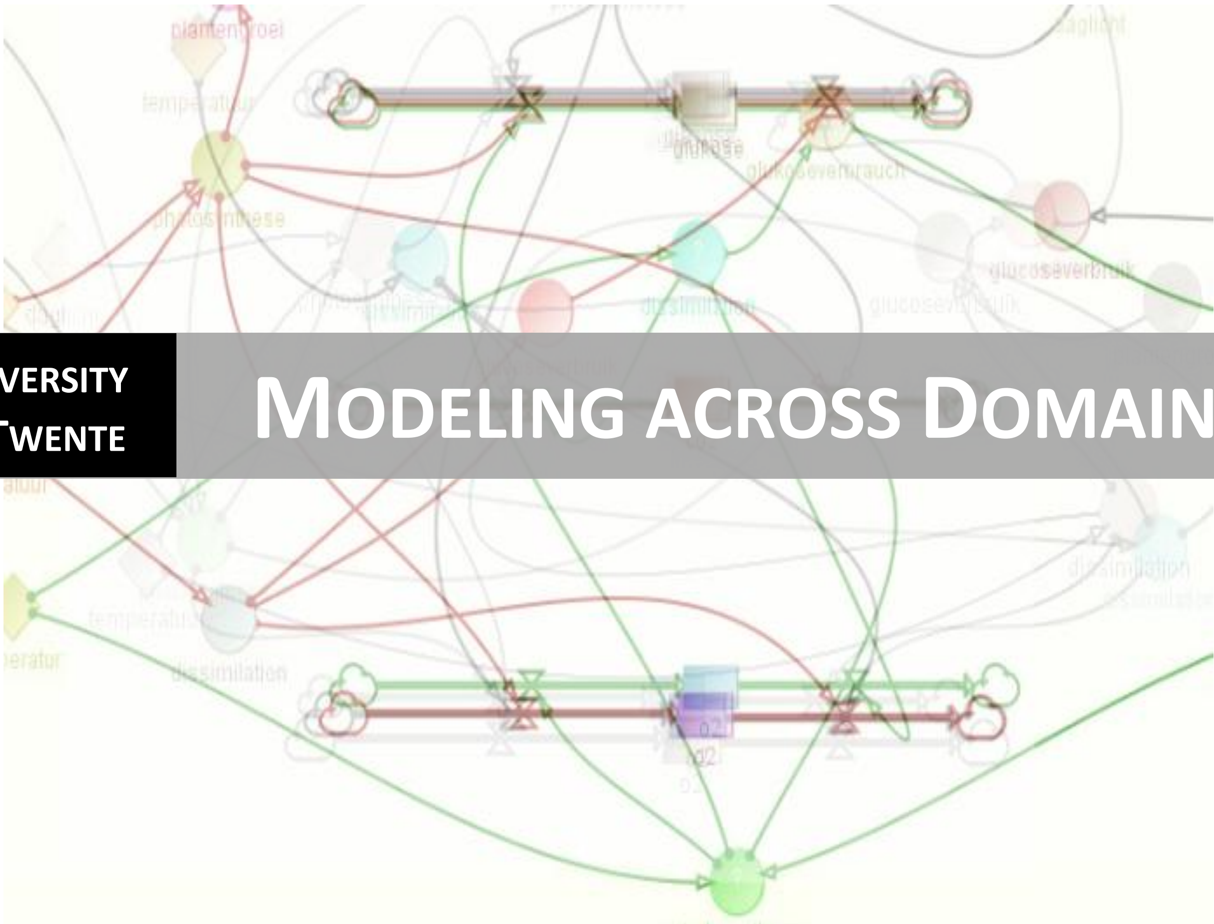
6.7.2012

Bachelor Thesis Psychology



UNIVERSITY OF TWENTE

MODELING ACROSS DOMAINS

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Abstract

The differences between experts' and students' cognitive reasoning processes during a computer-based modeling task were researched in this study. A sample consisting of 11 students and 4 experts was used to determine the differences in reasoning processes between the two groups. Their task was to model the biological processes of photosynthesis and dissimilation within the computer software SCY-Dynamics. Data were collected from the log files of the program and the audio recordings of a think-aloud technique. The qualitative results were judged by comparing them to a pre-established standard and comparing the auditive statements of the two groups against each other. The quantitative results of the experiment were analyzed using the Mann-Whitney-U test to compare the models and reasoning processes of the participants against each other. No significant differences have been found by analyzing the quantitative results of the experiment, but the qualitative results show that there is an advantage of the experts over the students, especially on the reasoning process of Orientation. In conclusion it can be stated that experts approach a modeling task more efficiently, as they orient themselves more thoroughly. While unguided inquiry learning is an efficient method and computer-based modeling is an efficient tool, which should both receive further research, this study shows that experts are still a valuable addition to scientific learning, as they have gathered an extensive amount of knowledge in their specific domain that helps them to deal with complex models more efficiently. This advantage enables them to help students and shows the need for them in the learning environment. There is a need for future research on this topic with bigger sample groups to verify these findings and to look for additional similarities and differences between the two groups.

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1. Introduction

1.1 Background

As early as in the late 1980s, cognitive scientists and educators have proposed that learners might develop a deeper and more profound understanding of phenomena in the physical and social worlds if they were given the possibility to build and manipulate models of these phenomena (Bransford, et al., 1999). Modeling, in a scientific way, can most easily be described as the process of building an abstract, physical, conceptual, graphical or mathematical representation of a real-world phenomenon, a model. Griffiths (2010) describes models as abstract and simplified “chunks of the real world”. A toy car for example, being a physical model, can be a very good representation of a real car. The purpose of this kind of representation is to enable the user to explore, comprehend, learn and communicate complex ideas (Bollen, et al., 2002). A model can be used to represent some features of the actual phenomenon while others can be left out, that way, the toy car can be used to show someone the design of the real car but it does not have to have the same size or functions. Conceptual models form a very different class of models and are different from physical models, as they do not depend on physical manifestation and can exist as concepts in the human mind only (Webb, 1993; Penner, 2000). Models are considered to be one of the most important means through which scientists can represent, investigate and control physical systems and phenomena and accordingly develop a theory and spread it throughout the scientific community efficiently (Halloun, 2006). Although some cognitive scientists have argued that model construction is not restricted to science alone (Giere, 1992), this study is focused on scientific modeling and its effects on learning and the representation of knowledge.

The old teaching approaches, in which the teacher was plainly feeding the students with information (called instructional learning environments), are heavily criticized and the more modern teaching approaches promote a more passive role of the teacher and more independent involvement of the learner (called discovery learning environments). It is important that students are able to make sense of the world in a scientific way and it seen as the role of the scientific and scholastic community to set them on the right track (Penner, 2000). The current trends in education are slowly moving towards learner-centered approaches (Quintana et al., 1999), in which the learner takes on a more active position in his own education and discovers the material in a less guided manner. Experiments and demonstrations are effective means to replace the outdated, passive approaches (Penner, 2000). Modeling can be used to display the effects and functions of experiments and an extensive amount of research has proven that scientific modeling is an effective tool for the educational sciences (Halloun, 2006; Sins et al., 2005; Louca and Zacharia, 2012; Zimmerman, 2000). Modeling, integrated into the learning process, improves the student’s cognitive, metacognitive and social abilities

(Halloun 2006), which made it an important part of the concept of inquiry learning. Inquiry learning is the kind of learning that lets the student explore the given materials themselves first, which is often cognitively exhausting (Kuhn, et al., 2000). It can be defined as the acquisition of knowledge by a learner-regulated process of data collection and data interpretation (van Joolingen, et al., 2004). The progress during inquiry learning can be assessed by how well students develop experimental and analytical skills rather than how much knowledge they possess. It has been shown that this method is very effective in helping the learners discover not only concepts (Bruner, 1961), but also rules (De Jong and van Joolingen, 1998) on their own.

Most of the German schools have adapted the teaching strategies of Klippert, who heavily promotes the effectiveness and usefulness of the inquiry learning method (Klippert, 2008) and the method is becoming more and more integrated into all kinds of schools and learning environments. Louca and Zacharia (2012) point out the contributions made by Modeling-based learning during inquiry learning, like fostering students' conceptual understanding and learning in science, and appeal to the need of future research investigating the learning processes which take place during this kind of learning. The goal of this study aimed in a similar direction, as the reasoning processes that occur during a modeling activity were researched. This topic is of interest to psychologists, because the reasoning processes are mental processes that are difficult to study.

The concept of inquiry learning has proven to be very efficient but has also been criticized by several researchers. Kirschner and his colleagues (2006), for example, are stating that discovery learning should be excluded from the classroom when it comes to the learning of new topics, because some experiments have shown that guided instruction is more effective than unguided instruction.

1.2 Ideas behind this study

The name of this study, Modeling across domains, explains the made assumption that the cognitive reasoning processes, that occur during a modeling task, can be generalized over several domains, meaning that, for example, the reasoning that occurs during modeling a Biology-related issue is expected to be similar to the reasoning that occurs during modeling a Physics-, Chemistry- or Psychology-related issue. This study is focused only on a Biology-related issue, as it is built around modeling the photosynthesis and dissimilation processes of the plant, but it is part of a bigger research by van Joolingen, in which other domains are included and researched on, making a generalization possible. The experiment in this study can be categorized as a structured inquiry task. The procedure and the aim of the task are known to the participants, but they have to arrive at the solution themselves. In an open inquiry task, on the other hand, the participants would have been told no aim/question and no procedure. They would have been provided with material and it would have been their personal decision how they handle the task (Banchi and Bell, 2008).

The modeling program SCY-Dynamics has been used to support the study and make it a computer-based modeling task. According to Löhner and his colleagues (2005) effective inquiry learning requires students to construct and evaluate their own hypotheses, and derive their own conclusions, which is exactly what SCY-Dynamics enabled the students to do in this study. It also gives the user the possibility to combine the two ideas of “learning by modeling” and “learning with models”. Milrad, Spector and Davidsen (2003) have pointed out the advantages of combining the two ideas of learning by and with models, as to create meaningful learning activities which support complex learning. Learners need to generate hypotheses, design experiments, analyze data, predict results and rethink their hypotheses on their own in order to construct knowledge about the domain they are studying. SCY-Dynamics is a very intuitive modeling tool as it works with a graphical/diagram representation and has variables as basic units of the model. It also allows for a qualitative specification and gives the user the possibility to fill out a lot of detail, meaning that it fulfills all the functional needs for supporting a complex modeling task. Intuitive modeling tools are opposed by high-precision tools, which are mostly descriptive, text-based tools that do not allow for much freedom, because they need all the quantitative data to be able to work correctly (Löhner, et al., 2005). The SCY-Dynamics program runs on a modeling language that is based on the ideas of the System Dynamics concept by Forrester (1968) and components of the Co-Lab tool by van Joolingen and his colleagues (van Joolingen, et al., 2004; de Jong and van Joolingen, 1998). It has first been published in 2005 and aims to be a digital and active extension of the chalkboard.

As the participants of the study were modeling the two biological processes within the program, they were asked to verbalize their thoughts and actions into a microphone. This method is an example of the think-aloud technique which has first been used systematically by Otto Selz in the early 1930s for studying creative reasoning processes (van Someren, et al., 1994). The participants of the study were asked to say whatever they are looking at, thinking, doing, and feeling, as they go about their task, because the recording then enables the researcher to get a very detailed look at each step of the modeling process and the reasoning processes that occur in the participants’ mind. A modified version of the coding scheme of Löhner and his colleagues (2005) was used as a kind of think-aloud protocol as it was used in the usability field by Lewis (1982). The modified coding scheme enabled the researcher to score the utterances of the participants on the following reasoning processes: Orientation, Hypothesizing, Experimenting, Implementation, Evaluation, Other Activities and Off Task / Experimenter. The article of Löhner and his colleagues (2005) shows that many researchers (e.g. de Jong, et al., (2002), Schecker, (1998), Stratford, et al., (1997)) agree on similar reasoning processes of the inquiry learning cycle occurring during a modeling task and the cyclic form that they take on. Sins and his colleagues (2005) state that next to researching the plain number of occurrences of reasoning processes, it is also important to assess their quality.

1.3 Research question

As it is an important goal in science education to help students make sense of the world in a scientific way (Penner, 2000), this study tries to support this goal by researching the reasoning processes of students and experts. The results of this research might improve the understanding of these processes which in turn might help the development of a method that can improve these processes and lead to better learning and understanding. Students are not as familiar as experts on a specific domain and do not understand models of that particular domain as fast as the experts. This might lead to wrong conclusions and an inefficient modeling process. To do research on this problem the following research questions have been posed:

1. *What are the differences and similarities between experts' and students' reasoning processes during a computer-based modeling task?*

2. *How can the participants prosper from their prior knowledge?*

2. Method

2.1 Participants

Next to the two people who were used for the pilot test, there were 15 participants who were being asked to be part of this study. Of the 15 participants, eleven were students and four were experts. The students came from a variety of different study courses and some were attending their first year of university, while others were finished with their study course or following a masters' degree. Some students' study courses required the understanding and ability to build models more than others, but not one of the students studied Biology or was familiar with the task. The "experts" were all qualified as experts because they had all graduated from a biology study course and are currently employed as biology teachers at different high schools. All of the experts were familiar with the task of modeling biological phenomena. Seven of the participants were women and eight were men. Three of the students and all of the experts were German, while the other eight students were of Dutch nationality. A table with all the collected demographical data of the participants can be found in the appendix.

2.2 Materials

It was the participants' main task to build a computer-based graphical model of a combination a the biological phenomena of photosynthesis and dissimilation within an intuitive modeling tool, in this case being the computer program SCY-Dynamics (the program can be tried out via the web page *http://modeldrawing.eu/?page_id=193*). SCY stands for Science Created by You and SCY-Dynamics was created by Prof. Dr. W.R. van Joolingen and his colleagues at the University of Twente. It was part of an EU project, which started in 2008 and ended in 2012. Together with other programs SCY-Dynamics aims to improve the educational sciences as educational software that enables learners to be more independent during inquiry learning.

The computer of the experimenter was used to conduct all the experiments. The modeling program ran on the computer as well as an audio recording program, called Audacity. Audacity is a very simple program that enables the user to record, cut, arrange, convert and replay audio input on several audio tracks. A microphone was connected to the computer. The participants were provided with one manual that explained the functions of the modeling program with the help of an example and one manual that contained the instructions for the actual modeling task and the information source. The information source was a text of two and a half pages written by the experimenter that explained the two biological processes in detail. The experiment in this study was completely bilingual, as for the Dutch participants the whole experiment (instructions from the experimenter and all of the manuals) was held in Dutch, while the German participants received the same treatment in their native language.

SCY-Dynamics is programmed to function for two types of modeling, being quantitative and qualitative modeling. In the quantitative modeling mode the participants have to fill in all the details, meaning that they have to specify the relations the different variables have with each other by giving them values and filling in formulas. The qualitative modeling mode functions very differently, as the participants do not have to fill it much detail and just have to define the tendencies between the variables, meaning that they have to decide, for example, what happens to one variable when another one increases in value.

The two processes the participants had to combine into one model were filled with very complex relations and SCY-Dynamics is still under construction. These two problems combined brought up an even bigger problem, which was discovered during the pilot test. Only if the participants constructed their model with 100% accuracy (made no mistakes in the computer program), they would be able to "experiment" with their model and see if they have had the correct mental model in mind. Unfortunately, it was impossible to create a perfect model, as the program needed some relations that are illogical on the content level and illogical for the participant, but still needed by the program to function. To circumvent this problem, the main task was split in half. The participants built their model in the first half of the main task and experimented on it during the second. The solution of this problem will be described more thoroughly in the following section (*2.3 Procedure*). After following the instruction manual and reading the information source (see appendix) the participants were confronted with the “basis” of the model (see *Figure A*). This “basis” is the set-up of the experiment on the digital whiteboard, because it contains all the variables of the model, meaning that the participants do not have to add new components. The circles, rhombs and rectangle all symbolize different components of the biological processes photosynthesis and dissimilation.

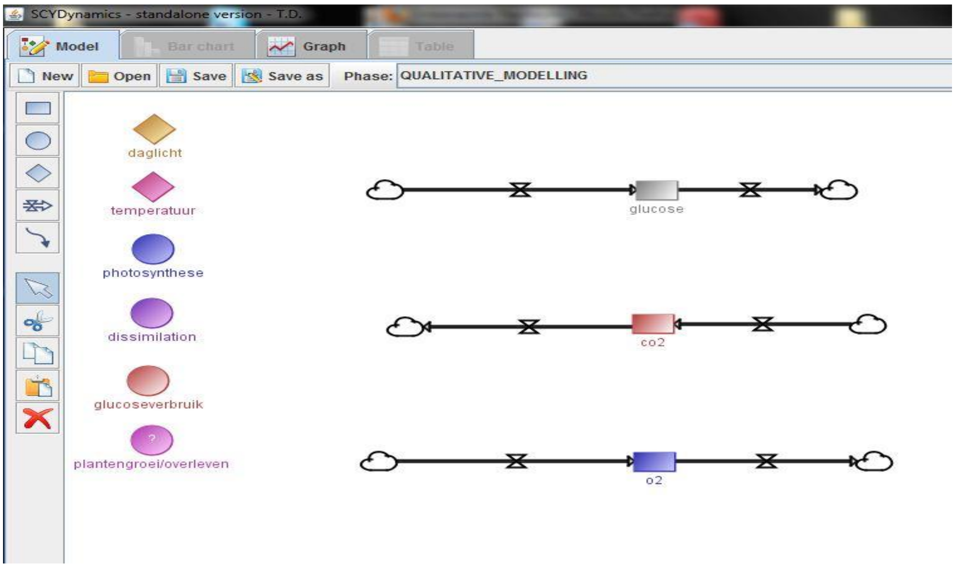

Figure A - The basis of the model

2.3 Procedure

Two thirds of the experiments were carried out in the house of the experimenter, while the rest of them were conducted in the homes of the participants. It was always possible to establish a comfortable environment for the participant, with the least possible number of disturbances. A test taker manual (see appendix) was used to ensure that all the participants receive the same instructions during the experiment. After being informed on the aim and procedure of the study, the participants had to accommodate themselves with the modeling program with help of a manual and an example. This instruction manual had to be followed step by step, as the participants had to get to know all the functions of the new program. When they were able to handle the functionality of the program they got to read the information text concerning the two biological processes. The experimenter waited for the participants cue, meaning that they understood the program, the instructions and the content of the task and then they were introduced to the real model. The participants faced the “basis” of the model (*Figure A*) in which all the needed variable are given in an unordered fashion. It was the participants’ task to order them into a logical model on the basis of the information text and to connect the components with each other by using the “relation arrow” function. Next to that, they were also given an example of the think-aloud technique by the experimenter before beginning with the task. When the participants thought that they had built the model to their best knowledge and verbalized all of their thoughts, their work was saved and they were confronted with the “correct” model (*Figure B*). This “correct” model is a finished version of the model, which was built by the experimenter and his supervisors and it depicts a model that fulfills all the criteria of the information text.

As discussed in the section on the *Materials* (*2.2*) this version of the model could not be build by the participants, as it needs some connections that are illogical but still needed by the program to function. Ultimately the participants used this version of the model to work on the last part of the modeling task. In this last part they used the functioning model to experiment on the two biological processes in a qualitative manner. They could, for example, set the “temperature” variable to “high” and see what effect that would have on the other variables. The results of their “experiments” were displayed in graphs (*Figure C*). The experiment ended as soon as the participants felt that they had built a logical model and “experimented” enough.

The whole task can be seen as a mix between explorative and expressive computer modeling, as the model is analyzed and modified, but the participants also have to build a model out of a textual representation at the same time (Bliss, 1994).

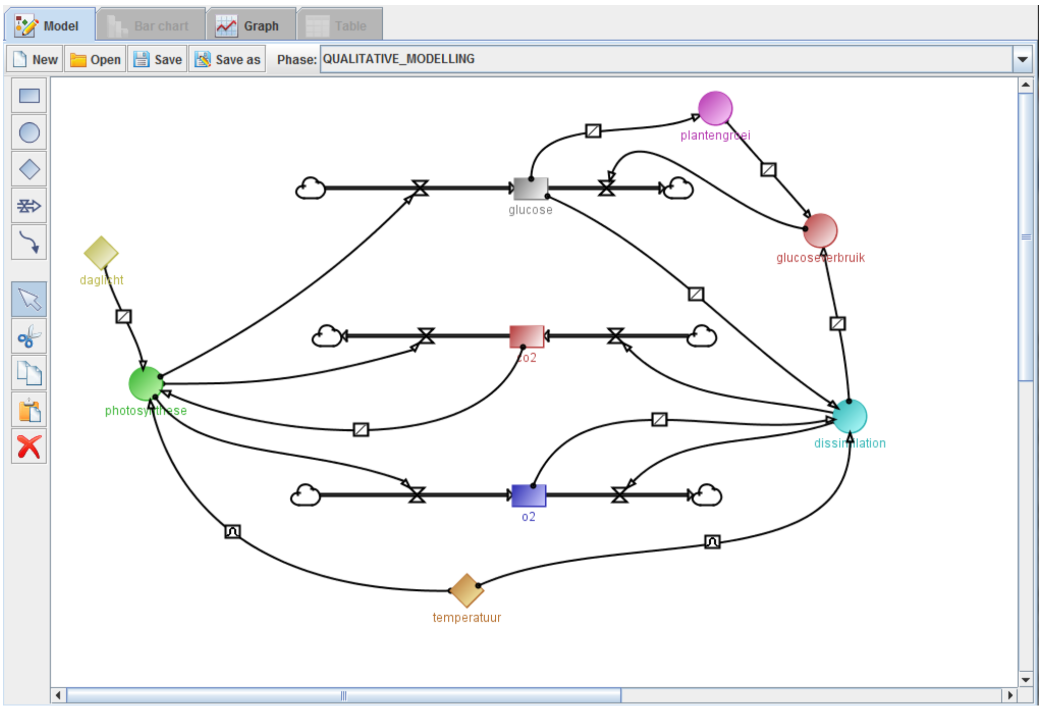

Figure B - The „correct” model

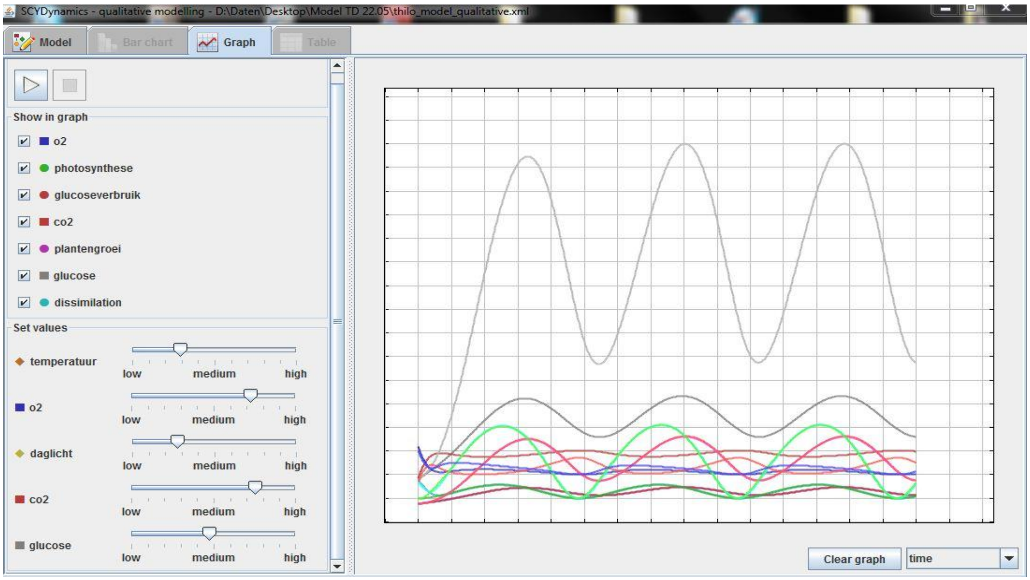

Figure C – The graphical representation mode of SCY-Dynamics

2.4 Analysis

The audio recordings of the think-aloud technique were used for the qualitative and the quantitative analysis. For the quantitative analysis of the results the recordings were split into time segments and the participants' statements were coded into different categories. The categories used correspond to the reasoning processes of the coding scheme created by Löhner and his colleagues (2005) (see appendix). The coding scheme has been modified in a way that ultimately the following reasoning processes of the inquiry cycle were studied within the statements of the participants:

Orientation: This reasoning process was scored when the participants were talking about facts from their prior knowledge, talking about getting information from the information source or talking about orienting themselves in the modeling window (for example: Expert "*Now, I have to think for a bit first…*" (PP07 S.K. at 07.19 min.); Expert "*I am going to reread the text to see if I have considered all the mentioned information… let us take it step by step*" (PP08 H.L. at 23.07 min.); Expert "*…concerning the plant growth it comes down to two points: There is energy being produced through the dissimilation…there is glucose being produced, and at the same time I have got glucose as a material for cell growth…*" (PP08 H.L. at 29.44 min.); Student "*…what adds to the glucose stock?….I have to check…*" (PP09 V.P. at 19.54 min.); Student "*I just have to consult the literature…*" (PP10 J.S. at 21.19 min.)).

Hypothesizing: This reasoning process was scored when the participants were making hypotheses about the relations between two variables, talking about what they expect to see if they change the effect of a variable or talking about the general effects of a variable on all the other variables (for example: Expert "*If I increase the glucose level, then the growth should increase as well*…" (PP05 U.L. at 34.50 min.); Expert "*If I increase the level of oxygen, then the effect of the daylight should increase, the CO2-use has to increase, the glucose use should increase as well and the temperature should also rise*…" (PP07 S.K. at 28.44 min.); Student "*Oh that means that I also know that photosynthesis is responsible for the decrease in CO2…*" (PP11 C.D. at 14.25 min.); Student "...*and photosynthesis is responsible for an increased use of glucose and a decreased CO2*..." (PP11 C.D. at 20.40 min.)).

Experimenting: This reasoning process was scored when the participants were talking about when they are letting the experiment „run" in the second part of the experiment. This reasoning process has to be differentiated from the process of Hypothesizing because Experimenting ultimately shows the results (for example: Expert "*And now once again with less CO2*…" (PP05 U.L. at 25.25 min.)
Expert "*Show me!*..." (PP07 S.K. at 29.05 min.); Student "*Then now I want to know what happens when there is plenty of glucose!?*" (PP09 V.P. at 44.46 min.); Student "*So.. let's take a look at this*..." (PP13 E.N. at 34.07 min.)).

Implementation: This reasoning process was scored when the participants were talking about all the actions they undertake within the modeling program, like repositioning variables and drawing relations between the variables (for example: Expert "…*That's why I put the "Growth" symbol to the right side of the screen*…" (PP07 S.K. at 02.40 min.); Expert "*I will now drag the glucose use into the output arrow*…" (PP08 H.L. at 16.05 min.); Student "*So, I'm straightening out the line now, I think that looks nicer*..." (PP11 C.D. at 19.59 min.); Student "*CLEAR GRAPH*" (PP11 C.D. at 32.35 min.)).

Evaluation: This reasoning process was scored when the participants were talking about the results they get from SCY-Dynamics after „running" the experiment, comparing these results to their expectations or talking about themselves obtaining knowledge from the results (for example: Expert "*The difference is not very significant…that surprises me, normally CO2 should have a bigger impact on photosynthesis…*" (PP05 U.L. at 25.35 min.); Expert "*The oxygen level has dropped…that has been confirmed*…" (PP08 H.L. at 45.40 min.); Student "*Okay, so my hypothesis has been falsified*..." (PP11 C.D. at 36.02 min.); Student "*The use of glucose just stays the same...it can really be said that all the values stay the same*..." (PP13 E.N. at 36.16 min.)).

Other Activities: This reasoning process was scored when the participants were talking about the use and function of the modeling tool, asking question to get more information on their assignment or criticizing the set-up of the experiment or the interface of the modeling program (for example: Expert "*Unfortunately, we don't have the scale system*…" (PP06 A.V. at 30.42 min.); Expert "*The* *program doesn't like this… it [the relation to the outflow]is not getting black…oh yeah, that's because it always works with only one relation*" (PP05 U.L. at 08.58 min.); Expert „*Oh yeah, I have to the the cursor function*…" (PP08 H.L. at 15.55 min.); Student "*Can you also relate something to the rectangle [stock variable] itself?*" (PP11 C.D. at 11.00 min.); Student "…*I don't want it going through the "cloud"...how can I do that?*" (PP11 C.D. at 21.10 min.)).

Off Task / Experimenter: This reasoning process was scored every time when the experimenter intervened during the audio recording, when the participants were talking about topics that have no single relation to the experiment or when the experiment was interrupted by external factors (for example: Expert "*[Experimenter] I still have to apply one little change*…" (PP07 S.K. at 16.36 min.); Student "…*I have got pain*…" (PP09 V.P. at 36.33 min.); Student *"[Experimenter] You have got all the time...you can also sit there in silence for a few minutes..*." (PP12 N.E.M.H. at 00.30 min.); Student "*Your chair is coming down*..." (PP12 N.E.M.H. at 25.42 min.)).

Whenever one of these reasoning processes occurred in the time segments the experimenter scored it within a statistical program (in this case *IBM SPSS Statistics 20*). These scores where then analyzed using the Mann-Whitney-U-test. This test is a non-parametric statistical hypothesis test, which is used to research whether one of two samples of independent observations tends to have larger values than the other (Kruskal, 1957). Furthermore, an analysis of the data has been done to get the "descriptive statistics", mainly to compile the means for each of the reasoning processes for the two groups (students vs. experts).
As it possible to generate a log-file from all the interactions the user undertakes with the modeling program, an analysis of the means of the variables of the log-file has been compiled. The variables in the log-file were number of undertaken actions, duration of the modeling activity, number the model has been run, number of errors while running the model, number of links (the relation arrows) added and number of links deleted.
On the qualitative side of the analysis the statements of the students have been compared to the ones of the experts. To show the similarities and differences on the quality of the statements between the students and the experts, the most meaningful statements have been selected and put into the results section of this article. Next to the analysis of the audio recordings, the models made by the participants have been compared to the "correct" model by the experimenter (*Fig. B*) and were compared in regard to the two groups for the qualitative analysis.

3. Results

3.1 Quantitative results

The analysis of the gathered results showed that even though the graphical representations of the quantitative data (see the most meaningful ones of them below (*Figure D – G*) and the others in the appendix) seem to give some convincing results, there has no significant difference (all $p>0.05$) been found on the reasoning processes between the students and the experts (see the appendix for the complete results of the Mann-Whitney-U-test).

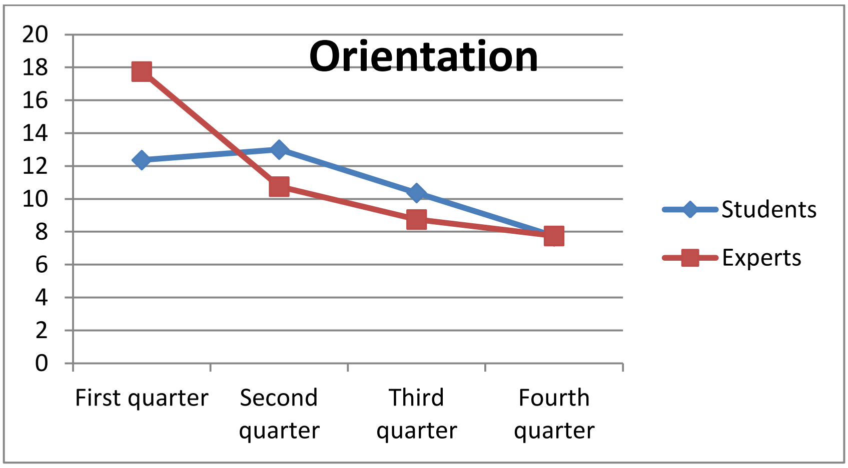

Figure D – The graph of the Orientation reasoning process and the two groups

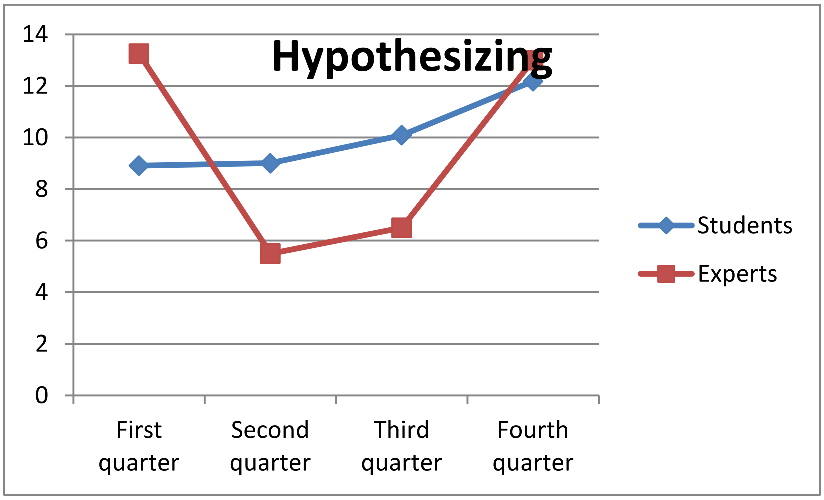

Figure E – The graph of the Hypothesizing reasoning process and the two groups

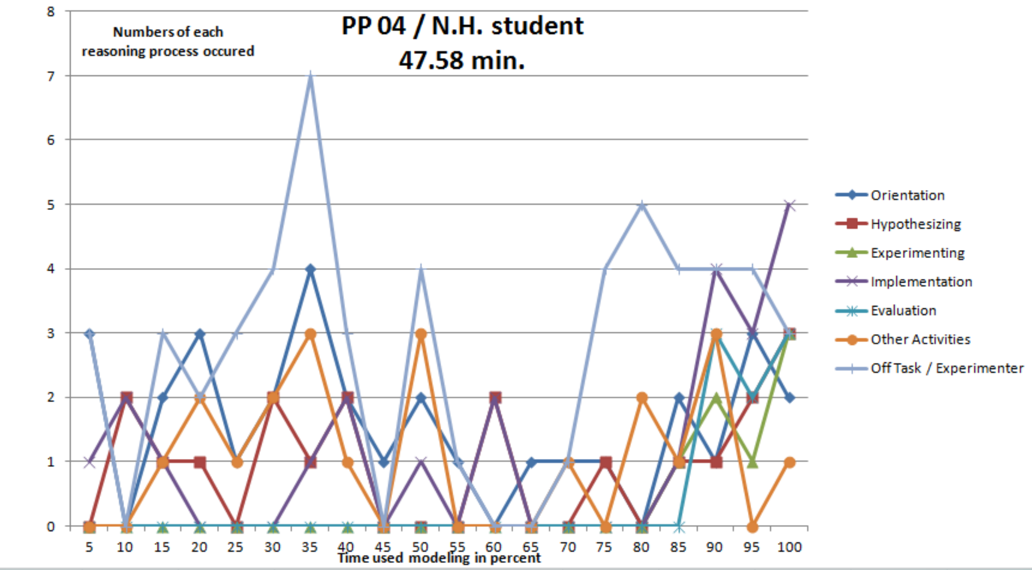

Figure F – The numbers of the reasoning processes of the worst participant

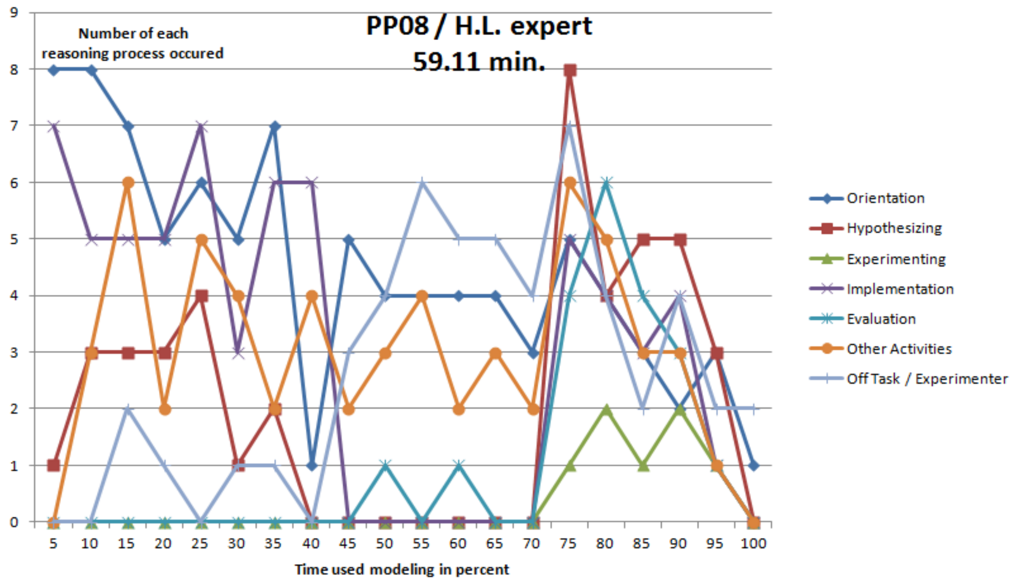

Figure G – The numbers of the reasoning processes of the best participant

Although the results are statistically insignificant, there are still important differences between the experts and the students, as shown by the graphical representations of the quantitative data. Looking at the figures *D* and *E* it is obvious that experts orient themselves much more frequently during the first quarter of the time used modeling. The same is true for the number of made hypotheses. The other reasoning processes occur more or less in a similar number during the task by both groups. Figures *F* and *G* display the reasoning processes of the worst, a student, and the best, an expert, participant. While the worst participant is mainly focused on asking the experimenter questions about the content of the information text, the best participant is showing a high rate of Orientation and Hypothesizing throughout the whole task.

The following table (*Table 1.*) shows how little the differences in the means are, if the reasoning processes are each viewed as a whole and not split up into time segments.

Table 1. – Descriptive Statistics on the two groups and the seven reasoning processes

Reasoning Processes	Students = 11 Experts = 4	Means
Orientation	Student	10,86
	Expert	11,25
Hypothesizing	Student	10,04
	Expert	9,56
Experimenting	Student	1,65
	Expert	2,43
Implementation	Student	10,18
	Expert	11,37
Evaluation	Student	4,18
	Expert	4,18
Other Activities	Student	4,65
	Expert	8,75
Off Task / Experimenter	Student	11,13
	Expert	8,75

The analysis of the log-files shows no significant results (see appendix) as well. The fastest participants needed only 19 minutes and 20 seconds for completing the whole task, while the slowest needed 67 minutes and 18 seconds. The log-file also shows that the experts "experimented" (to run the model) on their model much less often than the students.

3.2 Qualitative results

Although the modeling task was built around a very complex biological process, 85% of the participants built their model (making all the right relations by connecting the components) with a 90% similarity to the "correct" model. The eleven "relation arrows" that were needed to be drawn to make the right connections between the components and to make the model logically coherent, were nearly always in place. This means that both groups were for their biggest part able to fulfill the task, but there were still obvious differences in the quality of the models and the statements from the think-aloud technique.

To show the differences in the quality of the models, the worst and the best model are given below (*Figure H* and *Figure I*).

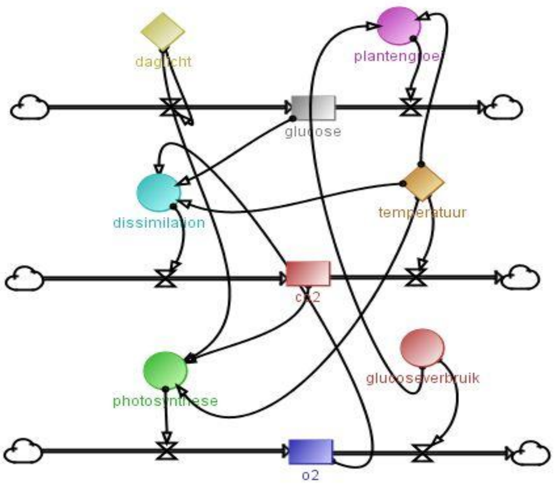

Figure H – The worst model (student)

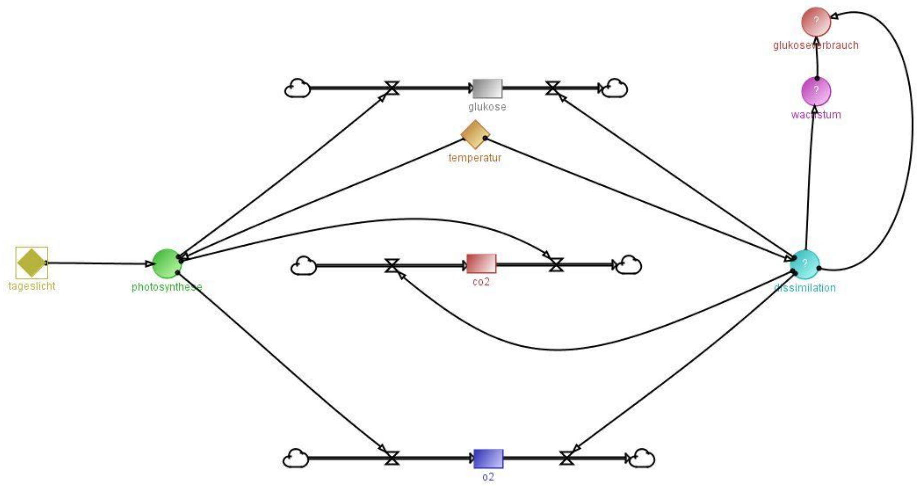

Figure I – The best model (expert)

While the worst model is built in a very chaotic fashion, with all the "relation arrows" crossing each other and no clear order, the best model is easily understandable, as all its components have been ordered in a manner logically connected to the content of the processes and all the "relation arrows" straightened out. All of the experts built their models in this elaborate fashion.

The qualitative analysis of the audio recordings of the think-aloud techniques brought up the most interesting results of this study. The most obvious and remarkable differences between the experts and the students on the quality and meaningfulness of their statements lie within the reasoning processes Orientation and Hypothesizing. The quality of the other reasoning processes is more or less similar between the two groups. To show the important differences between the groups a few statements, which show the general tendencies, have been selected and discussed:

Orientation

Expert "*The process of photosynthesis is very important to the survival of the plant. It produces the glucose, but to produce it, two factors are needed. […] First off, I need temperature* …" (PP07 S.K. at 01.20 min.)During this Orientation reasoning process the expert gives a partial explanation of the process of photosynthesis. Utterances of this kind of quality where only made by experts. Experts have got an extensive knowledge of all the biological content in the experiment, which helps them to orient themselves more efficiently.

Expert "*So, now I'll take a look at all the symbols first and figure out how they can be combined*." (PP06 A.V. at 00.30 min.) The considerate kind of approaching the task by the experts is perfectly reflected through this example. The order and meaning of all the elements of the modeling task, as well as the functions of the program, are analyzed thoroughly, before making the first adjustments. In contrast, the students show less quality in this reasoning process, because they are not very familiar with the domain.

Student "*It seems I have made a mistake there. I always confuse CO2 with H2O, but that is very wrong.*" (PP04 N.H. at 07.45 min.) and Student "*Okay, I'm going to start now, even if that is wrong, I can certainly change it later*…" (PP14 S.W. at 01.25 min.)These statements clearly show the main difference that has been found between the students and the experts. While the students jump right into the modeling process and try out the functions of the program by trial-and-error or orient themselves halfheartedly, the experts approach the task much more careful and considerate, as they scan the functions and all the given variables thoroughly and look for a logical starting point, based on their prior existing knowledge of the biological process.

Student "*I always have to reread the information manual*." (PP04 N.H. at 10.00 min.)The students often have to consult the information text to see if they are still on the right track, while the experts just have to search through their prior knowledge in their mind. Expert "*Now, I have to think for a bit first…*" (PP07 S.K. at 07.19 min.)

Hypothesizing

Expert "*The photosynthesis is responsible for the production of glucose, but also, concerning the CO2 parameter, for the influence on carbon dioxide concentration… in a way that carbon dioxide is being used up, meaning that ultimately the level of carbon dioxide decreases*." (PP06 A.V. at 10.32 min.) This statement makes the superior choice of words of the experts obvious. The experts make a much higher use of domain specific terms, because they are much more familiar with the terminology. Next to that, the experts also understand and explain the logical connections, which exist between all the components of the model, much more thoroughly, which is proven by the nested syntax of their utterances. This gives their Hypothesizing reasoning process a much higher quality than the students'.

Student "*Then I'm going to increase the glucose level… and I think that the plant growth will increase through that*." (PP04 N.H. at 38.57 min.) and Student "*Oh that means that I also know that photosynthesis is responsible for the decrease in CO2…*" (PP11 C.D. at 14.25 min.) These statements show how the students often make hypotheses that are more vague and they do it without having arguments for their expectations. The students plainly "try out" things and base their hypotheses on these findings.

Some students performed much better than others, as their reasoning processes are of much higher quality. An example for this on the Hypothesizing reasoning process can be found by comparing the aforementioned statements with the following one. Student "*…When the flower has glucose that is its energy, than it can grow and it uses much glucose, which means that glucose decreases…*" (PP14 S.W. at 09.41 min.)

Except for one expert, all the participants spent some time saying nothing during their recordings. The one superior expert, participant 08, had such an extensive knowledge of the domain and an incomparable understanding of the model that he did not spend one minute without saying anything. Next to that all of his statement were of the quality and formulated in a very considerate manner. Expert "*I am going to reread the text to see if I have considered all the mentioned information… let us take it step by step*" (PP08 H.L. at 23.07 min.)

Experimenting, Implementation and Evaluation

The two groups made statements of similar quality on the other three important reasoning processes. Experts made statements like, Expert "*And now once again with less CO2*…" (PP05 U.L. at 25.25 min.), and students made statements like, Student "*Then now I want to know what happens* *when there is plenty of glucose!?*" (PP09 V.P. at 44.46 min.). It is difficult to find a difference in quality with statements like these. The same goes for the Implementation and Evaluation reasoning process. More examples can be found in the section on the *Analysis* (*2.4*).

The reasoning processes Other Activities and Off Task / Experimenter have been excluded from the qualitative analysis, as they are not concerned with the content of the modeling task.

4. Discussion

The results of the quantitative analysis are all statistically insignificant, because the sample group of the experts was much too small in this study. No further statistical analyses have been conducted due to this small sample-size. As the log file shows, the experts did not feel the need to "experiment" excessively with their model, as they already know the consequences of changing the value of a variable from their prior knowledge.

The effects of prior knowledge are also reflected by the main results of the qualitative analysis. This study has found that the prior knowledge of the experts, which they have probably collected during their domain specific study course and their job, is the factor that separates them the most from the students. It enables them to structure their thoughts in much more scientific and analytical manner, especially during the Orientation and Hypothesizing reasoning processes. It remains the question, how the students can benefit from the positive effects of unguided inquiry learning and perform as well as the experts without the extensive prior knowledge. Research is needed to study, if it would help the students to be guided during the first quarter of their modeling task and then be left alone to discover the rest of the (scientific) phenomena on their own.

The finding from Sins and his colleagues (2005) can be supported by the qualitative results of this study, as it can be stated that modeling of dynamic phenomena is a complex undertaking for novice modelers and that probably more experience is needed in order to obtain a learning benefit. Appropriate support should be provided, either in the modeling tool or in the classroom context to scaffold students' reasoning processes. One way to do so would be to help the students activate their prior knowledge not only during modeling, but also before engaging in any modeling activities with a textual or graphical reminder of the lessons they had on the particular topic. Another way would be to enrich the program with a "help-button" that could provide the students with suggestions on how they can orient themselves. As Sins and his colleagues (2005) point out, it might also be helpful to give the students the possibility to model phenomena of which they already have knowledge, as it would allow them to dedicate cognitive processing resources to translating their mental model into their own kind of model instead of having to invest too much effort in identifying relevant variables and relationships between them, thus making the modeling process more free.

While students enjoy the freedom of modeling on their own, which was repeatedly stated by the students of this study during the feedback-talk at the end of the experiment, students should also be guided during the first quarter (the beginning of the task) to receive the most efficiency. This study has shown that further research is needed with guided und unguided learner groups.

As the “experimenting” part of the modeling task was separated from the actual building of the model in this study it is recommended to bring together and overlay both tasks in future studies.

Future studies should look for a confirmation of the finding that experts have got a quicker understanding of the basic concepts of the model and should also research how this understanding can be passed on to the students. It should also be considered that drawing can be a very effective tool in modeling (Ainsworth, et al., 2011). Further studies should compare the effectiveness of drawing to the effectiveness of a model with pre-established components.

A very successful part of this study was the qualitative modeling mode, provided within the modeling program, as it enabled the users to “experiment” with the variables and relationships without having to be concerned about the mathematical form of the relationships.

Looking back at the first research question (*What are the differences and similarities between experts’ and students’ reasoning processes during a computer-based modeling task?*), it can be stated that differences between experts’ and students’ reasoning processes exist especially within the reasoning processes of Orientation and Hypothesizing, with the experts performing with better quality, while the other reasoning processes seem to be of similar quality between the two groups.

In further studies the quality of the reasoning processes could be analyzed more precisely by having a fixed set of “correct” statements, which could be compiled by a group of experts prior to the experiment. That would enable the experimenter to make better informed comparisons between “good” and “bad” statements of reasoning processes.

The second research question (*How can the participants prosper from their prior knowledge?*), can be answered by stating that prior knowledge seems to be an important factor for the reasoning processes of Orientation and Hypothesizing. Experts possess much more prior knowledge in their domain and they efficiently use it to orient themselves in a more structured manner and to make clearer and more specific hypotheses.

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Appendix

1. Demographic data of the participants
2. Experimental material: Manuals
3. Coding scheme by Löhner et al., 2005
4. The SPSS results of the quantitative analysis
5. The graphs

Demographic data of the participants					
Number/Initials	**Student/Expert**	**Age**	**Gender**	**Studycourse**	**Nationality**
01/J.K	Student	21	Male	Technical Chemnistry	Dutch
02/J.J.	Student	24	Male	Technical Medicin	Dutch
03/S.H.	Student	22	Male	CiT	Dutch
04/N.H.	Student	24	Male	Media Music	German
09/V.P.	Student	22	Female	Psychology	German
10/J.S.	Student	21	Male	Advanced Technology	Dutch
11/C.D.	Student	21	Female	Medical Sciences	Dutch
12/N.E.M.H.	Student	21	Female	Management	Dutch
13/E.N.	Student	21	Female	Technical Medicin	Dutch
14/S.W.	Student	21	Female	Psychology	German
15/I.B.	Student	19	Female	CiT	Dutch
05/H.U.L.	Expert	59	Male	Finished Biology Study	German
06/A.V.	Expert	42	Male	Finished Biology Study	German
07/S.K.	Expert	53	Female	Finished Biology Study	German
08/H.D.L.	Expert	61	Male	Finished Biology Study	German

Manual of SCY-Dynamics in Dutch

HANDLEIDING MODEL EDITOR

Het gebruik van SCYDynamics

Om het experiment te kunnen doorlopen, moet je je eerst met het modeleer programma SCYDynamics bekend maken. Deze handleiding laat je zien hoe het programma werkt, zodat je daarna met het experiment aan de slag kan gaan.

1. EEN MODEL MAKEN EN GEBRUIKEN

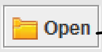
Door deze handleiding leer je werken met de Model Editor programma SCYDynamics. Het programma wordt stap-voor-stap uitgelegd aan de hand van het volgende voorbeeld.

VOORBEELD

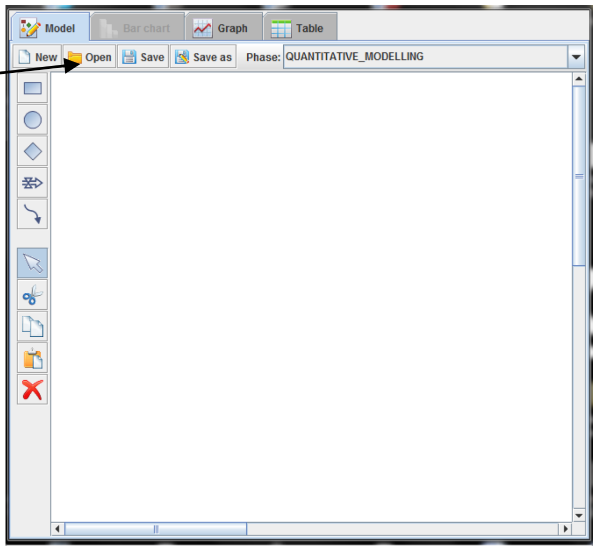
Je wilt een DVD recorder kopen. Die kost €275,= Je opent een bankrekening en stort hierop elke maand je zakgeld (€40,=). Wanneer heb je genoeg gespaard om de DVD recorder te kopen?

Dit voorbeeld lijkt erg eenvoudig: na 7 maanden heb je €280,= gespaard. Maar dan houd je geen rekening met de uitgaven en daardoor wordt het dan al snel complexer. Het maken van een model kan je helpen te voorspellen wanneer je de DVD recorder kunt kopen.

Een model openen

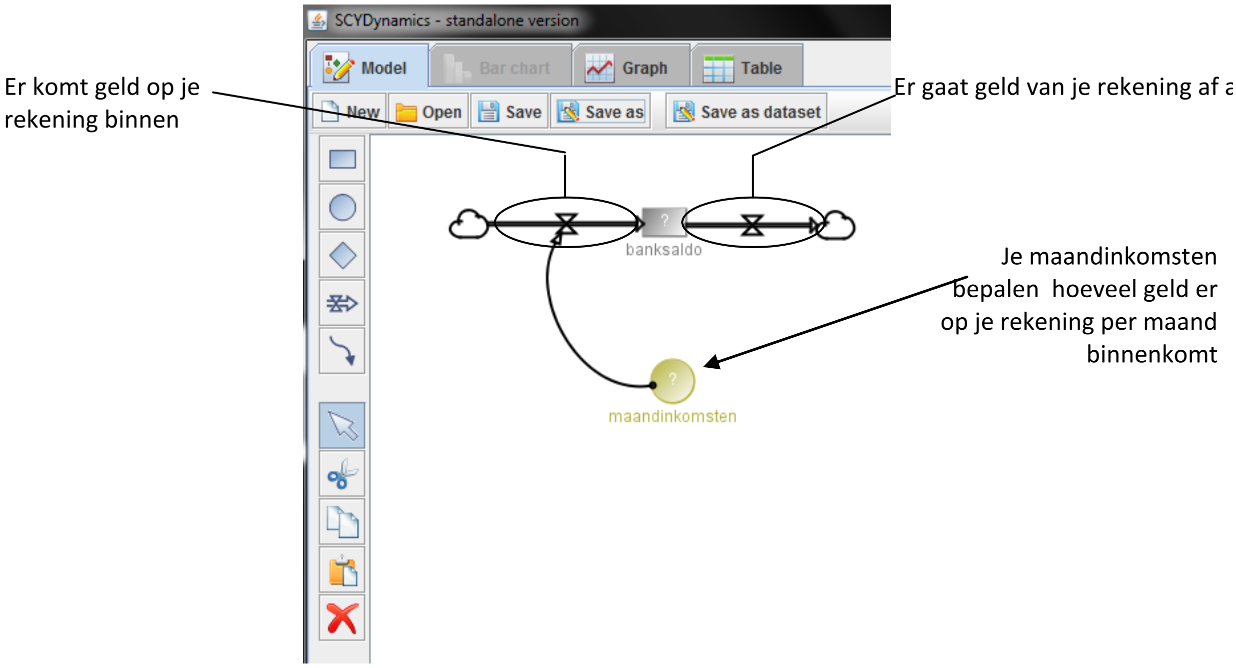
1. Om het voorbeeld model te openen klik op 

en selecteer het bestand "DVDRecorder0"



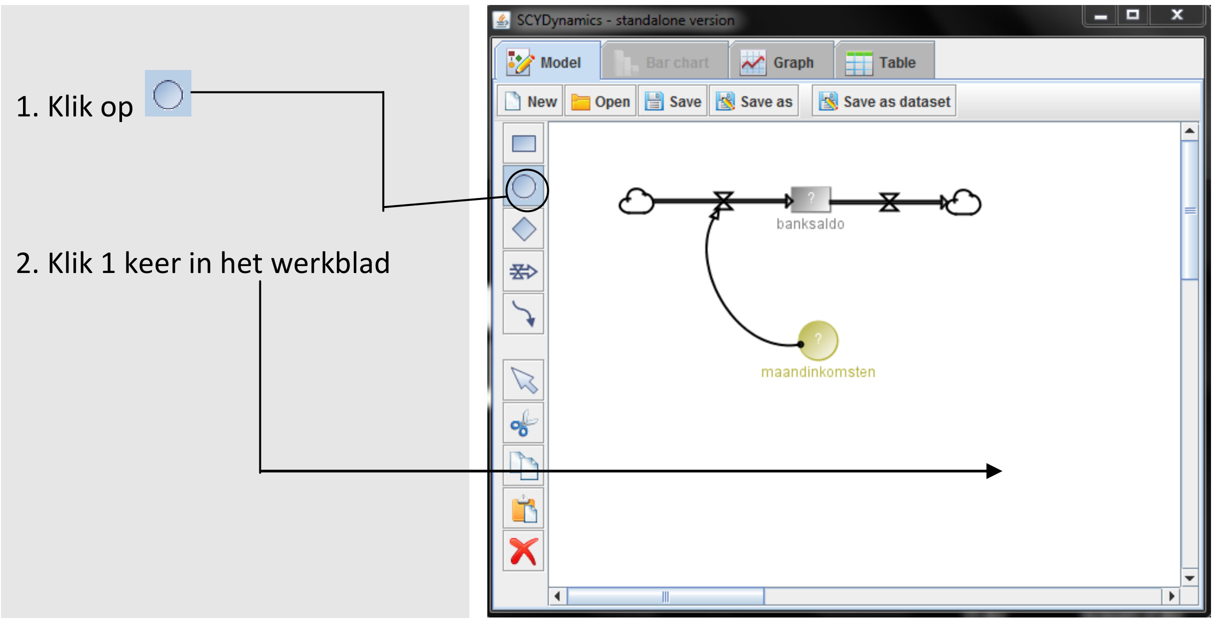
Een model begrijpen

Je ziet een eenvoudig model van je bankrekening. De betekenis van de onderdelen staat hieronder.



Een nieuwe variabele maken

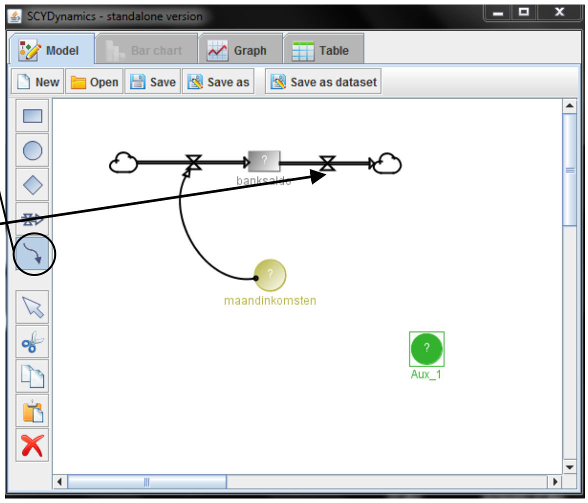
In het voorbeeld wordt niets gezegd over uitgaven. Maar die hebben wel invloed op je banksaldo. Je moet de uitgaven dus ook in het model opnemen. Hiervoor moet je eerst een nieuwe variabele maken.



Een relatie toevoegen

Je kunt nu aangeven dat de nieuwe variabele invloed heeft op het geld dat van je bankrekening afgaat. Dit doe je door een relatie toe te voegen.

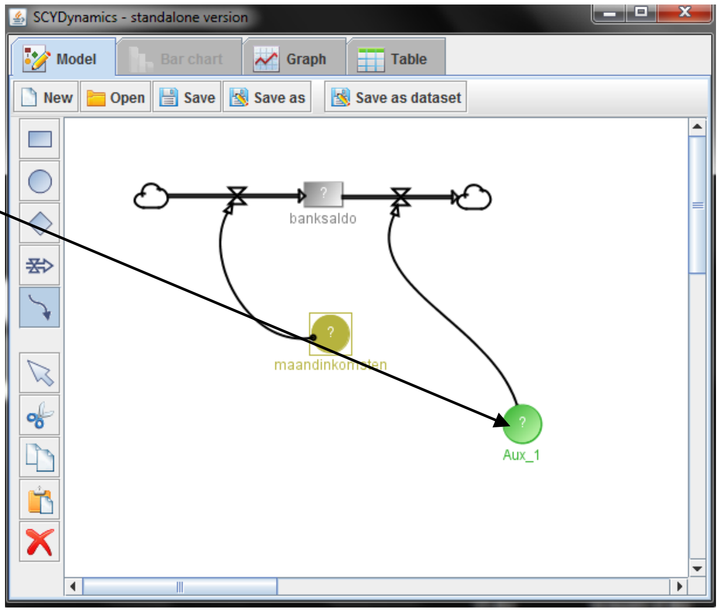
1. Klik op
2. Klik op Aux_1
3. Sleep de muis naar
4. Laat de muisknop los als het teken zwart wordt ()



Een variabele definiëren

Je kunt nu de naam en de waarde van de nieuwe variabele instellen.

1. Dubbelklik op Aux_1



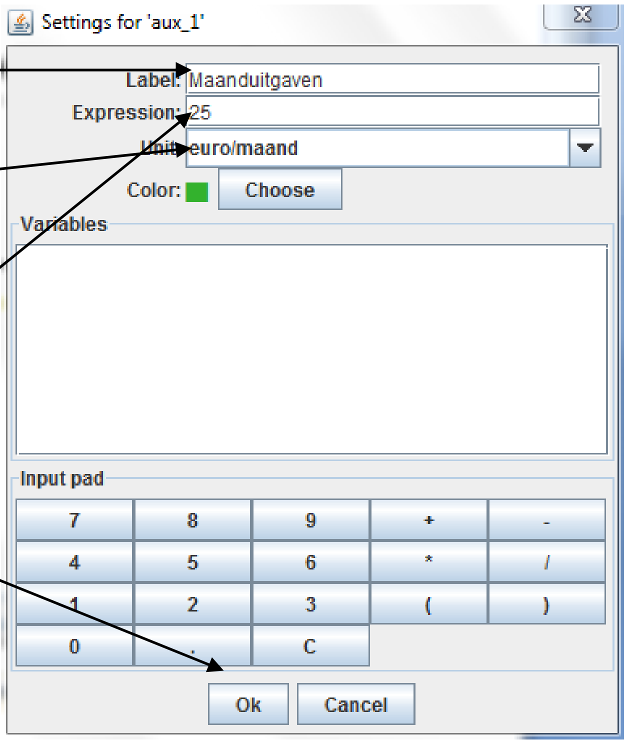
Er verschijnt een apart window. Hier kun je de instellingen van de variabele definiëren.

2. Verander de naam van de variabele in "Maanduitgaven"

3. Vul de eenheid in (je kunt uit de lijst kiezen of zelf iets invullen)

4. Verander de waarde van de variabele in 25

5. Klik op Ok



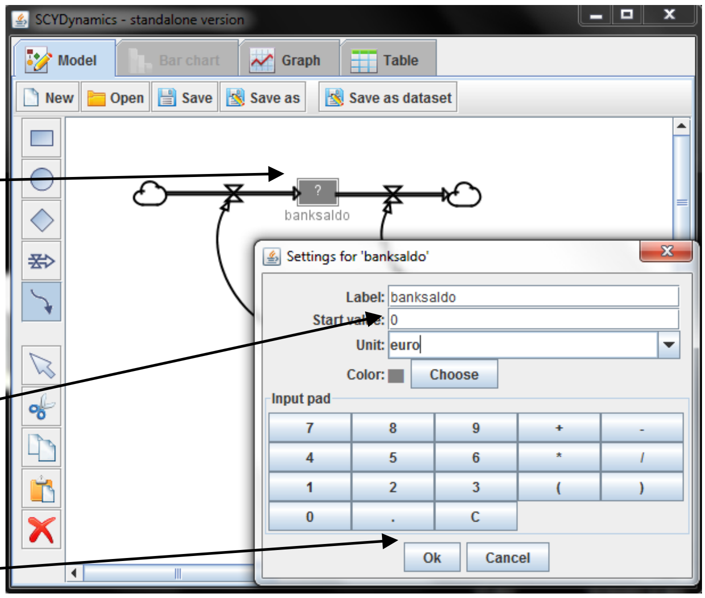
Je hebt nu de variabele Maanduitgaven aan het model toegevoegd. Je hebt de hoogte van de maanduitgaven op €25,= gezet en aangegeven dat dit bedrag maandelijks van je bankrekening afgaat.

De definitie van een variabele veranderen

1. Klik in het model op banksaldo

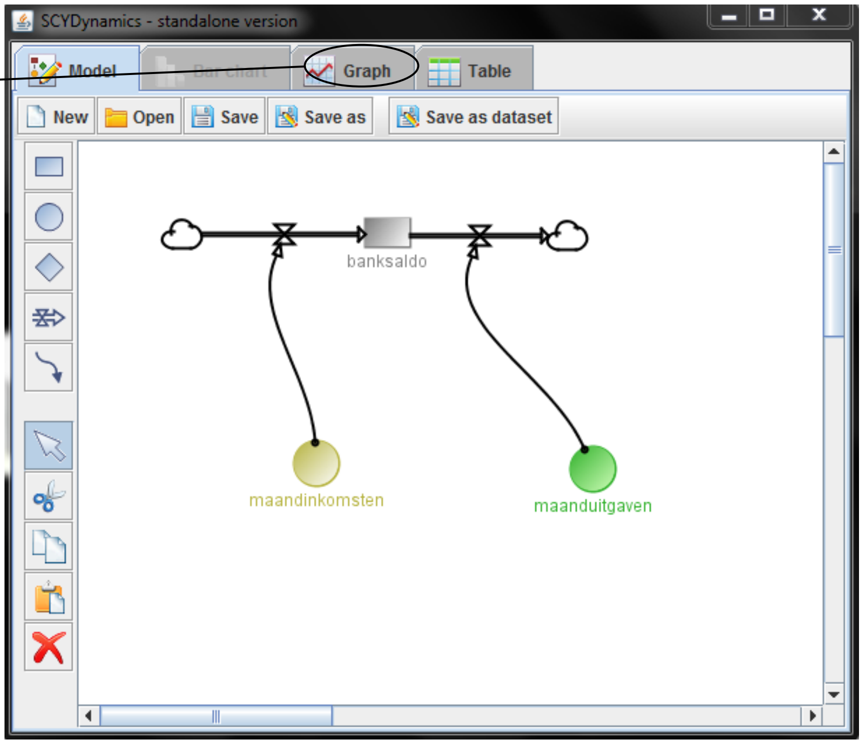
2. Verander de waarde van de variabele in 0

3. Klik op Ok



Een model runnen en de resultaten bekijken

1. Klik op Graph

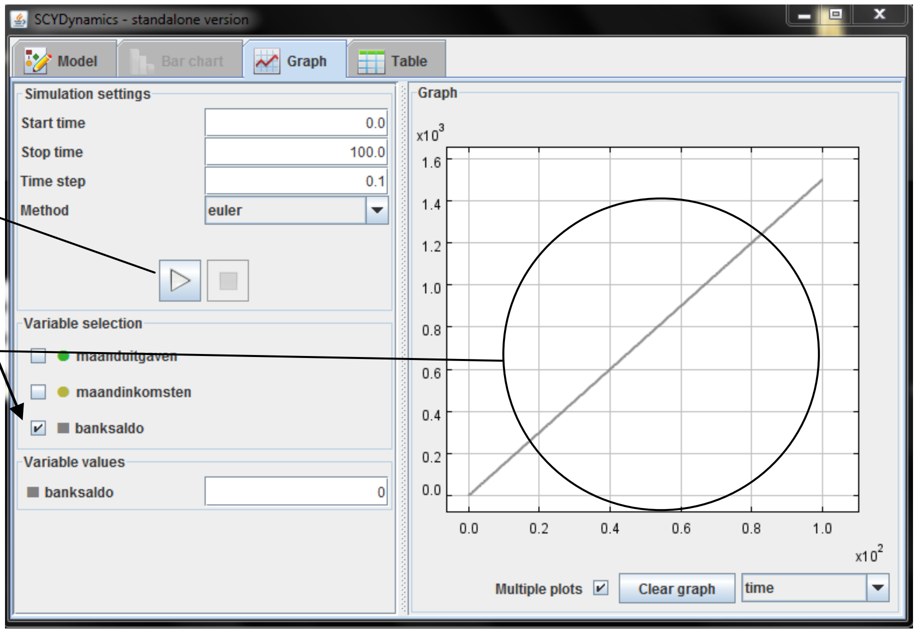


Je komt in een tab terecht waar je een grafiek van je resultaten kunt maken en het model runnen.

2. Kies de variable "Banksaldo"

3. Klik op

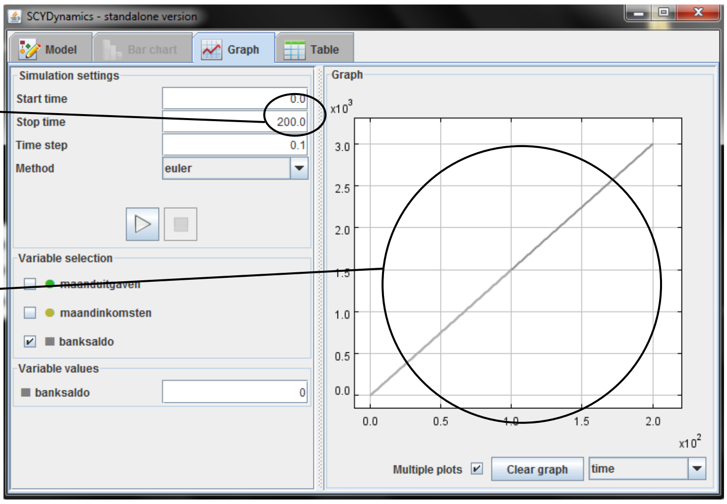
4. En je krijgt volgende grafiek te zien



In de grafiek zie je hoe het banksaldo met de tijd toeneemt. Na 10 maanden heb je €150,= gespaard. Dat is nog niet genoeg om de DVD speler te kopen, dus moet je de looptijd van het model uitbreiden.

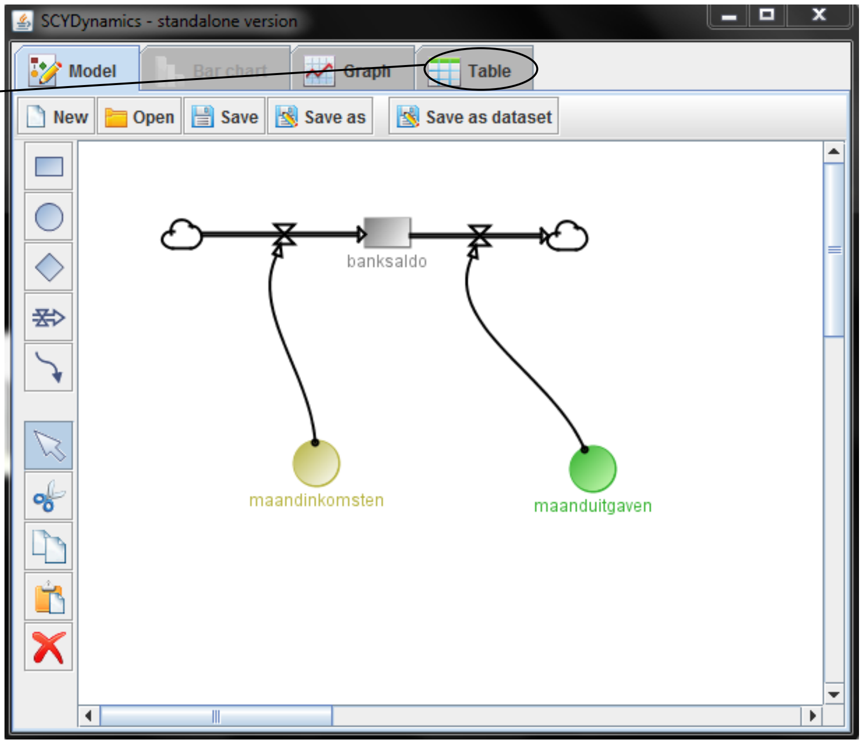
5. Verander de "stop time" naar 200.0

6. En run het model nog een keer om deze uitvoer te krijgen



In de grafiek kun je zien dat er na 20 maanden €300,= op je rekening staat. Als je precies wilt weten na hoeveel maanden je de benodigde €275,= hebt, kun je de tabel openen.

1. Kies in de menubalk voor Table

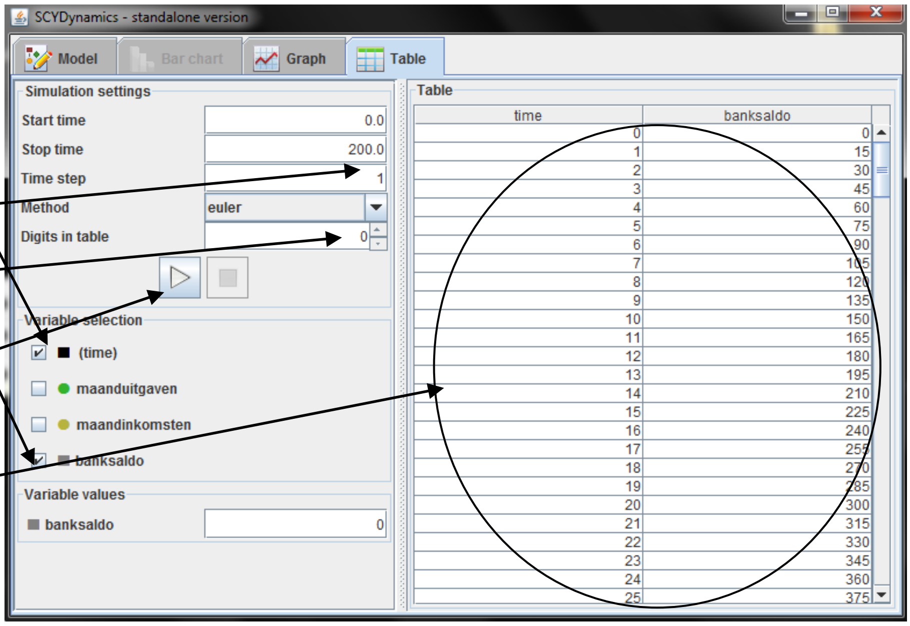


Je komt in een tab terecht waar je een grafiek van je resultaten kunt maken en het model runnen.

1. Kies voor de variablen "time" en "Banksaldo"

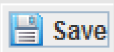
2. Verander de "time step" naar 1 en de "digits in table" naar 0

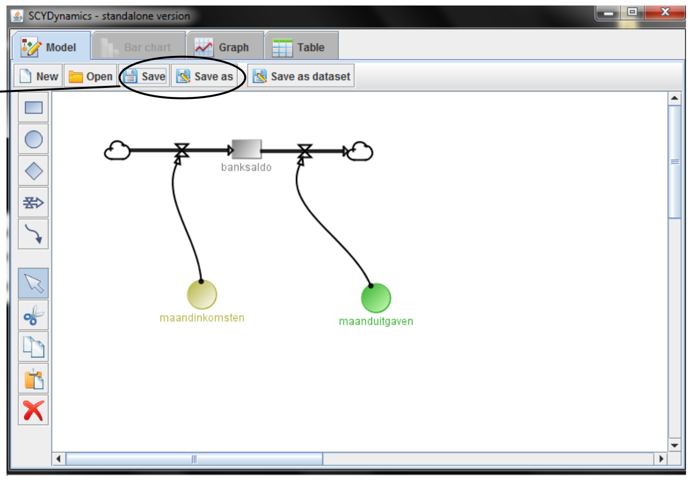
3. En run() het model om volgende tabel te krijgen



In de tabel staat dat je na 19 maanden €285,= hebt gespaard. Na meer dan anderhalf jaar heb je dus genoeg geld voor de DVD recorder.

Een model bewaren *(Niet doen!)*

1. Klik op  of 

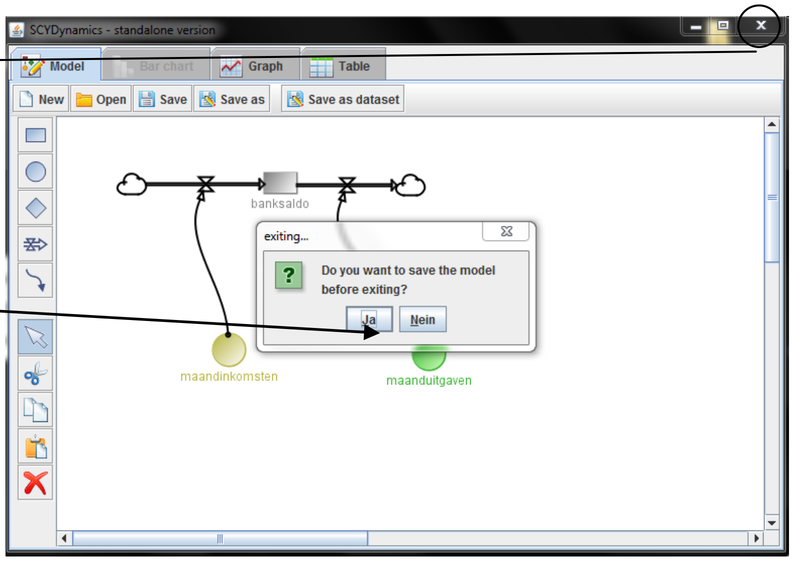


2. En bewaar het model onder de naam "DVDRecorder[jouw naam]"

Een model sluiten *(Niet doen!)*

1. Klik op 

2. Klik op



2. KWALITATIEF EN KWANTITATIEF MODELEREN

Voor het tweede deel van de handleiding wordt het voorbeeld wat uitgebreid.

VOORBEELD

Je vindt 19 maanden sparen veel te lang en besluit een baantje in een supermarkt te nemen. Je verdient hier €35,= per week. Bovendien ben je gaan sporten; je betaalt maandelijks €30,= aan contributie voor je sportvereniging. Wanneer heb je genoeg gespaard voor de DVD recorder?

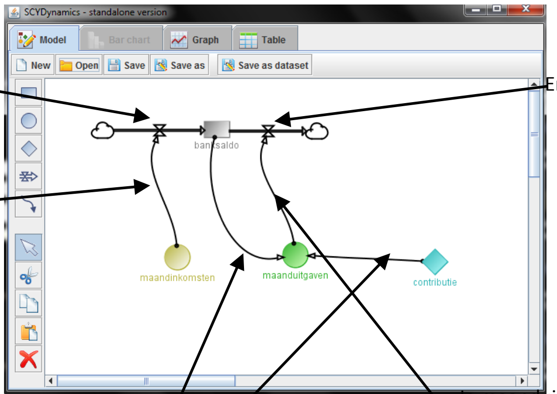
Een model openen

1. Open nu het bestand “DVDRecorder2”

Je ziet dat dit model wat ingewikkelder is. De betekenis van de onderdelen staat hieronder.

Er komt geld op je rekening binnen

Je maandinkomsten bepalen hoeveel geld er op je rekening binnenkomt



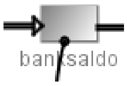
Er gaat geld van je rekening af

Je maanduitgaven bepalen hoeveel geld er van je rekening afgaat

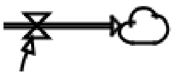
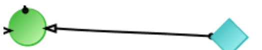
Je maanduitgaven zijn afhankelijk van de contributie en de hoogte van je banksaldo (als er veel geld op je rekening staat, geef je veel uit; als je weinig geld hebt doe je zuiniger aan)

Een model beter begrijpen

In dit model zijn drie verschillende symbolen gebruikt. Hun betekenis staat hieronder.

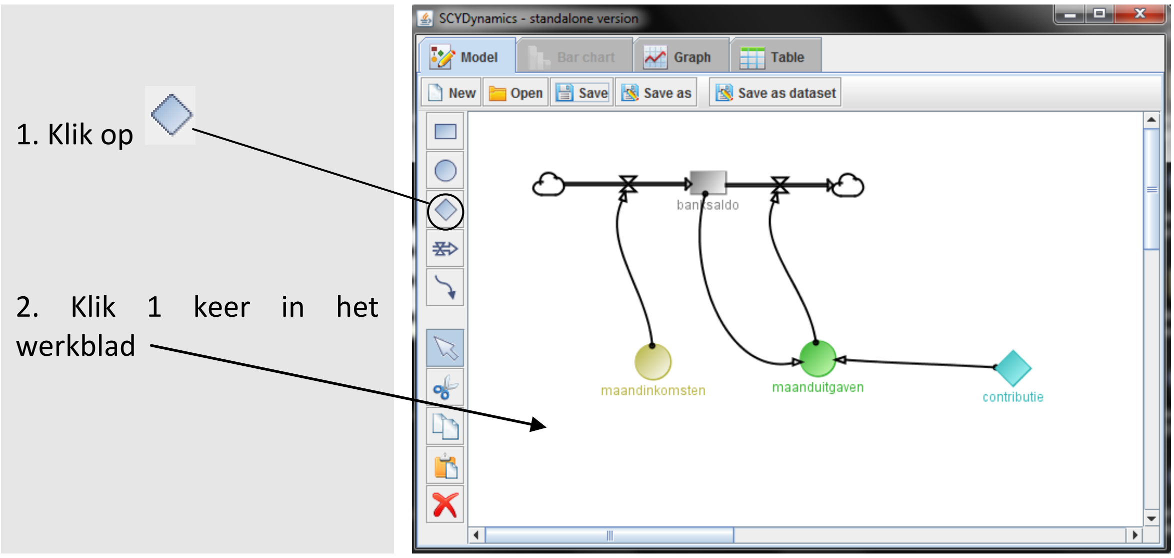
Symbool	Naam en betekenis	Voorbeeld
	*Voorraadgrootheid* Deze grootheid kan in de loop van de tijd van waarde veranderen. Er kan steeds iets bijkomen of iets afgaan.	Je banksaldo kan elke maand toenemen of afnemen.
	*Rekengrootheid* Deze grootheid wordt berekend op basis van andere grootheden.	Je maanduitgaven worden bepaald door de hoogte van je banksaldo en de contributie voor je sportvereniging
	*Constante* Deze grootheid verandert in de loop van de tijd niet van waarde	Contributie is elke maand gelijk (€30,=)

In het model staan ook twee soorten pijlen.

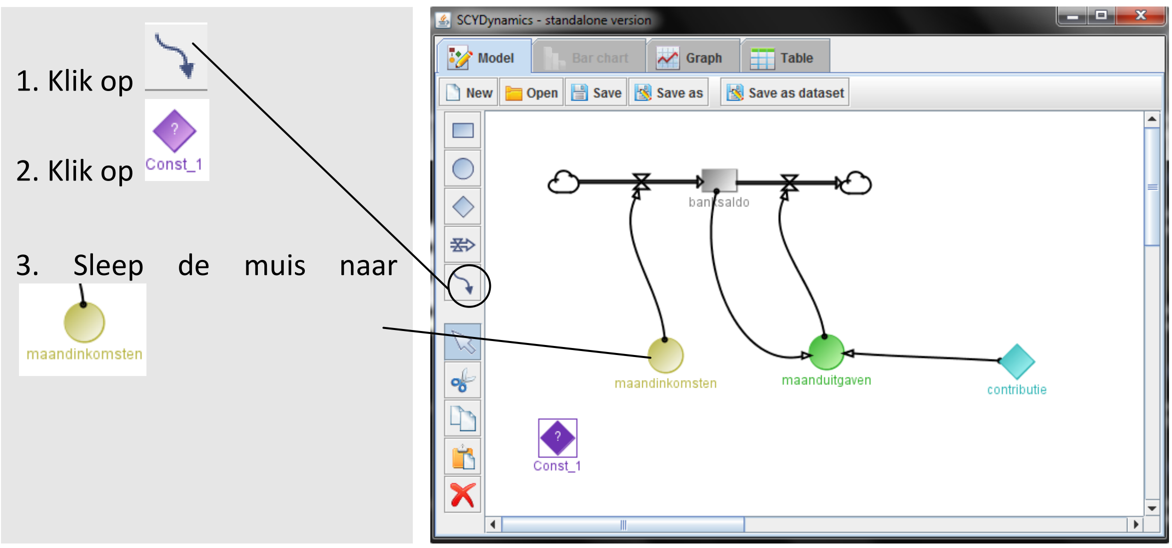
Pijl	Naam en betekenis
	*Stroompijl* Een stroompijl begint en/of eindigt altijd in een voorraadgrootheid. Deze pijl geeft aan dat er iets van de voorraadgrootheid af gaat of dat er iets bijkomt.
	*Relatiepijl* Een relatiepijl kan in twee gevallen worden gebruikt.
	<u>(1) Tussen twee symbolen</u> Een relatiepijl loopt **altijd** naar een rekengrootheid toe. De pijl begint in een andere grootheid. Dit geeft aan dat de rekengrootheid van deze andere grootheid afhankelijk is.
	<u>(2) Tussen een rekengrootheid en een stroompijl</u> De relatiepijl loopt van de rekengrootheid naar de stroompijl. Dit geeft aan dat de in- of uitstroom van deze rekengrootheid afhankelijk is.

Een constante toevoegen en definiëren

In het voorbeeld staat dat je elke week €35,= verdient in de supermarkt. Je kunt deze extra inkomsten als *constante* aan het model toevoegen (je salaris is immers elke week hetzelfde).



Je kunt nu aangeven dat de constante (je salaris) invloed heeft op je maandinkomsten. Dit doe je door een relatie toe te voegen.



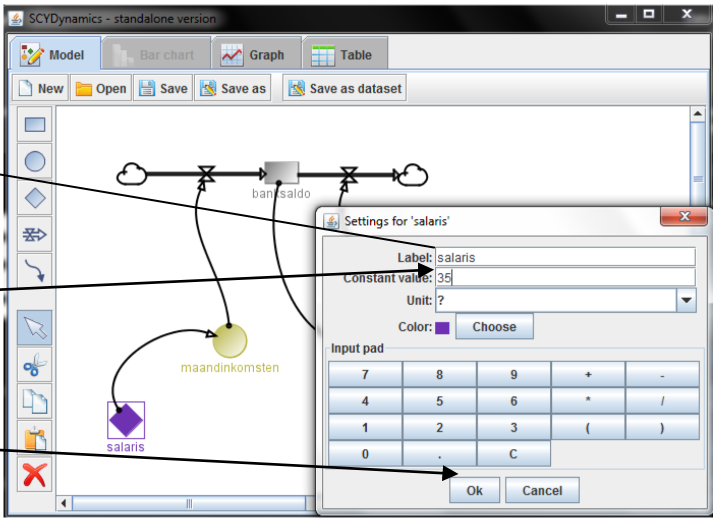
Tot slot kun je de naam en de waarde van de constante definiëren

1. Dubbelklik op 

2. Verander de naam in "Salaris"

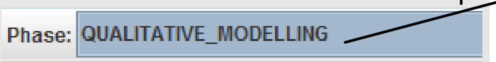
3. Verander de waarde in 35

4. Klik op 

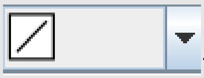


Een kwalitatieve relatie definiëren

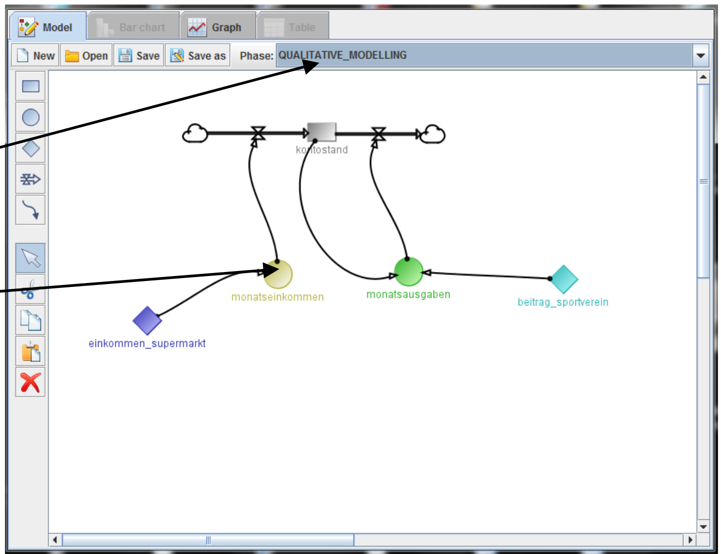
Je kunt nu de relatie tussen Maandinkomsten en Salaris definiëren. Je begint eenvoudig, zonder formules. Dit heet *kwalitatief* modeleren.

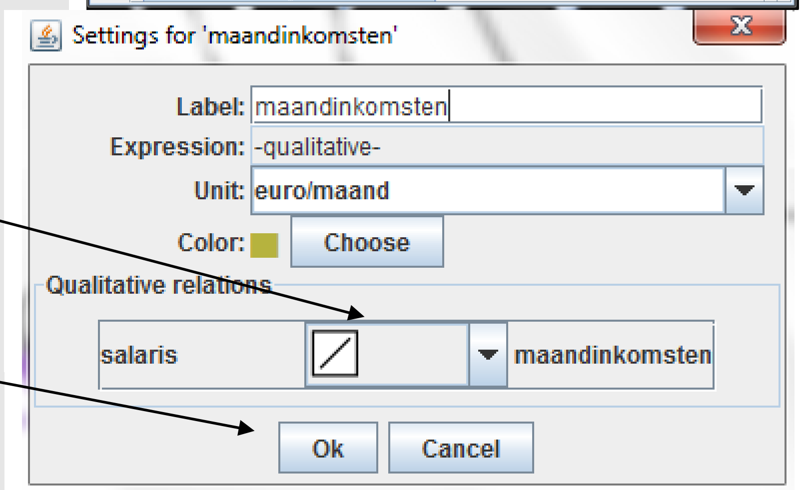
1. Om kwalitatief te kunnen modeleren klik ten eerste op 

2. Daarna dubbelklik op 

3. Klik op 

4. Klik op 





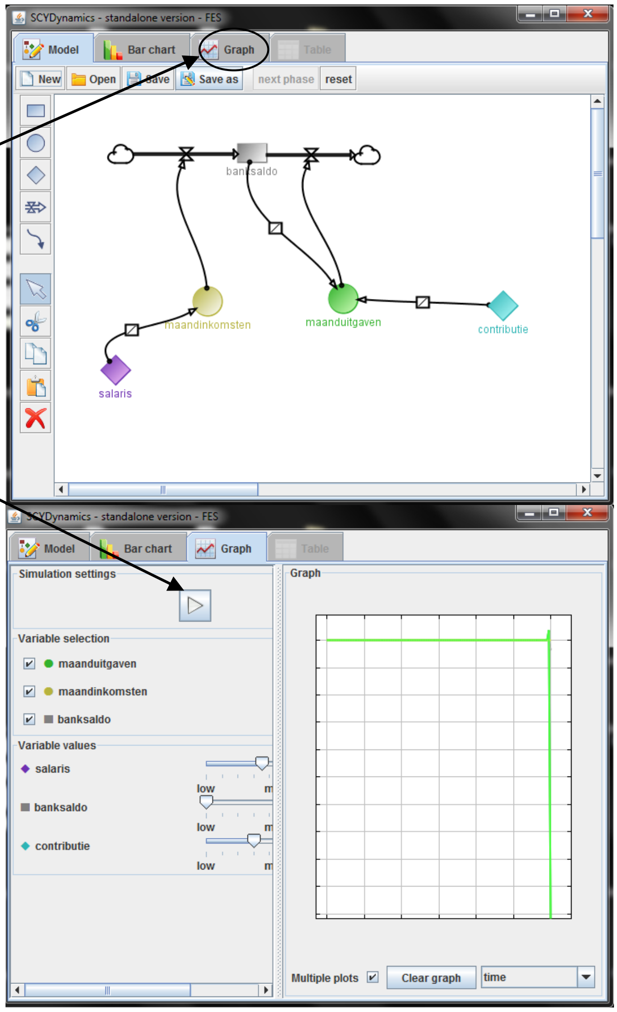
Je hebt nu de constante Salaris aan het model toegevoegd en de waarde hiervan op €35,= gezet. Met een kwalitatieve relatie heb je aangegeven dat je maandinkomsten hoger wordt als je salaris hoger wordt.

Doe nu alsjeblieft hetzelfde voor de realtie tussen "contributie" en "maanduitgaven"!

Een model runnen

1. Klik op Graph

2. In het nieuwe tab, kies dan de variablen en run het model

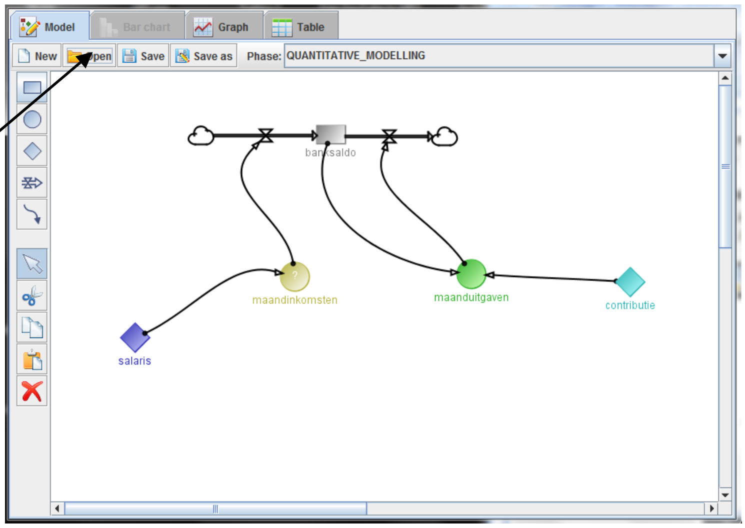


Je kunt de uitkomsten van het model in een grafiek bekijken. Hierin zie je hoe het banksaldo in de tijd verandert. Zo kun je controleren of je model globaal gezien klopt.

Een kwantitatieve relatie definiëren

Als je vindt dat het model klopt, kun je de relaties in getallen gaan uitdrukken. Dit heet *kwantitatief* modeleren.

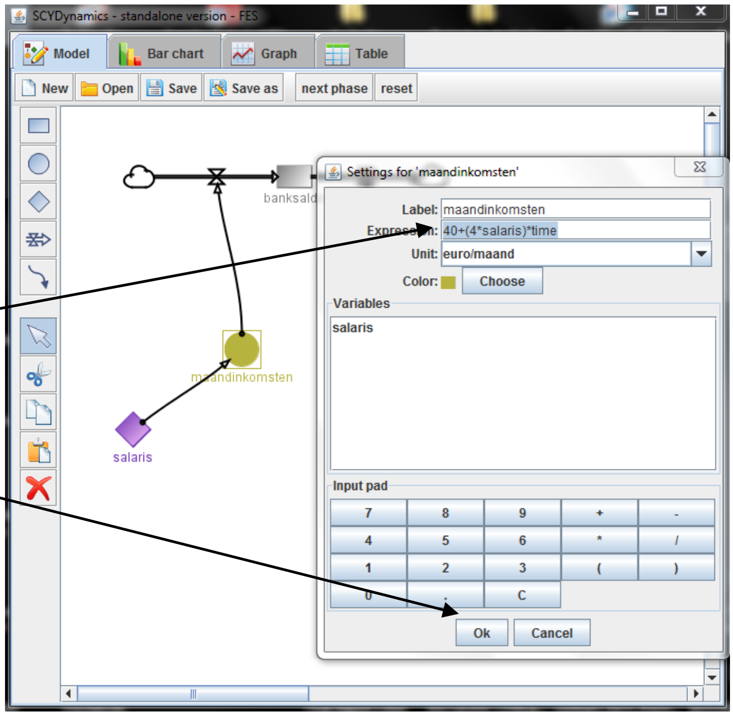
1. Om weer kwantitatief te kunnen modeleren, open nu het bestand “DVDRecorder3”



Je kunt nu de Maandinkomsten nauwkeurig specificeren. Je weet bijvoorbeeld dat je elke maand €40,= zakgeld krijgt. Je weet ook dat je elke week €35,= bijverdient. Je maandinkomsten bestaan dus uit je zakgeld van €40,= plus vier maal je weeksalaris van €35,= Dit kun je als volgt invullen.

2. Verander de expression in “40+(4*salaris)*time”

3. Klik op Ok



Run daarna het model door weer in de grafiek tab op  te klikken!

Uit de grafiek blijkt dat je na ongeveer een half jaar het bedrag voor de DVD recorder bij elkaar hebt gespaard. Volgende de tabel staat er na 4 maanden ongeveer €280 op je rekening. Net genoeg voor de DVD recorder dus.

Nu ken je de belangrijkste features van SCYDynamics en kun je met het experiment beginnen! Open daarvoor de file "Handleiding modeling photosynthesis" van het bureaublad!

Manual of the photosynthesis model in Dutch

HANDLEIDING FOTOSYNTHESE MODEL

Thilo Doepel - s0202266

Prof. dr. W.R. van Joolingen – IST / GW

Twente University

In dit experiment zal je fotosynthese gaan modeleren met behulp van het SCYDynamics programma. Om met het echte experiment te beginnen, open nog een keer het programma van het bureaublad als het niet nog ergens geopend is. Open dan in het programma de file "Model Photosynthesis.jar" van het bureaublad.

Je kunt al zien dat dit model nog iets ingewikkelder is, maar probeer het zo goed mogelijk te doen. De volgende tekst zal je eerbij helpen om de belangrijkste delen van het proces fotosynthese te begrijpen.

1. Achtergrondinformatie fotosynthese en dissimilatie

Fotosynthese is een proces waarin lichtenergie wordt gebruikt om koolstofdioxide om te zetten in koolhydraten, zoals glucose. Het proces, in zijn eenvoudigste vorm, komt voor in bijna alle planten. De vereenvoudigde formule van de chemische reactie is:

Water + Koolstofdioxide + Licht → Glucose + Zuurstof + Water

Je kunt zeggen dat het water uit de grond, samen met de koolstofdioxide uit de lucht en de lichtenergie het mogelijk maken dat de plant glucose produceert waarbij water en zuurstof als afvalproducten ontstaan. De glucose wordt door de plant gebruikt om te overleven en verder te groeien. Om fotosynthese en de belangrijkste factoren die daarop invloed hebben goed te kunnen modeleren, moeten sommige onderdelen nog nader verklaard worden.

Fotosynthese bestaat uit een groot aantal reacties, die kunnen gescheiden worden in twee reactiewegen: de Lichtreactie en de Calvincyclus.

Bij de lichtreacties wordt lichtenergie omgezet in chemische energie. Hierbij wordt via *Fotolyse* water gesplitst in waterstof protonen, elektronen en zuurstof. De protonen en elektronen worden gebruikt om uiteindelijk belangrijke energiedragende stoffen te maken (Water + Licht → Zuurstof + Waterprotonen + Energie).

Deze Energie wordt dan in het andere onderdeel van de fotosynthese (de Calvincyclus) samen met de waterprotonen en het koolstofdioxide verder verwerkt om uiteindelijk glucose te produceren. Dit proces wordt assimilatie genoemd, omdat doormiddel van de energie de waterprotonen en het koolstofdioxide met elkaar verbonden worden.

(Koolstofdioxide + Energie + Waterprotonen → Glucose)

Er ontstaat dus door het gebruik van de energie uit de lichtreactie tijdens het hele fotosynthese proces glucose wat de plant erg nodig heeft om te overleven en verder te groeien, maar de plant heeft ook nog energie nodig om andere belangrijke stoffen te produceren.

Ervoor bestaat naast de hele fotosynthese proces nog een ander groot proces en dat is de dissimilatie of celademhaling/respiratie, die ook bij ons dieren bestaat. Dissimilatie is ook een essentieel levensproces in planten. Het is noodzakelijk voor de synthese van essentiële metabolieten, waaronder sacchariden, aminozuren en vetzuren. Dit proces levert energie door het gebruik van de, tijdens de fotosynthese gewonen, glucose en zuurstof. Tijdens dit proces wordt het energierijke vertrekproduct (glucose) gedissimileerd tot CO_2. De vereenvoudigde formule van de chemische reactie is hierbij:

Glucose + Zuurstof → Koolstofdioxide + Water + Energie

Gezien uit de zicht van de relatie tussen koolstofdioxide, zuurstof en glucose en wat ervan versterkt verbruikt wordt, gebeurd bij fotosynthese en dissimilatie dus precies het tegenovergestelde. Er ontstaat dus een cyclus. Dissimilatie vindt veel over nacht plaats omdat er dan geen zonlicht voor de lichtreactie van de fotosynthese is, maar over dag natuurlijk ook.

Het samenspel van deze processen wordt onder natuurlijke omstandigheden door veel verschillende interne en externe factoren beïnvloed. In ons model gaan we nu alleen op twee van de belangrijkste externe factoren in. De twee variabelen, die in het model belangrijk zijn zijn temperatuur en lichtenergie. Het wordt nu nader uitgelegd in hoeverre deze factoren het proces fotosynthese efficiënter of onefficiënter maken.

Temperatuur is een heel belangrijke factoor voor de processen fotosynthese en dissimilatie. Zowel bij te lage als ook bij te hoge temperatuur gaat de plant dood. De enzymen, de gasuitwisseling en het water zijn ervoor verantwoordelijk. Als de temperatuur onder 0°C daalt, vriest het water en de *fotolyse* kan niet meer doorgaan en tegelijkertijd kunnen de temperatuur afhankelijke enzymen niet meer werken. Ook bij te hoge temperatuur, dat betekent boven de 36°C, wordt de koolstofdioxide assimilatie en dissimilatie rate minder. Als de temperatuur boven de 36°C stijgt, sluiten zich langzaam de bladmondjes van de plant om niet te veel water door condensatie te verliezen. Daardoor kan dan geen gasuitwisseling meer plaatsvinden en beide belangrijke processen, assimilatie en dissimilatie, worden onefficiënter en dit kan uiteindelijk de plant laten sterven.

De factor licht verandert op twee verschillende manieren. Ten eerste verandert de licht intensiteit volgends de positie van de zon. Vervolgens beschrijft de invloed van het licht op de *fotolyse* en later de assimilatie van koolstofdioxide een sinusachtige golf met het maximum om twaalf uur middags en het minimum om twaalf uur nachts. Ten tweede is het ook belangrijk om te weten of de plant meer in de schaduw of dirkt in het zonlicht opgroeit.

Deze factoren zijn de enige die variëren. Alle andere belangrijke factoren, zoals hoeveelheid water, mineralen in de grond en koolstofdioxide in de lucht worden als constant en gemiddeld goed verondersteld. Het is dus niet belangrijk hoeveel kooldioxide in de lucht buiten de plant zit en geen invloed van andere externe factoren. Ook gaan we uit van een gestandaardiseerde C3 plant en worden C4 en CAM planten buiten beschouwing gelaten.

2. De modeleertaak

Nu dat je een vereenvoudigd overzicht over de processen fotosynthese en dissimilatie hebt, kun je met het modeleren beginnen. Maak je geen zorgen over de wiskundige deel en al de formules die in de variabelen en constanten moeten staan, deze zijn al in het programma gegeven. Het gaat dus erom de goede opbouw en relaties tussen de factoren, zoals je de processen verstaat, op te bouwen. Je moet alleen maar de icons op een goede plek trekken en de verbindingen opbouwen. Een half uur voor het eind wordt je dan nog een laatste opgave gegeven.

Test-Taker Manual

1. Before arrival of participant, create the set-up so participant is directly able to start: Computer with direct access to SCY-Dynamics and all the necessary files on the desktop, Audacity already running and microphone adjusted correctly, Paperwork (Informed-Consent Form etc.) and pen on the desk.
2. Upon arrival of participant, formal greeting and asking how he/she has been to create warm atmosphere, ask the participant if there are any questions in need of answering before getting started and inform the participant that the test-taker will stay close during the entire experiment to provide help, ultimately inform the participant about the duration of the experiment and the debriefing at the end, which will reveal the purpose of the experiment, and let him/her fill out the paperwork.
    - “Welcome, dear Mr./Mrs. […]! My name is Thilo Doepel and I am very grateful that you took the time to participate in the experiment for my Bachelorthesis. How are you? / How was your trip here?”
    - “Before we get started, I would like to ask you, if you have any questions concerning the experiment?
    - “Do not worry much, the experiment is very manageable and I will stay close in case you experience any difficulties along the way. This experiment is concerned with modeling the basic concepts of the processes photosynthesis and dissimilation with help of the program SCY-Dynamics. You belong to the student/expert group, because you have not / have studied (are currently studying) a biology-related study course.”
    - “The whole experiment will probably take up 180 minutes of your time and at the end I will give you a short debriefing, about the purpose of this experiment.”
    - “If you would have a second to fill in this informed-consent form and after that we are good to go.”
    - “Now, let us start with the experiment!”
3. Let the participant start with the experiment, therefore the SCY-Dynamics Manual should be already opened and explain in short the steps the participant has to follow throughout the experiment, also inform the participant that the microphone will only be turned on during the second part (the actual modeling of photosynthesis).
    - “This is the first document and it is there to make you familiar with the SCY-Dynamics program.”
    - “To give you a short overview: First you will finish this document and after that, when you are able to handle the modeling-program, we will start with the real experiment. During the real experiment, the modeling of photosynthesis and dissimilation, your voice will be recorded, but I will explain that more thoroughly later on. Please do not worry about not having enough knowledge concerning the two processes. Before starting with the real experiment, information about them will be given to you in the second document.”
    - “Now, please start with the first document.”
4. Check every ten to twenty minutes on the participant, when the participant is finished with the SCY-Dynamics Manual explain the workings and purpose of the thinking-aloud-method thoroughly (maybe with one example) and turn on the microphone and start the recording, let the participant continue with the experiment and stay close.
    - “Now, how do you get along with SCY-Dynamics? Are there any functions that you do not understand?”
    - “Okay, we will now continue with the second document. Please notify me when you are finished reading and understand the first paragraph, the background-information, because then I will explain to you the method and purpose of the recording of your voice.”

   - Explain the Cursor-Option!
   - "The microphone is needed for the thinking-aloud method that I am using to analyze your progress throughout the modeling of the processes with the program. The thinking-aloud method implies that you say every thought that comes into your head. I am of course not interested in your personal thoughts, but only about the ones you are having about the workings of the two processes. If you are for example thinking about a hypothesis like "I think the amount of CO_2 is having an influence on the amount of glucose that is being produced", I need you to verbalize this thought, so that I can record it for my analysis of your progress. Your thoughts do not have to be verbalized in perfect sentences; just try to explain to me via the microphone what you are doing during the experiment with the program and how you think all the factors, constants and variables are interconnected."
   - "Do you understand what I need you to do?"
   - "Alright, then let us start the recording and I will let you begin with modeling how you think the processes work."
5. After the experiment, save all the necessary data (if the participant has not done so) and debrief the participant, thank the participant for his/her participation and give him/her the test-takers e-mail address if he/she is interested in the outcomes and conclusions of the experiment and/or more information about the topic.
   - "Thank you very much for doing all this for me! Are you very exhausted?"
   - "Okay, give me a second to save the data."
   - "I will now give you a quick debriefing; you see, the reason behind this experiment was not about finding out your knowledge of photosynthesis or dissimilation, it was about how you understand, analyze and make up the different parts of a model and about how you go through the different phases of the modeling process in comparison to an expert/student. With the recording of your thoughts about the model and the two processes and the model you made yourself, I am able to analyze with steps you took throughout the experiment and, combined with the data of the other participants, I am hoping to find some kind of pattern there. I am actually looking for a difference between the way in which persons that have studied the subject of concern, here biology, and persons that have not, are handling the given task."
   - "If you are interested in the final results of this experiment, I will send them to you, if you provide me, with your e mail address."
   - "Finally, as a small compensation I have got something prepared for you." [Sweets for the students / Money or coupons for the experts]
   - "Again, thank you very much, have a nice day and Good Bye!"

The coding scheme by Löhner et al. (2005)

Orientation
- Defining variables
- Domain talk
- Experience knowledge
- Theoretical knowledge
- Refer to instruction

Hypothesizing
- Predictions
- Hypothesis generation

Experimenting

Model implementation

Model evaluation
- Interpretation model output
    - Concluding
    - Describing
- Evaluation model

Other activities

Actions
- Model syntax
- Tool is not working
- Tool use
- Reading
- Calculating

Regulation
- Planning
- Choose activity
- Evaluation
- Task
- Frustration

Off task

Experimenter

1. *The seven reasoning processes and gender*

Übersicht über Hypothesentest

	Nullhypothese	Test	Sig.	Entscheidung
1	Die Verteilung von Orientation ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,040[1]	Nullhypothese ablehnen.
2	Die Verteilung von Hypothesizing ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,004[1]	Nullhypothese ablehnen.
3	Die Verteilung von Experimenting ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
4	Die Verteilung von Implementation ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,094[1]	Nullhypothese behalten.
5	Die Verteilung von Evaluation ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,397[1]	Nullhypothese behalten.
6	Die Verteilung von OtherActivities ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,867[1]	Nullhypothese behalten.
7	Die Verteilung von OffTaskExperimenter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,779[1]	Nullhypothese behalten.

Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,0

[1] Für diesen Test wird die exakte Signifikanz angezeigt.

Gruppenstatistiken

	Gender	N	Mittelwert	Standardabweichung	Standardfehler des Mittelwertes
Orientation	Male	8	8,8125	6,11460	2,16184
	Female	7	13,4286	3,33452	1,26033
Hypothesizing	Male	8	7,9375	2,01667	,71300
	Female	7	12,1786	2,78281	1,05180
Experimenting	Male	8	1,9375	1,02426	,36213
	Female	7	1,7857	,58503	,22112
Implementation	Male	8	8,8750	3,50510	1,23924
	Female	7	12,3571	2,51602	,95097
Evaluation	Male	8	3,6563	1,81235	,64076
	Female	7	4,7857	1,93880	,73280
OtherActivities	Male	8	6,0313	4,35570	1,53997
	Female	7	5,4286	3,69040	1,39484
OffTaskExperimenter	Male	8	8,7500	3,05018	1,07840
	Female	7	12,5000	8,03897	3,03844

2. The seven reasoning processes and Students vs. Experts

Übersicht über Hypothesentest

	Nullhypothese	Test	Sig.	Entscheidung
1	Die Verteilung von Orientation ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,851[1]	Nullhypothese behalten.
2	Die Verteilung von Hypothesizing ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
3	Die Verteilung von Experimenting ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,280[1]	Nullhypothese behalten.
4	Die Verteilung von Implementation ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,571[1]	Nullhypothese behalten.
5	Die Verteilung von Evaluation ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
6	Die Verteilung von OtherActivities ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,056[1]	Nullhypothese behalten.
7	Die Verteilung von OffTaskExperimenter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,753[1]	Nullhypothese behalten.

Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,C

[1] Für diesen Test wird die exakte Signifikanz angezeigt.

Gruppenstatistiken

	StudentvsExpert	N	Mittelwert	Standardabweichung	Standardfehler des Mittelwertes
Orientation	Student	11	10,8636	4,89944	1,47724
	Expert	4	11,2500	7,47217	3,73609
Hypothesizing	Student	11	10,0455	3,69935	1,11540
	Expert	4	9,5625	1,23111	,61555
Experimenting	Student	11	1,6591	,57307	,17279
	Expert	4	2,4375	1,21407	,60703
Implementation	Student	11	10,1818	3,77341	1,13773
	Expert	4	11,3750	2,75000	1,37500
Evaluation	Student	11	4,1818	2,06486	,62258
	Expert	4	4,1875	1,59915	,79958
OtherActivities	Student	11	4,6591	3,36019	1,01314
	Expert	4	8,7500	4,23773	2,11886
OffTaskExperimenter	Student	11	11,1364	6,74941	2,03502
	Expert	4	8,7500	3,32290	1,66145

3. *The log-files and Students vs. Experts*

Übersicht über Hypothesentest

	Nullhypothese	Test	Sig.	Entscheidung
1	Die Verteilung von Actions ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,226[1]	Nullhypothese behalten.
2	Die Verteilung von Duration ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,661[1]	Nullhypothese behalten.
3	Die Verteilung von Model_ran ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,078[1]	Nullhypothese behalten.
4	Die Verteilung von Model_ran_error ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,343[1]	Nullhypothese behalten.
5	Die Verteilung von Links_added ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,571[1]	Nullhypothese behalten.
6	Die Verteilung von Links_deleted ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,343[1]	Nullhypothese behalten.

Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,0

[1]Für diesen Test wird die exakte Signifikanz angezeigt.

Gruppenstatistiken

	StudentvsExpert	N	Mittelwert	Standardabweichung	Standardfehler des Mittelwertes
Actions	Student	11	114,18	40,880	12,326
	Expert	4	128,25	15,607	7,804
Duration	Student	11	88,55	30,755	9,273
	Expert	4	92,00	13,832	6,916
Model_ran	Student	11	13,82	11,152	3,362
	Expert	4	3,75	2,363	1,181
Model_ran_error	Student	11	1,09	2,386	,719
	Expert	4	,00	,000	,000
Links_added	Student	11	19,45	5,905	1,781
	Expert	4	20,00	3,367	1,683
Links_deleted	Student	11	3,36	2,873	,866
	Expert	4	5,75	3,775	1,887

4. The log-files and gender

Übersicht über Hypothesentest

	Nullhypothese	Test	Sig.	Entscheidung
1	Die Verteilung von Actions ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,867[1]	Nullhypothese behalten.
2	Die Verteilung von Duration ist übe Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,152[1]	Nullhypothese behalten.
3	Die Verteilung von Model_ran ist über Kategorien von Gender gleich	Mann-Whitney-U-Test unabhängiger Stichproben	,397[1]	Nullhypothese behalten.
4	Die Verteilung von Model_ran_error ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,867[1]	Nullhypothese behalten.
5	Die Verteilung von Links_added ist über Kategorien von Gender gleich	Mann-Whitney-U-Test unabhängiger Stichproben	,152[1]	Nullhypothese behalten.
6	Die Verteilung von Links_deleted ist über Kategorien von Gender gleich	Mann-Whitney-U-Test unabhängiger Stichproben	,336[1]	Nullhypothese behalten.

Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,C

[1] Für diesen Test wird die exakte Signifikanz angezeigt.

Gruppenstatistiken

	Gender	N	Mittelwert	Standardabweichung	Standardfehler des Mittelwertes
Actions	Male	8	118,25	45,200	15,981
	Female	7	117,57	24,899	9,411
Duration	Male	8	77,88	21,557	7,621
	Female	7	102,71	27,421	10,364
Model_ran	Male	8	9,63	10,901	3,854
	Female	7	12,86	10,699	4,044
Model_ran_error	Male	8	,38	,744	,263
	Female	7	1,29	2,984	1,128
Links_added	Male	8	17,63	3,021	1,068
	Female	7	21,86	6,492	2,454
Links_deleted	Male	8	3,13	2,532	,895
	Female	7	5,00	3,742	1,414

5. All variables and Students vs. Experts

Übersicht über Hypothesentest

	Nullhypothese	Test	Sig.	Entscheidung
1	Die Verteilung von Actions ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,226[1]	Nullhypothese behalten.
2	Die Verteilung von Duration ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,661[1]	Nullhypothese behalten.
3	Die Verteilung von Model_ran ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,078[1]	Nullhypothese behalten.
4	Die Verteilung von Model_ran_error ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,343[1]	Nullhypothese behalten.
5	Die Verteilung von Links_added ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,571[1]	Nullhypothese behalten.
6	Die Verteilung von Links_deleted ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,343[1]	Nullhypothese behalten.
7	Die Verteilung von Orientationfirstquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,489[1]	Nullhypothese behalten.
8	Die Verteilung von Orientationsecondquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,489[1]	Nullhypothese behalten.
9	Die Verteilung von Orientationthirdquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,753[1]	Nullhypothese behalten.
10	Die Verteilung von Orientationfourthquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,949[1]	Nullhypothese behalten.
11	Die Verteilung von Hypothesizingfirstquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,006[1]	Nullhypothese ablehnen.

Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,05

[1] Für diesen Test wird die exakte Signifikanz angezeigt.

Übersicht über Hypothesentest

	Nullhypothese	Test	Sig.	Entscheidung
12	Die Verteilung von Hypothesizingsecondquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,226[1]	Nullhypothese behalten.
13	Die Verteilung von Hypothesizingthirdquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,412[1]	Nullhypothese behalten.
14	Die Verteilung von Hypothesizingfourthquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,753[1]	Nullhypothese behalten.
15	Die Verteilung von Experimentingfirstquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
16	Die Verteilung von Experimentingsecondquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
17	Die Verteilung von Experimentingthirdquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,753[1]	Nullhypothese behalten.
18	Die Verteilung von Experimentingfourthquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,104[1]	Nullhypothese behalten.
19	Die Verteilung von Implementationfirstquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,018[1]	Nullhypothese ablehnen.
20	Die Verteilung von Implementationsecondquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,949[1]	Nullhypothese behalten.
21	Die Verteilung von Implementationthirdquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,661[1]	Nullhypothese behalten.

Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,05

[1] Für diesen Test wird die exakte Signifikanz angezeigt.

Übersicht über Hypothesentest

	Nullhypothese	Test	Sig.	Entscheidung
22	Die Verteilung von Implementationfourthquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,753[1]	Nullhypothese behalten.
23	Die Verteilung von Evaluationfirstquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,851[1]	Nullhypothese behalten.
24	Die Verteilung von Evaluationsecondquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,851[1]	Nullhypothese behalten.
25	Die Verteilung von Evaluationthirdquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
26	Die Verteilung von Evaluationfourthquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
27	Die Verteilung von OtherActivitiesfirstquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,056[1]	Nullhypothese behalten.
28	Die Verteilung von OtherActivitiessecondquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,280[1]	Nullhypothese behalten.
29	Die Verteilung von OtherActivitiesthirdquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,056[1]	Nullhypothese behalten.
30	Die Verteilung von OtherActivitiesfourthquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,343[1]	Nullhypothese behalten.
31	Die Verteilung von OffTaskExperimenterfirstquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,489[1]	Nullhypothese behalten.

Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,05

[1] Für diesen Test wird die exakte Signifikanz angezeigt.

Übersicht über Hypothesentest

	Nullhypothese	Test	Sig.	Entscheidung
32	Die Verteilung von OffTaskExperimentersecondquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,571[1]	Nullhypothese behalten.
33	Die Verteilung von OffTaskExperimenterthirdquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,412[1]	Nullhypothese behalten.
34	Die Verteilung von OffTaskExperimenterfourthquarter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,177[1]	Nullhypothese behalten.
35	Die Verteilung von Orientation ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,851[1]	Nullhypothese behalten.
36	Die Verteilung von Hypothesizing ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
37	Die Verteilung von Experimenting ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,280[1]	Nullhypothese behalten.
38	Die Verteilung von Implementation ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,571[1]	Nullhypothese behalten.
39	Die Verteilung von Evaluation ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
40	Die Verteilung von OtherActivities ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,056[1]	Nullhypothese behalten.
41	Die Verteilung von OffTaskExperimenter ist über Kategorien von StudentvsExpert gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,753[1]	Nullhypothese behalten.

Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,05

[1] Für diesen Test wird die exakte Signifikanz angezeigt.

6. All variables and gender

Übersicht über Hypothesentest

	Nullhypothese	Test	Sig.	Entscheidung
1	Die Verteilung von Actions ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,867[1]	Nullhypothese behalten.
2	Die Verteilung von Duration ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,152[1]	Nullhypothese behalten.
3	Die Verteilung von Model_ran ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,397[1]	Nullhypothese behalten.
4	Die Verteilung von Model_ran_error ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,867[1]	Nullhypothese behalten.
5	Die Verteilung von Links_added ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,152[1]	Nullhypothese behalten.
6	Die Verteilung von Links_deleted ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,336[1]	Nullhypothese behalten.
7	Die Verteilung von Orientationfirstquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,072[1]	Nullhypothese behalten.
8	Die Verteilung von Orientationsecondquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,152[1]	Nullhypothese behalten.
9	Die Verteilung von Orientationthirdquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,040[1]	Nullhypothese ablehnen.
10	Die Verteilung von Orientationfourthquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,121[1]	Nullhypothese behalten.
11	Die Verteilung von Hypothesizingfirstquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,397[1]	Nullhypothese behalten.

Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,05

[1] Für diesen Test wird die exakte Signifikanz angezeigt.

Übersicht über Hypothesentest

	Nullhypothese	Test	Sig.	Entscheidung
12	Die Verteilung von Hypothesizingsecondquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,021[1]	Nullhypothese ablehnen.
13	Die Verteilung von Hypothesizingthirdquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,463[1]	Nullhypothese behalten.
14	Die Verteilung von Hypothesizingfourthquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,021[1]	Nullhypothese ablehnen.
15	Die Verteilung von Experimentingfirstquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
16	Die Verteilung von Experimentingsecondquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
17	Die Verteilung von Experimentingthirdquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,072[1]	Nullhypothese behalten.
18	Die Verteilung von Experimentingfourthquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,232[1]	Nullhypothese behalten.
19	Die Verteilung von Implementationfirstquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,867[1]	Nullhypothese behalten.
20	Die Verteilung von Implementationsecondquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,281[1]	Nullhypothese behalten.
21	Die Verteilung von Implementationthirdquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,397[1]	Nullhypothese behalten.

Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,0!

[1] Für diesen Test wird die exakte Signifikanz angezeigt.

Übersicht über Hypothesentest

	Nullhypothese	Test	Sig.	Entscheidung
22	Die Verteilung von Implementationfourthquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,006[1]	Nullhypothese ablehnen.
23	Die Verteilung von Evaluationfirstquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,694[1]	Nullhypothese behalten.
24	Die Verteilung von Evaluationsecondquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,536[1]	Nullhypothese behalten.
25	Die Verteilung von Evaluationthirdquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,694[1]	Nullhypothese behalten.
26	Die Verteilung von Evaluationfourthquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,054[1]	Nullhypothese behalten.
27	Die Verteilung von OtherActivitiesfirstquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,694[1]	Nullhypothese behalten.
28	Die Verteilung von OtherActivitiessecondquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,955[1]	Nullhypothese behalten.
29	Die Verteilung von OtherActivitiesthirdquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,694[1]	Nullhypothese behalten.
30	Die Verteilung von OtherActivitiesfourthquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,779[1]	Nullhypothese behalten.
31	Die Verteilung von OffTaskExperimenterfirstquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,779[1]	Nullhypothese behalten.

Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,05

[1] Für diesen Test wird die exakte Signifikanz angezeigt.

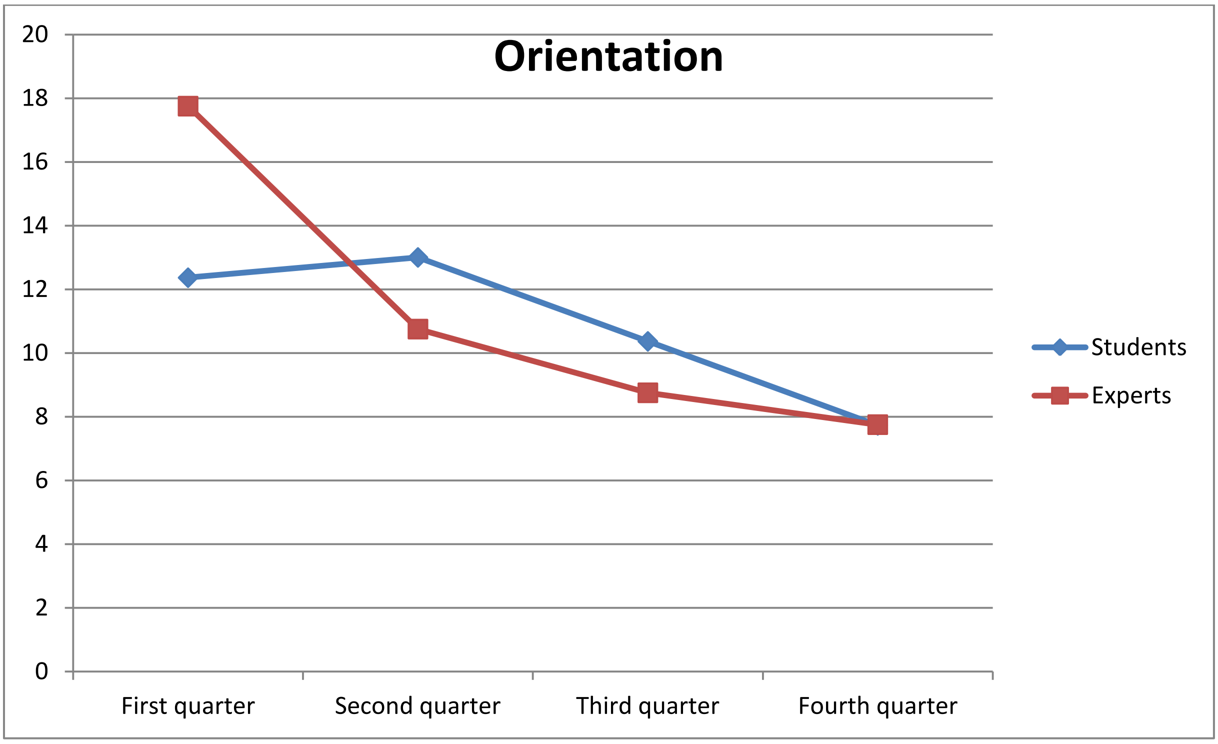
Übersicht über Hypothesentest

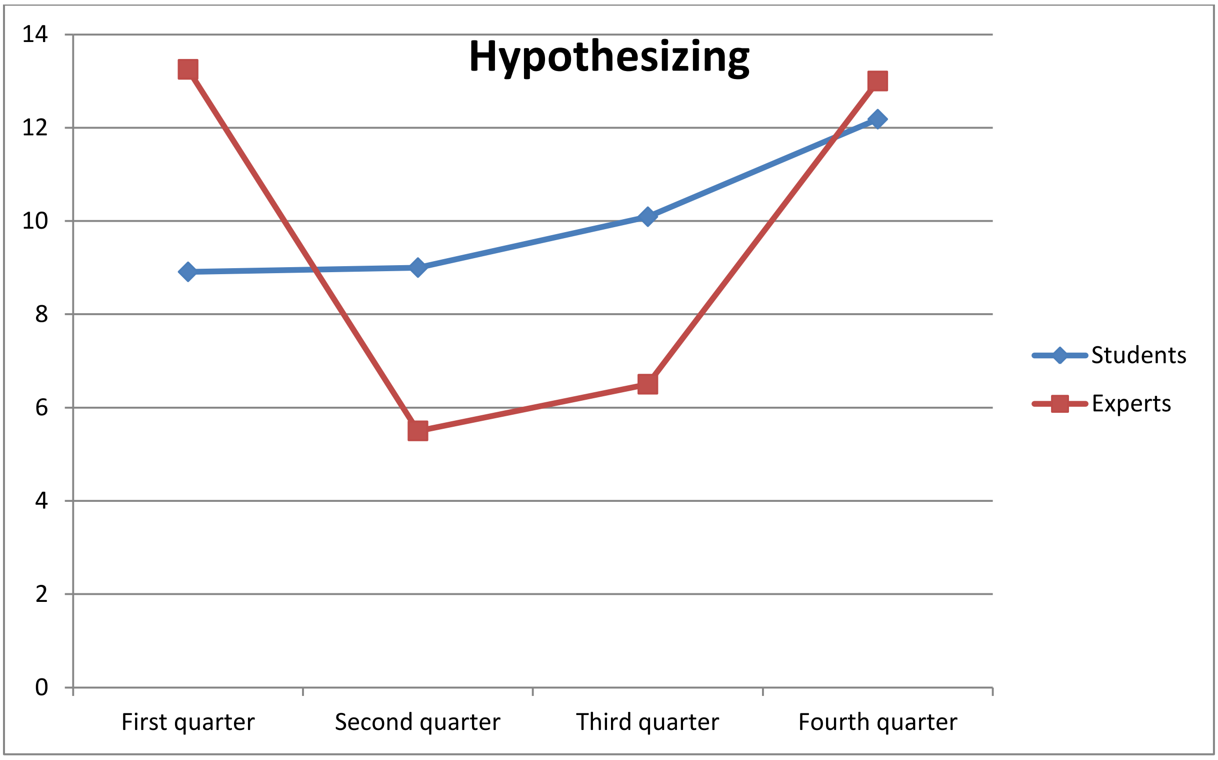
	Nullhypothese	Test	Sig.	Entscheidung
32	Die Verteilung von OffTaskExperimentersecondquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,152[1]	Nullhypothese behalten.
33	Die Verteilung von OffTaskExperimenterthirdquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
34	Die Verteilung von OffTaskExperimenterfourthquarter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,232[1]	Nullhypothese behalten.
35	Die Verteilung von Orientation ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,040[1]	Nullhypothese ablehnen.
36	Die Verteilung von Hypothesizing ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,004[1]	Nullhypothese ablehnen.
37	Die Verteilung von Experimenting ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	1,000[1]	Nullhypothese behalten.
38	Die Verteilung von Implementation ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,094[1]	Nullhypothese behalten.
39	Die Verteilung von Evaluation ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,397[1]	Nullhypothese behalten.
40	Die Verteilung von OtherActivities ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,867[1]	Nullhypothese behalten.
41	Die Verteilung von OffTaskExperimenter ist über Kategorien von Gender gleich.	Mann-Whitney-U-Test unabhängiger Stichproben	,779[1]	Nullhypothese behalten.

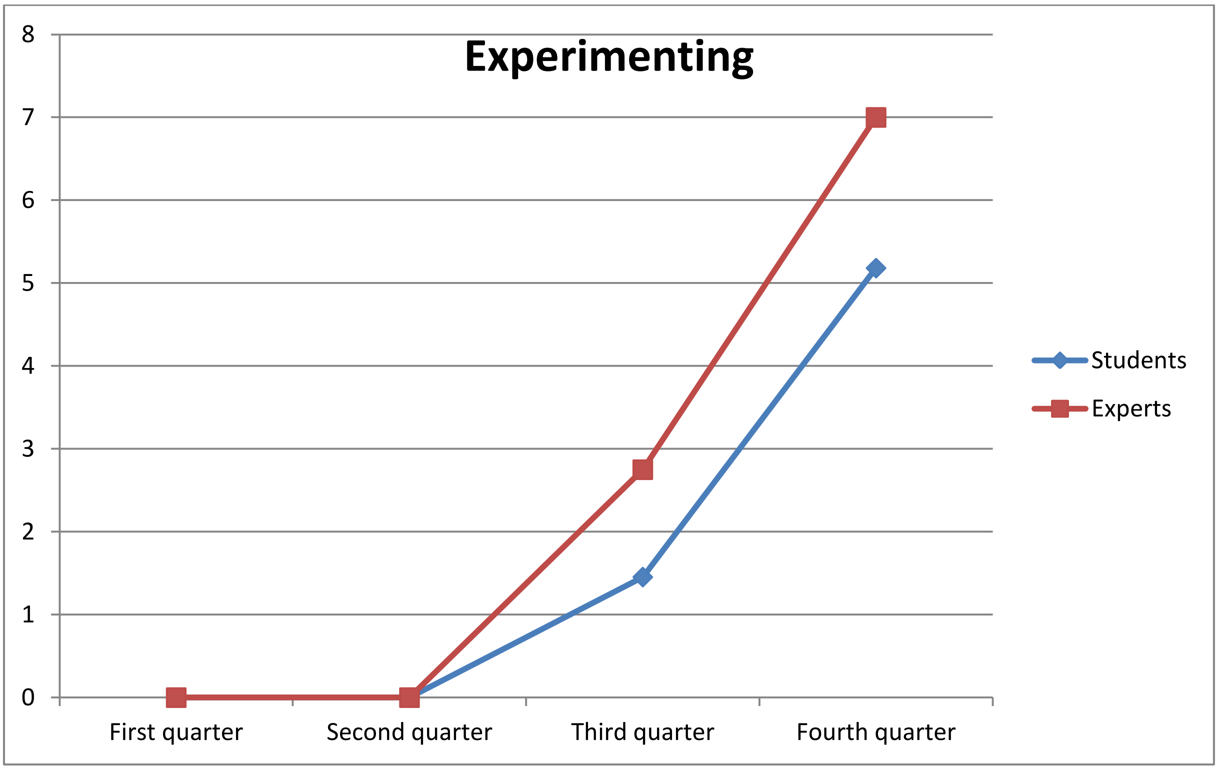
Asymptotische Signifikanzen werden angezeigt. Das Signifikanzniveau ist ,05

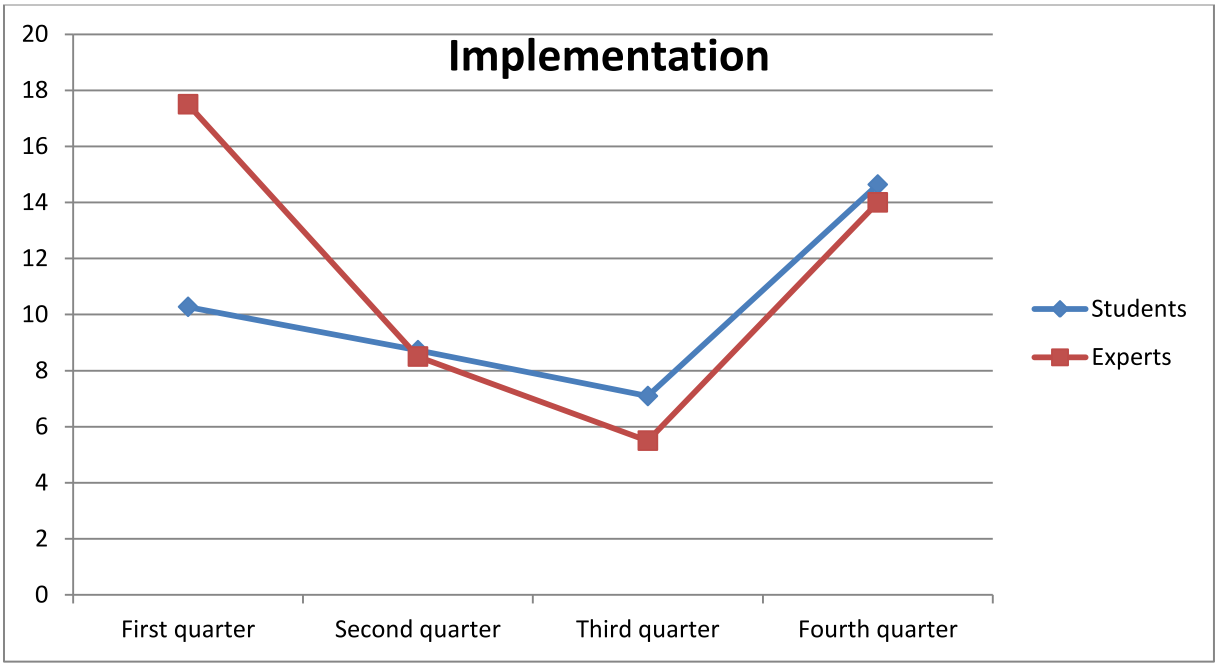
[1] Für diesen Test wird die exakte Signifikanz angezeigt.

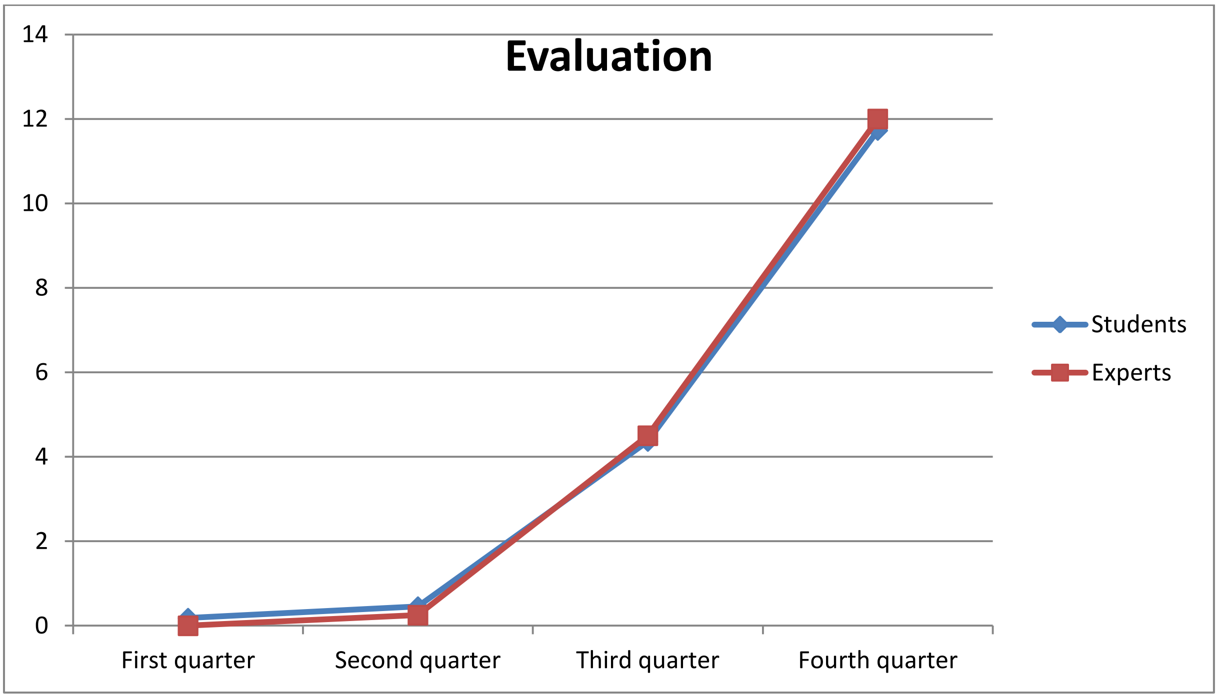
The graphs of the seven reasoning processes and Students vs. Experts

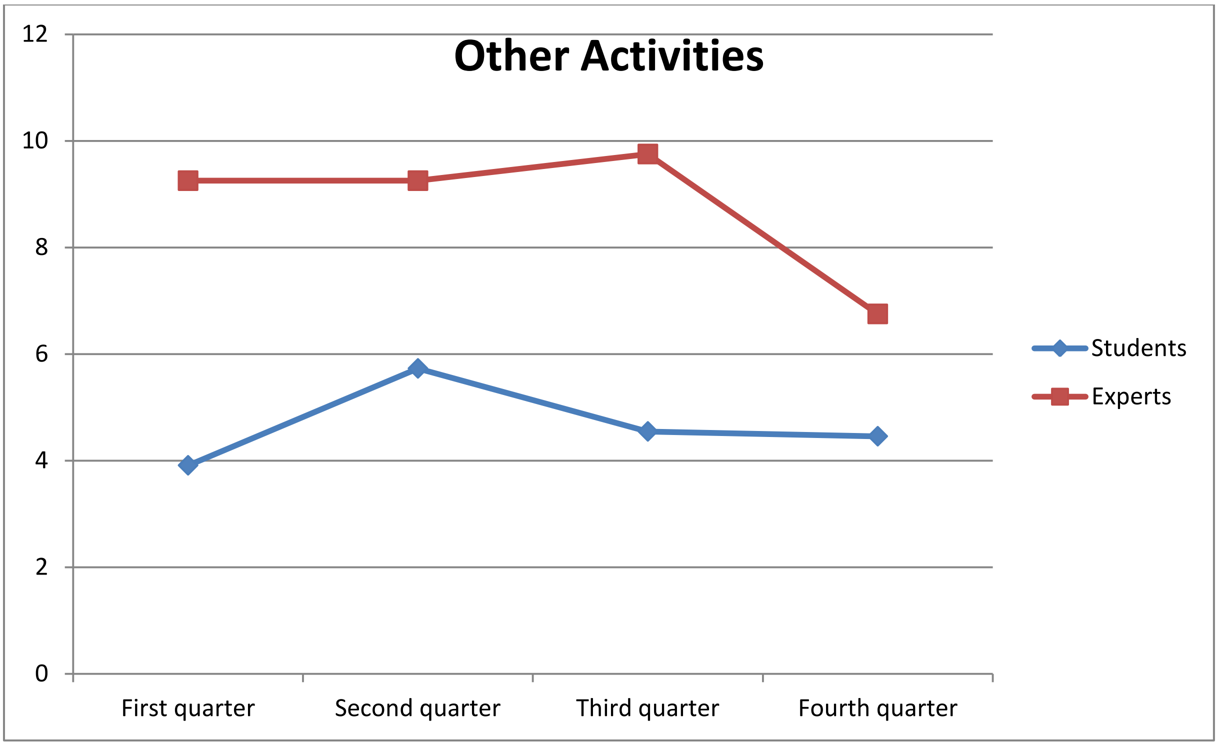





Experimenting
8
7
6
5
4
3
2
1
0
First quarter
Second quarter
Third quarter
Fourth quarter
Students
Experts


Implementation
20
18
16
14
12
10
8
6
4
2
0
First quarter
Second quarter
Third quarter
Fourth quarter
Students
Experts


Evaluation
14
12
10
8
6
4
2
0
First quarter
Second quarter
Third quarter
Fourth quarter
Students
Experts


Other Activities
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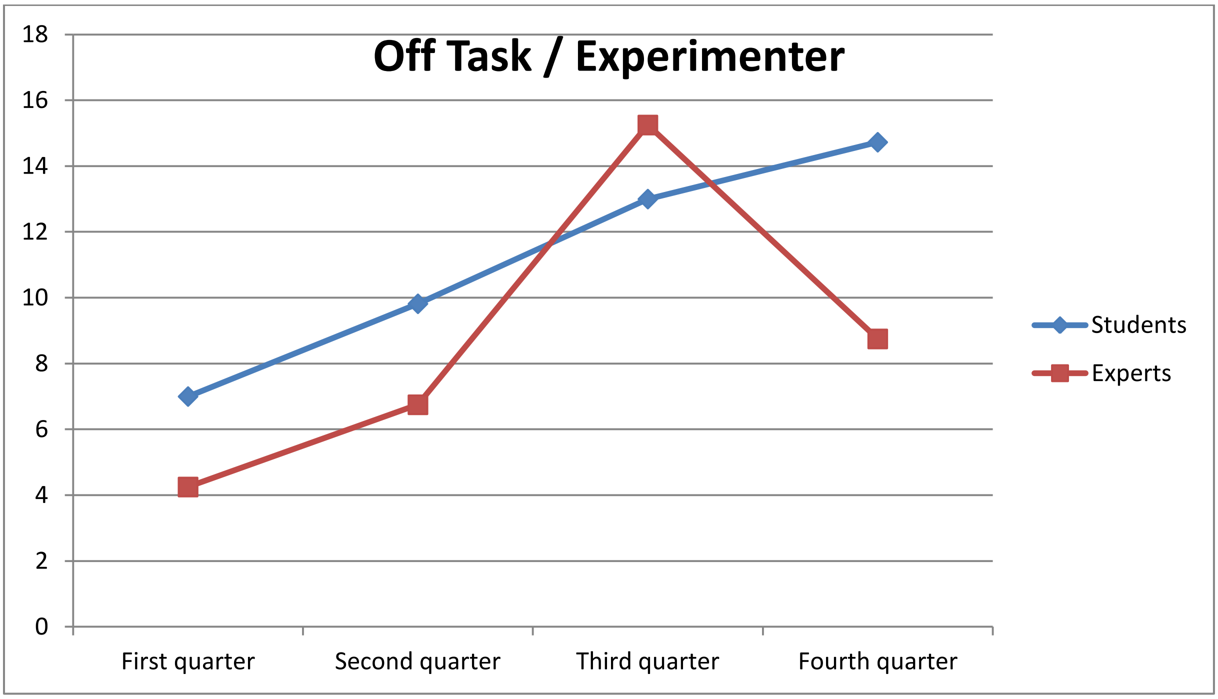
10
8
6
4
2
0
First quarter
Second quarter
Third quarter
Fourth quarter
Students
Experts


Off Task / Experimenter
18
16
14
12
10
8
6
4
2
0
First quarter
Second quarter
Third quarter
Fourth quarter
Students
Experts