants were given 10 minutes to complete the test. Cronbach's alpha for this test is 0,255.

The post-test
The post-test consisted of thirteen, four answer alternative multiple choice question. The eight items from the pre-test were included and five new questions were added to the test. The 5 additional questions again tested children's knowledge about the movement of the sun, the earth and the moon and certain astronomical phenomena, but were extended and asked for more understanding and insight. Figure 5 presents and example of the newly added questions
All 40 children completed the test at the same time. They subjects were given 15 minutes time for the knowledge . Reliability analysis showed a Cronbach's alpha of 0,538

Cognitive load measurements
During the first and the second session, after the cognitive load was assessed after each completed task, Cognitive load was assessed with a short questionnaire consisting of 5 Likert scale items, ranging from "1=not at all" to "5=very much".
Cognitive load was measured with 3 items assessing which investigates the amount of mental effort being put into solving the task (see fig.6).
During the first session, cognitive load was assessed three times, the first time after having completed the pre-knowledge test, the second time after the first drawing task and the third time after the second drawing task. During the second session, cognitive load was assessed twice. Students were asked to fill in the scale after the first and the second drawing task.

The cognitive load questionnaires were administered in a pen and paper format and handed out with the instructions for each session. The experiment leader explained at which point students had to fill out the questionnaire, prompted students complete the questionnaire and supervised the students while they filled out the questionnaire. Reliability analysis of the items resulted in the removal of one item. Cronbach's alpha for the pre-test was: 0,656. For session 1, the Cronbach's alpha was: 0.876, for session to it was: 0,876.

2.6 Process Analyse

In order to assess the quality of the drawings and animations that students created during the learning session a coding scheme was developed as seen in Table 1. The coding scheme focussed on the representation of domain related concepts, with one point given for each element correctly represented in the drawing. The total score of the table was 14 points.

Table 1. Overview of the concepts

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

Light blocker planet	
Light source sun	
Total score:	

2.7. Results

In this section the results of the knowledge tests will be presented, followed by the results of the created drawings and animations and the experienced cognitive load during the different session. For the knowledge test differences between conditions will be explored. Regarding the cognitive load we will explore the load experienced at different phases of the learning process.

For the pre-knowledge test, we could asses a mean of 6,46 points (SD=1,189), with 8 points being the highest number to be possibly achieved. Table 2 presents the mean pre-test scores for each condition. Comparing the means, we can observe a so-called *plafond-effect* which occurs when the test is too easy to solve, causing the majority of participants to almost achieve the maximum number of points.

An One-way Anova showed no significant differences between the conditions for the pre-test with ($F(1, 37) = .753$, $p = .391$). The results reflect that the participants entered the experiment sharing the same knowledge.

Table 2. Mean pre-test scores

	Control (n=19)		Experimental (n=20)	
	Mean	SD	Mean	SD
scores	6,63	1,07	6,3	1,3

For the post-knowledge test, we could observe an average of 7, 57 points (of 13 points being possibly achieved in total). The lover achieved number of points, compared to the pre-test, can be explained by the five additional questions which were added to the pre-test. As reflected in the results, the newly added questions were more prone to be answered wrongly by the children. In Table 3 we can see the mean post-test scores of each condition. We could observe no statistically significant difference between the conditions with ($F(1, 35) = .034$, $p = .856$)

Table 3. Mean post-test scores

	Control (n=19)		Experimental (n=20)	
	Mean	SD	Mean	SD
scores	7,5	2,2	7,63	2,17

Results also showed, their was no main effect for the average cognitive load experienced by each participant of the two conditions with ($F(1, 33) = .106$, $p = .747$) in the first session. Table 4 can be consulted for the average cognitive load of each condition.

Table 4. Perceived cognitive load session 1

	Control (n=19)		Experimental (n=16)	
	Mean	SD	Mean	SD
scores	14,95	5,48	15,5	4,37

There was no main effect for the average cognitive load experienced by each participant of the two conditions in the second session with ($F(1, 33) = 1.262$, $p = .269$). Table 5 reflects the average cognitive load as perceived in each condition.

Table 5. Perceived Cognitive load session 2

	Control (n=19)		Experimental (n=16)	
	Mean	SD	Mean	SD
scores	11,0	5,12	12,71	3,7

The quality of the representations did not significantly differ between the conditions with ($F(1, 35) = 2.392$, $p = .131$) for the static pictures. For the static elements the experimental group had an average score of 4, 3. In comparison, the average score of the control group was 4, 77. For the dynamic pictures, the average score of the experimental group was 1, 55.

3. Discussion

3.1 Evaluation of the Results

The aim of the study was to examine how animation could influence the effectiveness of children's learning and how they could be effectively used in education. Also, we wanted to investigate, whether knowledge gained by using animations systemically differs from knowledge gained by static pictures. The hypothesis, that children from the animation group would gain a deeper insight into the topic could not be confirmed. Working with the animations did not lead to a significantly different learning outcome.
Children from the experimental group did not show a higher or lower success rate in answering the post-knowledge test. Children from the dynamic pictures condition reported a cognitive load that is slightly, yet not significantly higher than reported in the static pictures condition. However, observations indicate that cognitive load was indeed higher in the experimental group, although not mirrored by the cognitive load measurements.

In comparison to children from the control group, children from the experimental group needed significantly more time to solve the task. The average time to solve the task for each child in the control group was beneath the 45 minutes time they were given. Children from the experimental group, however, were on average hardly finished before the 45 minutes. Moreover, children from the experimental group had a higher need for assistance. Typical questions asked by the students in the experimental group revolved around operating the system itself. Children were prone to make small mistakes in handling the behavioural stickers, which prevented the animation from running properly and resulted in confusion on the side of the learner. For students it was kind of hard to detect where the mistakes were made and they often blamed the system. Typical statements from the children "I don't understand that program" or "That doesn't work for me," which does indicate children experienced frustration and insecurity. Also, children from the experimental group were more prone to ask the experiment leader, whether their work could be checked for correctness. Furthermore, children felt a higher need to communicate with each other and compare their own work with the work of other learners form the group. This does reflect a relatively high level of insecurity but also indicates that working with the animation software stimulated collaboration and exchange of ideas.

The software might have not guided children effectively on their way to new knowledge transition. As mentioned by Smeets (1996) it is crucial for beginners especially, to be offered a structure that will guide their self-navigated learning. As in the experiment, learners in both could work very freely on the task without being given structure from outside, they might have not been able to effectively gather and apply new ideas. Learners could have been misguided to turn the focus too much on non-essential parts of the learning task, such as creating drawings of beautiful appearance rather than of correct content. This overload of control can have resulted in what Borsook and Higginbotham (1991) have described as "giving the students just enough rope, to hang themselves with". This is also suggested by informal observations made by the experiment leader during the experiment. It would be interesting to investigate the amount of structure needed that students need when they generate pictures or animations.

3.2 Limitations and Implications for future research

There are several points that can be regarded as critical in this study. At first, the children from the experimental group were even in the second session not very comfortable with using the program but in the contrary, experienced problems that might have lead the children to focus their concentration to much on operating the program itself rather than on solving the task. During the sessions, children from the experimental group asked a lot of questions about operating the program itself rather than topic-related questions. This is another indicator for focus shift from the learning to operate the computer system that might have impeded successful knowledge transmission. This goes back the cognitive load theory by Paivio (1990). By focussing too much on operating the computer software, children might have to little mental capacities left to identify core aspects of the problems and absorb new information. Children were given a tutorial, but due to the limited amount of time, children might have not been able to study the tutorial intensively. Also, children from the experimental group were given the same amount of time per session as the children from the control group, although the letter one did not need to follow a tutorial. As a consequence, children from the experimental group had less time to look into the learning task. This difference in time, together with the focus shift might play an important role in how much the children from the experimental group were actually able to really work and reflect on the topic to be learned. For further studies, it is recommendable to grant children more time to get familiar with the program. It is also advisable, to give the children from the experimental group extra time for the following of the tutorial, so in the end, children from all group will be able to spend the same amount of time for completion of the task itself.
The second problem was that almost all the children were familiar with the movements of the planets (in regard to the sun) and the procedures of a solar eclipse. Knowledge acquisition could have been better tested with a process, the children were less familiar with at the point the study started (e.g. eclipse of the moon). Solving a problem children already new the

answer for might have not stimulated the transfer of new ideas and knowledge. This is also reflected in the amount of cognitive load that children reported, that indicates children were slightly under stimulated during the learning process. The cognitive load might have been just too low to stimulate children to reflect on the task and truly engage into problem solving by connecting existing ideas and knowledge with knowledge that was newly gained from working on the task. As a consequence, children might have also not been stimulated to combine different ideas to go beyond their existing knowledge and transfer it to new problems, since they have not learned to do so during the learning process. This is also reflected in the results of the post-knowledge test that shows no significant differences between the groups. Also the knowledge test did not reflect different ways of approaching the problem between the groups. Thus, it is advisable to perform a pre-knowledge test some time before the first session and then adjust the learning task to children's knowledge.
As the test consisted of multiple choice questions, it did not reflect children's way to the answer but only the answer itself. It might be possible, that working with animations might have delivered a deeper or different understanding of the topic or simply stimulated to approach the problem differently. This could have been better with questions, that focus less on factual knowledge but those that would address different viewpoints of the same process. The knowledge test focused too much on covering different domains of the topic, which required a transfer of knowledge. Children might have still been too unfamiliar with the topic as a whole to meet the test's requirements. The test was one step to far, testing a level of knowledge they had not yet reached. The knowledge test should have been more focused on the domain of the solar eclipse itself and asking about different aspects of that problem instead of spreading into new domains like the eclipse of the moon or the evolving of the seasons.

Cronbach's alpha proved the cognitive load measurements a reliable source of investigation. The 5-pount Likert scale is a good way to asses and compare children's and compare the mental effort that children felt exposed to during completion of the tasks. Nevertheless, it must be considered that the marginally diverged from the average derives from the fact, that people, when having to choose between a range of statements, people always tend to choose for the moderate one (medium effect).

3.3 Conclusion

There are several claims that can be predicted based on the outcome of this study.

Firstly, the study shows that computer software can be used in advance of learning, may it be with animations or not. This conclusion is taken from the fact that children showed clear interest in working with the software and as a result were willing to engage themselves in completing the learning tasks. The rather low cognitive load in both conditions indicated, that although children still experienced struggles with the program, they also experienced curiosity and motivation which made them evaluate their cognitive load as low in hardness and frustration and their work as rather high in success. These findings implicate that animations do motivate children to engage in learning, even if they face difficulties while performing a task. Hence, the research has proved animations to be a precious tool in knowledge-construction, even when in a different way that was assumed at the beginning of the study. Animations can help to deliver pleasant learning experiences, even if problem solving itself was challenging and high in cognitive demand. This opens a whole field of research, as it has not yet been extensively studied in how far animations can improve how the learning-process is experienced by the student himself. If future research indeed reveals an adequate connection between working with animations and a higher quality learning experience, this

can lead future education to a significantly stronger focus on instructional animations.
Furthermore, the study possibly implicates that the design of the animation is of high relevance for the degree, to which learning can be positively influenced.
Furthermore, this study highlights the importance of further research in designing optimal instructional animations. The animation and the software itself must be set up efficiently, to positively direct children's focus on the learning task. Even if animations do encourage children to put a higher amount of mental effort into a task, this effort is wasted if not lead into the right direction. In the end, it is not merely quantity but just as well quality that decides over the benefit that mental effort can execute on forming of new knowledge.

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Appendix

Appendix A

Cognitive load measurements

1. How difficult was it for you, to solve the task?

1. Very easy 2. Easy 3. Moderate 4. Difficult 5. Very difficult

2. How much time did it take you to solve the task?

1. Very little 2. Little 3. Moderate 4. Much 5. Very much

3. How insecure, irritated and/or frustrated were you while solving the task?

1. Very little 2. Little 3. Moderate 4. Much 5. Very much

Appendix B

Pre-knowledge test

Dear students

Thank you for participating in a study of the University of Twente.

The study consists of several parts. You will answer a couple of questions and then create two drawings with the help of your laptops.

Please be as honest as you can while answering the questions. You don't need to worry if you don't know how to answer a question.

Best wishes!

I want to start the study with a small knowledge test. There's only **one** correct answer to every question. Draw a circle around the answer you think is right. Don't worry if you don't know the answer to every question.

1. What does the solar system consist of?

A) all stars together

B) a sun with planets circling her

C) sun, moon and earth

D) several suns

2. What is the earth?

A) a planet

B) a star

C) a moon

D) a little sun

3. What does the earth circle?

A) the earth circles the sun

B) the earth circles the moon

C) the earth doesn't circle anything, but the sun and the moon do circle the earth

D) the earth doesn't circle anything but the sun circles the earth

4. What does the sun circle?

A) the sun circles the planet

B) the sun circles the earth

C) the sun spins around herself

D) the sun doesn't circle anything

5. What does the moon circle?

A) the moon circles the earth

B) the moon circles the sun

C) the moon doesn't circle anything but the earth circles the moon

D) the moon spins around itself and circles the earth

6. How do day and night occur?

A) The earth moves around its own axis and only one part is turned towards the sun

B) The sun circles around the earth and casts her light on only one part of the earth

C) The moon is on one part of the earth and causes night

D) The moon moves in front of the sun

7. What does happen during a solar eclipse?

A) the sun disappears behind the clouds

B) a planet stands between the sun and the earth, whereat the planet casts a shadow on the earth

C) the moon casts its shadow on the earth while standing directly between the sun and the earth

D) the sun is on the other side of the earth

8. How is it possible that from the earth's perspective the sun is always at a different spot?

A) the earth rotates around its own axis

B) the sun is moving

C) the earth circles the sun

D) the sun rotates around its own axis

Appendix C

post-knowledge test

1, How do day and night occur?

A) The earth moves around its own axis and only one part is turned towards the sun

B) The sun circles around the earth and casts her light on only one part of the earth

C) The moon is on one part of the earth and causes night provides learners with a deeper understanding of the domain, using, and testing computer models (Borkulo, 2009)D) The moon moves in front of the sun

2. What does the earth circle?

A) the earth circles the sun

B) the earth circles the moon

C) the earth doesn't circle anything, but the sun and the moon do circle the earth

D) the earth doesn't circle anything but the sun circles the earth

3. What does the solar system consist of?

A) all stars together

B) a sun with planets circling her

C) sun, moon and earth

D) several suns

4.. What does happen during a solar eclipse?

A) the sun disappears around the clouds

B) a planet stands between the sun and the earth, whereat the planet casts a shadow on the earth

C) the moon casts its shadow on the earth while standing directly between the sun and the earth

D) the sun is on the other side of the earth

5. What does the sun circle?

A) the sun circles the planet

B) the sun circles the earth

C) the sun spins around herself

D) the sun doesn't circle anything

6. What does the moon circle?

A) the moon circles the earth

B) the moon circles the sun

C) the moon doesn't circle anything but the earth circles the moon

D) the moon spins around itself and circles the earth

7. When it's midnight in Europe, on the other side of the planet, e.g. New Zealand it's...?

A) ...noon, since the earth rotates around its own axis. Hence, always the sun always casts her light on only one part of the earth

B) ...also midnight since during night the entire earth isn't sunlit

C) ...noon, since the earth circles the sun

D) ...noon, since the sin circles the earth

8. How do the different seasons evolve?

A) Due to the inclination of the earth's axis. The earth is not placed vertically on the earth's orbit but slightly oblique. In the summer, the earth is more inclined towards the sun then in winter.

B) In summer, the earth moves towards the sun, in winter, the earth moves off the sun.

C) Due to the earth's orbit, the earth does not always have the same distance to the sun. At some points on the orbit, the earth is closer to the sun, which causes summer. During winter, the earth is on a point, that is further away from the sun.

D) The sun circulates around the earth. During winter, she's further away from the earth and during summer, she's close to the earth.

9. Why does the moon wane and wax?

A) the sun circles the moon, whereat she casts her light on the moon from a different angle. It takes the sun one month to circle the moon.

B) the moon circles the earth, the earth, in turn, circles the sun. This causes the moon to always be in different position between the sun and the earth, so at times the sun lits the moon entirely and at times only partly

C) the earth circles the sun while the moon doesn't. The changing viewpoint causes us to not always see the moon entirely

D) The moon circles the earth, whereas the earth circles the moon. Due to the earth's orbit, moon and earth do not always have the same distance to the sun, so the sun cannot always lid the entire moon

10. When it's summer in Europe, on the other side of the earth, e.g. New Zealand it's...?

A) ...winter. The earth rotates around its own axis so that at any given time a different part of the earth is more exposed to the sun

B) ...winter. The earth's axis is being slightly tilted so at any given time one part of the planet is more exposed to the sun.

C) ...also summer. On it's circle around the sun, at any given time the earth either moves towards the sun or moves away from her

D) ...also summer. The southern hemisphere finds itself in a closer position to the sun, so it's warmer there than on the northern hemisphere the entire year

11. How is it possible that from the earth's perspective the sun is always at a different spot?

A) the earth rotates around its own axis

B) the sun is moving

C) the earth circles the sun

D) the sun rotates around its own axis

12. How does a lunar eclipse occur?

A) Since the earth rotates around its own axis but the moon doesn't circle the earth, we do not always see the moon

B) Since the moon rotates around its own axis at any given time only one part is exposed to the rays of the sun. During a lunar eclipse, the earth faces the non-exposed part

C) The moon circles the sun faster than the earth does. Due to the difference in speed at some point the sun stands directly between the earth and the moon, so we do not see the moon

D) A lunar eclipse occurs when the earth stands directly between the sun and the moon. The sun lits the earth whereat the earth casts its shadow on the moon

13. How can the moon cover the entire sun during a solar eclipse?

A) the moon and the sun are of same size

B) the moon is smaller than the sun but has a smaller distance to the earth

C) the moon is smaller than the sun but casts a shadow that is big enough to cover the entire sun

D) the moon doesn’t cast any shadow on the sun but the earth does. The earth's shadow is big enough to cover the sun entirely