

Learning by computer based teaching - A case study with the teachable agent Betty



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Abstract

The purpose with this case study was to see if the teaching element in the teachable agent Betty increases the understanding for the students. To do this I let one group of students learn by creating a dynamic model of the content and one group learn by teaching the computer agent Betty. To measure the knowledge of the students I had a pre- and posttest. The results from the tests showed that both the learning methods were excellent. Almost all of the students scored max points. Unfortunately I cannot show if the teaching element increases the understanding for the students who taught Betty. However the students teaching Betty did only learn what they were teaching Betty. Compared to just reading the information modeling and teaching increased the students' understanding. Another interesting point was that some students managed to create a perfect model or concept map by teaching Betty with a trial and error method. This resulted in that they got a perfect teaching result without really learning the content. The problem was that these students didn't fully understand the meaning of the concepts and the relationships in their model.

Foreword

The reason I got interested in teachable agents is my background in computer science and e-learning. Since 1999 I've not only been studying computer science but also working for an e-learning company (LUVIT AB). Combining learning pedagogic and computer science feels very compelling to me. Nowadays in Sweden the computer is almost as common as the television in our homes. Also every school has a computer room, but how is the computer used in everyday school teaching? My experience is that the computer in school is mainly used for searching information and word processing and this is also confirmed in reports made by a Swedish foundation called *KK-stiftelsen* (www.kks.se). A computer has many more possibilities to support learning at schools. One possibility which I have been studying is to use teachable agents.

I want to thank the following persons for helping me making this case study possible:

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1 Introduction

This report is the result of my degree project in cognitive science at Lund University. My project contains a case study in learning by computer based teaching.

That we learn by teaching is an old pedagogic thesis. According to Skinner (1994) Seneca wrote 2000 years ago “docendo discimus – We learn by teaching”. There have also been informal reports from teachers who find that teaching students is effective in improving their own understanding of the subject (Berliner, 1989 in Nichols, 1994). From this learning by teaching thesis there has derived a couple of pedagogical methods where you turn the students into teachers.

Another way of teaching is to let the students create dynamic models of a specific problem. By creating these models also known as causal loop diagrams the student creates an image of their own knowledge (Haraldsson, 2000). When they visualize their knowledge they also seem to learn the complex structures.

In USA some researchers (Schwartz et al, 2005) have taken this a step further by combining learning by teaching and dynamic models. They let the students create a dynamic model and teach this knowledge image to a computer agent – a teachable agent. The idea is that the student will learn from teaching, but instead of teaching another person you teach a computer agent. What is then a computer or software agent?

The definition of a software agent is according to Wikipedia.org (2005) the following:

“In computer science, a software agent is a piece of autonomous or semi-autonomous proactive and reactive, computer software. Many individual communicative software agents may form a multi-agent system.

To be considered an agent, a software object must be a self-contained program that is capable of making independent decisions and taking actions to satisfy internal goals based upon its perceived environment.”

A teachable agent is simply a software agent which is capable to be taught. The teachable agent which I used in my study is called Betty and the program where the agent is active is called Betty’s brain. I performed my study on twenty students by teaching them the gas laws in physics. The students were in the ages of 15 to 16. To have something to compare with I let one group of students create models on a paper and one group teach Betty.

In the rest of my report you will be able to read more about learning by teaching, modeling and of course the teachable agent Betty. Then I will present my study with my results and conclusions.

2 Problem and purpose

The purpose with my study will be to find out if the teaching element in learning by teaching improves the learning process for the student. I will measure the students' learning process by letting them take a posttest before and after the training session.

3 Analysis

In my analysis I will write about learning by teaching, learning by causal loop diagrams and of course teachable agents. Especially the teachable agent called Betty.

3.1 Learning by teaching

According to Schwartz (2005) there are many reasons to suppose that teaching improves the learning of the teacher. Teachers organize their knowledge to anticipate the needs of their students, and they can receive feedback about the quality of that organization. Responsibility and public performance may also lead to a more in-depth effort at understanding. Biswas (Biswas et al. 2001) showed in a study that students who prepared to teach a class learned better than students who prepared themselves to take a test.

I have found that there are many different approaches to learning by teaching.

Here I present three of them:

1. Let a pair of students teach the rest of the class
2. Let a more talented student teach a less able student
3. Learning by programming

3.1.1 Classroom teaching

The first method is maybe the most advanced one. Here you let the students fully prepare and teach lessons or parts of lessons. A difference to normal presentations or lectures performed by students is the preparations of their lessons. The students don't only present their content, but also choose a methodological and didactical approach in teaching their classmates.

The first book about this topic was published 1971 in USA by Gartner and 1975 by Kruger in Germany (Lockergnome Encyclopedia, 2005). Dr. Jean-Pol Martin made this method more acknowledged by his work with foreign language teaching in Germany. He developed the concept systematically for the teaching of French and also gave it a theoretical background in many publications on the topic. The method has spread widely in Germany through a network called LDL (Lernen durch lehren). The LDL community is currently running on their website www.ldl.de. According to Skinner (1994) this method can be used in both schools and universities. However you might need to have a different approach for more experienced students than children in compulsory school.

3.1.1.1 The approach

First the students are divided into groups of maximum three people. The teacher also hands out different subject areas which the groups should work with. The students' task is to teach their material to the rest of the class. An important step in this method is that the students have to prepare their lesson didactically and methodologically. The students should also make sure that their classmates have learned what they have been taught. In the end of their lesson the groups provide quizzes or exercises to evaluate their performance and also their classmates' knowledge. To make sure the motivation is high the students should have as a general rule to never have a boring lecture (Skinner, 1994). This method also requires a lot of work from the teacher. As a teacher you must learn when to speak and when to listen. Skinner usually interrupts after half of the session to correct the errors which the teaching students has done. The teacher acts more like a coach, supporting his students to perform well during their lessons.

3.1.1.2 Advantages and disadvantages

There are both advantages and disadvantages with this method.

Advantages (Skinner 1994, and Lockergnome encyclopedia, 2005):

- The students work more intensively on the material and are more active during their learning sessions
- The students learn how to think independently and critically
- The students develop skills in communicating information to groups
- The students receive planning abilities and learn how to work in teams
- The students also seem to gain self-confidence and reliability
- The students' learning motivation increases

Disadvantages (Skinner 1994, and Lockergnome encyclopedia, 2005):

- Both the students' and the teacher's workload increases
- The introduction of the method requires a lot of time
- If the students don't receive didactic impulses from the teacher the lessons might get very monotonous or dull

3.1.2 Peer tutoring

The second method is also known as peer tutoring. A more able student takes a role as a teacher or tutor and supports a less able student, the tutee with knowledge. When the tutee encounters problems with understanding the subject or other difficulties the tutor is there to help. The relationship between the tutor and the tutee can be seen as a form of collaborative activity (Katz & Lesgold, 1993 in Nichols, 1994). The learners work together, coaching each other whenever one student possesses knowledge the other one lacks.

Studies which have been made on peer tutoring report cognitive benefits from both the tutor and the tutee (Goodlad & Hirst, 1989 in Nichols, 1994). The great benefit with peer tutoring is that the students seem to work more with the content which reinforces the subject knowledge. Other advantages from peer tutoring is that the students improve their skills in communication of ideas and they also train their skills in confronting others understanding and perception of the subject domain. The tutors also develop insight in the teaching/learning process and report improved co-operation with their own teachers.

A common problem with peer tutoring is the collaboration between the tutor and the tutee. When tutors report what they liked least with this type of learning their most frequent answers include problems with attentiveness and discipline among their tutees (Goodlad, 1985 in Nichols 1994). These drawbacks to human-human peer tutoring might be solved by human-computer peer tutoring, also known as teachable agents (Nichols, 1994).

3.1.3 Learning by programming

Learning by programming can also be seen as a variant of learning by teaching (Papert, 1980 in Brophy et al., 1999). The students' task is to create a computer program, which often is some kind of simulation. By creating the program the student learns the important structure and algorithms for the simulation. A disadvantage is the overhead time for programming. Often the student use much time debugging their code instead of learning the subject domain. Of course the students also need to know how to program before the learning can take place.

3.2 Learning with causal loop diagrams

Causal loop diagrams (CLD) can be described as a method to visualize your knowledge. Causal loop diagrams may also be a powerful tool for learning abstract concepts and system thinking. I will now describe what causal loop diagrams are and how they work.

3.2.1 Causal loop diagrams

I start with describing the symbols in a CLD (adopted from Roberts *et al.* 1983, p56 in Haraldsson, 2000)

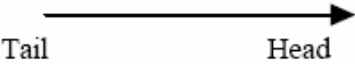
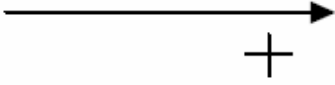
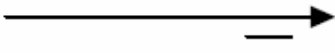
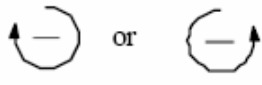
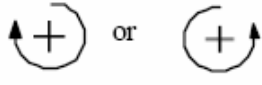
| Symbol | Meaning |
|--|---|
| <p style="text-align: center;">Arrow</p>  | <p>The arrow is used to show causation. The item at the tail of the arrow cause a change it the item at the head of the arrow.</p> |
|  | <p>The + sign near the arrowhead indicates that the item at the tail of the arrow and the item at the head of the arrow change in the <i>same</i> direction. If the tail <i>increases</i>, the head <i>increases</i>; if the tail <i>decreases</i>, the head <i>decreases</i>.</p> |
|  | <p>The -sign near the arrowhead indicates that the item at the tail of the arrow change in the <i>opposite</i> direction. If the tail increases, the head decreases; if the tail decreases, the head increases.</p> |
|  | <p>This symbol (also B), found in the middle of a closed loop, indicates that the loop continues going in the same direction, often causing either systematic <i>growth</i> or <i>decline</i>, behaviour that unstable moves away from equilibrium point. This is called a <i>positive feedback loop</i>.</p> |
|  | <p>This symbol (also R), found in the middle of a closed loop, indicates that the loop changes direction, causing the system to <i>fluctuate</i> or to <i>move toward equilibrium</i>. This is called a <i>negative feedback loop</i>.</p> |

Figure 1. The symbols in a causal loop diagram (Roberts *et al.* 1983, p56 in Haraldsson 2000).

Hörður Haraldsson (2000) further explains causal loop diagrams by a hypothetical example. The diagram contains three variables A, B and C with the following relationships. Variable A has an increase effect on variable B, variable B has a decrease effect on variable C and variable C has an increase effect on variable A. These conditions will give you the following CLD:

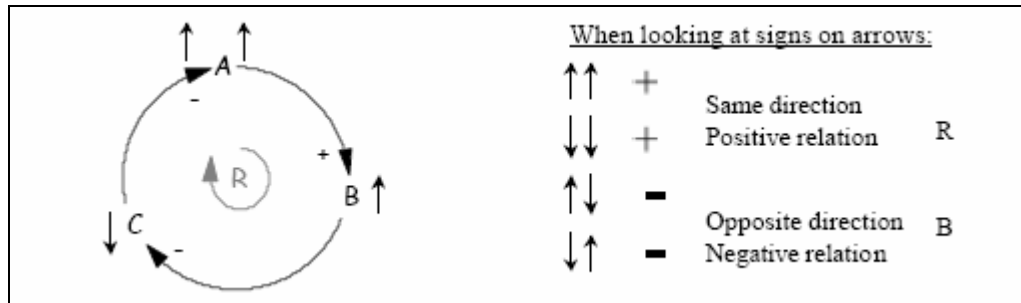


Figure 2. Example of Causal loop diagram (Haraldsson, 2000).

Haraldsson use the small arrows to show the changes in variables (see figure 2). We analyze the CLD by starting with the relationship between A and B. *If A increases, B will also increase* (↑↑). Since it is a relationship in the same direction (notice the arrows), we add a plus sign (+) which tells us that it is a positive relationship. Note that variables can also decrease in the same direction ↓↓ which also gives us a positive relationship. Further, *if B increases, C will decrease* (↑↓). This will give us a negative (-) relationship between B and C. At last *C decreases, which causes A to increase* (↓↑). This gives us a negative relationship (-) between A and C.

3.2.1.1 Reinforcing or balanced system

A causal loop diagram is either a reinforcing (indicated by R) or a balanced system (indicated by B). In our case we have a reinforcing system. You can easily see that by analyzing the arrows on the variable A. The variable A starts with increasing and also ends by increasing (↑↑). If we had a system with opposite starting and ending arrows (↑↓), we would have a balanced system. When we are done with the loop we should erase all the small arrows (not the causal links between the variables).

3.2.1.2 Example of reinforcing and balanced systems

In this example from Haraldsson (2000) we have that population increase from increases of birth. This is a typical reinforcing system.

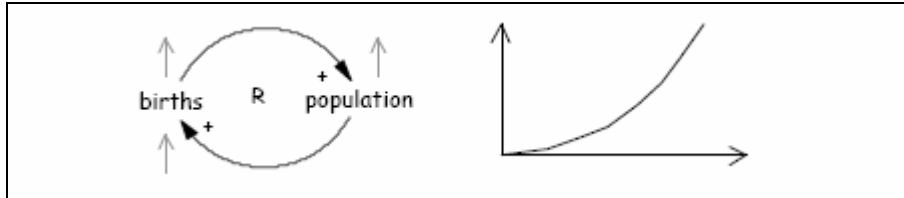


Figure 3. A reinforcing system (Haraldsson, 2000).

But when we add the factor “death” to the system we get a balanced system.

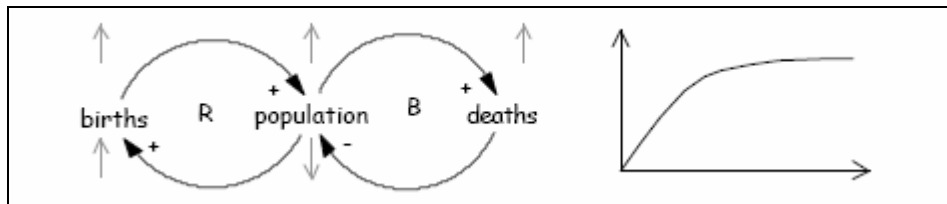


Figure 4. A balanced system (Haraldsson, 2000)

According to Haraldsson (2000) *all systems attempt to balance themselves in one way or another*. This indicates that reinforcing systems are temporary and will sooner or later become balanced.

3.3 Teachable agents

As I wrote in the introduction a teachable agent is simply a software agent which is capable to be taught. There are many teachable agents. Here I will present the one which I used in my study, the teachable agent Betty. I will start with how the program works and then I will present some studies which have been done. Finally I will present some extensions of Betty and some other teachable agents.

3.3.1 Betty – a teachable agent

Betty's brain and Betty was developed in USA by AAA lab at Stanford University (<http://aaalab.stanford.edu>) and by TAG-V group at Vanderbilt University (<http://www.teachableagents.org>). Currently there is only a beta version of Betty and the program has only been used for study purposes. My conclusion is that Betty is built on the notation of peer tutoring where the student is the more-able tutor and Betty is the tutee. However in this case the tutee is always highly motivated to be taught.

When creating Betty Biswas and Schwartz tried to embody four principles of design (Biswas et al., 2005a):

1. Teach through visual representations that organize the reasoning structures of the domain
2. Build on well-known teaching interactions to organize student activity
3. Ensure Betty has independent performances that provide feedback on how well she has been taught
4. Keep the start-up cost of teaching Betty very low (compared to programming). This occurs by only implementing one modeling structure with its associated reasoning mechanisms.

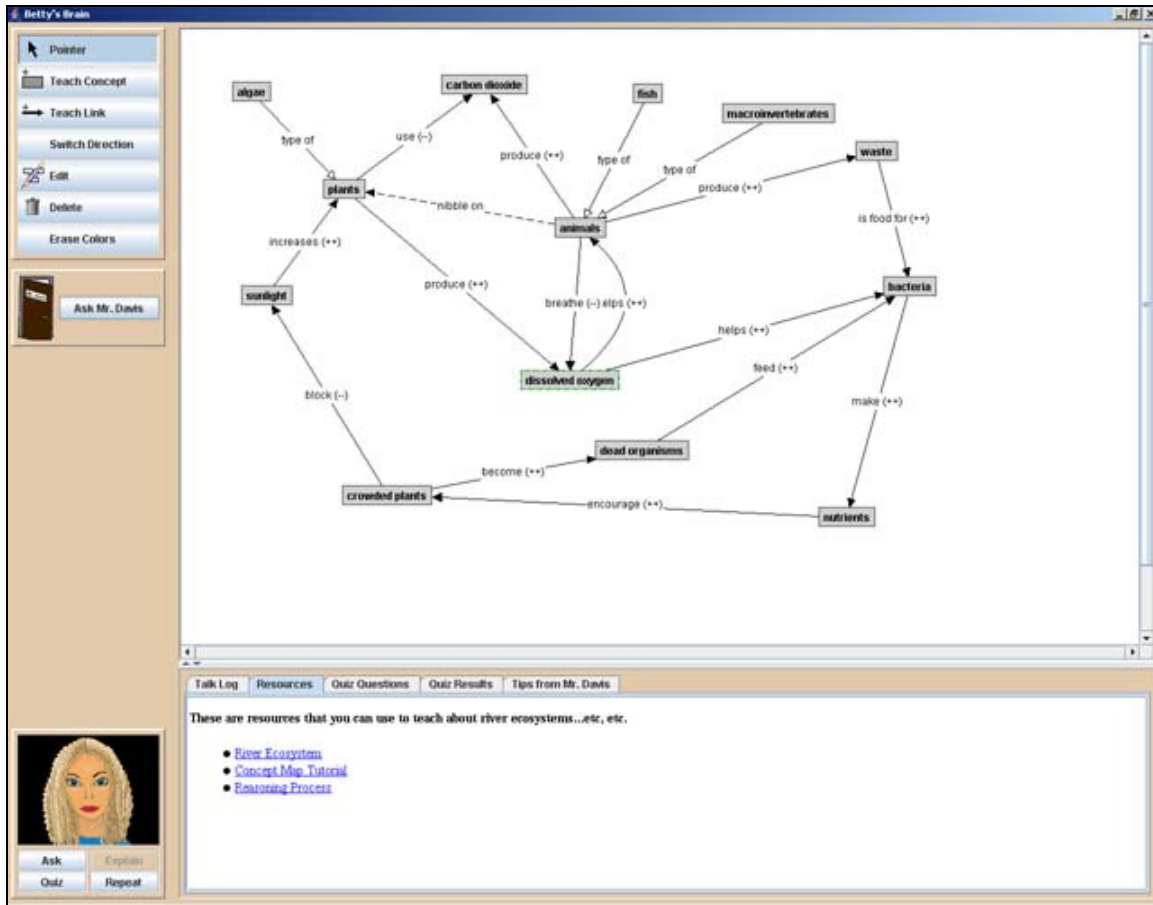


Figure 5. Screenshot of Betty's Brain. Here she is taught the system dynamics of a river ecosystem.

Betty's brain consists of the teachable agent Betty and also a mentor agent called Mr. Davis. The student is able to teach, query and quiz Betty. Betty communicates to the students by both speech and animations. The student also has access to a talk log where everything Betty has said can be read. The student may ask Betty to repeat her explanations at anytime.

3.3.1.1 Teach Betty

Students teach Betty by creating a concept map (see figure 5). A concept map is a collection of concepts with relations between each other (Novak, 1996 in Biswas, 2005a). A relation is a unidirectional link connecting two concepts. Concept maps provide an expressive graphic language for creating domain knowledge structures, and this provides students a means for creating sophisticated structures without getting involved in programming (Biswas et al., 2001 and Leelawong et al., 2003). You can teach her three different types of relationships; causal, hierarchic or property.

- A **causal** link specifies how one concept affects another concept. You can teach Betty how one concept decrease or increase another concept. For

example we have the concepts *fish*, *oxygen* and *carbon dioxide*. We can then teach her that *fish produce carbon dioxide* by creating an *increasing* causal link between *fish* and *carbon dioxide*. By creating a *decreasing* causal link between *fish* and *oxygen* we taught Betty that *fish breathe oxygen*.

- **Hierarchical** links are used when a concept is a type of another concept. For example a *fish is a type of animal*. *Fish* then inherits the attributes from *animal*. For example if you taught Betty that *animals eat plants* she then also knows that *fish eat plants*.
- **Property** links are used when the student wants to add notes or interesting characteristics of an object in their concept map. For example you can teach Betty that *fish live by rocks*.

The student who is teaching Betty has access to searchable HTML-resources about the subject domain. There the student should find all the information which is needed to teach Betty.

3.3.1.2 Query Betty

After the student has taught Betty something the student are able to start asking her questions. The student can ask her two types of questions:

1. If concept A increases / decreases what happens to concept B?
2. Tell me what you know about concept A

The screenshot shows a dialog box titled "Ask Betty". It contains two main sections. The first section, "What is the question?", has two lines of input. The first line is "If" followed by a dropdown menu with "algae", a dropdown menu with "decrease", and a comma. The second line is "what happens to" followed by a dropdown menu with "animals" and a question mark. The second section, "My Note", has a label "What Betty's answer should be:" followed by a dropdown menu with "decrease". At the bottom are "OK" and "Cancel" buttons.

Figure 6. Screenshot of how to ask Betty questions.

The student should also guess what he/she thinks is the correct answer to the question. This is done to ensure that the student also reasons about the question and not only Betty. Betty answers the questions based on what she has been taught by the student. While explaining her answer she also animates her thoughts in the concept map by lighting up the concept boxes. She explains her answers by speech, animations and text in the talk log. On the first type of question she starts with just telling the student her answer. Then if the student doesn't understand how Betty got her answer, the student may ask her to explain. Then she step by step explains and animates in the concept map how she reasons (see figure 7). The reasoning and explanation mechanisms are more described in detail by Biswas (2005a).

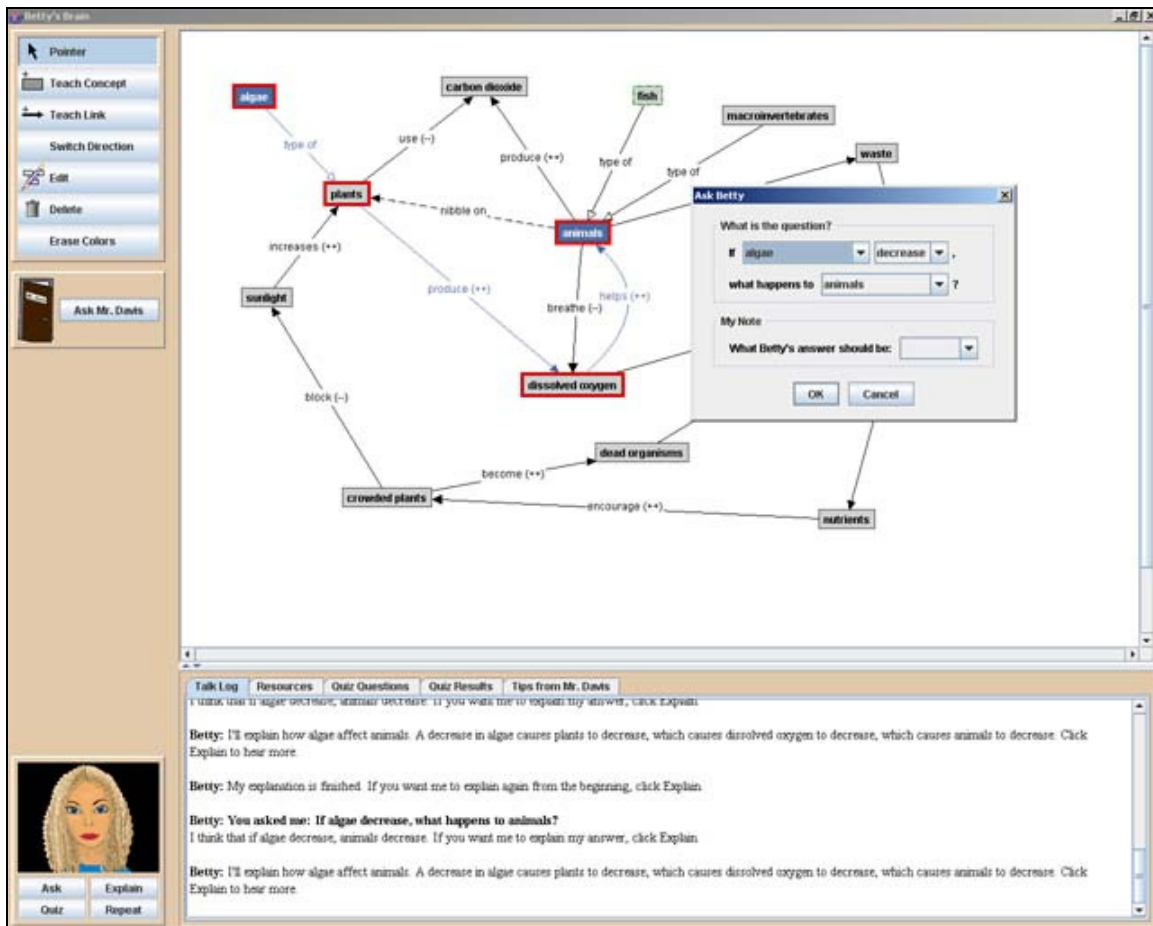


Figure 7. Screenshot of how Betty animates her explanations in the concept map. Here I asked Betty what happens to animals if algae decrease. First she tells me that animals decrease if algae decrease. Then I asked her to explain why. She tells me that a decrease of algae causes plants to decrease, which causes dissolved oxygen to decrease, which causes animals to decrease.

3.3.1.3 Quiz Betty

When the student has taught Betty a certain amount of knowledge she is able to take a quiz. The questions of this quiz are preset by the system designer (teachers) when configuring the application. The questions in the quiz are of a

similar type as the questions the student is able to query Betty. This provides an external assessment mechanism, which examines how well the student has taught Betty. While Betty is taking the quiz she is sent to Mr. Davis (the mentor agent) which also grades her results. Afterwards Mr. Davis gives feedback to Betty (and the student) of how it went. He also provides hints which could help the student to find errors in their concept map. Mr. Davis also knows the correct concept map which he can compare with the student's map. Mr. Davis then knows what link or concept is missing and then generates a hint for the student. There are also three levels of hints.

1. The first time a student has an incorrect answer Mr. Davis refers to where the student can find the answer in the online resources.
2. The second time Mr. Davis explicitly mentions the name of the missing concept or link.
3. The third time Mr. Davis also tells the student where to put the concept or link in the concept map.

The screenshot shows the 'Betty's Brain' interface. On the left is a toolbar with tools like Pointer, Teach Concept, Teach Link, Switch Direction, Edit, Delete, and Erase Colors. Below the toolbar is an 'Ask Mr. Davis' button and a character portrait of Betty. The main area displays a concept map with nodes: 'plants', 'carbon dioxide', 'fish', 'macroinvertebrates', and 'animals'. Relationships include 'use (-)', 'produce (++)', 'type of', and 'nibble on'. A 'Quiz 1' window is open at the bottom, showing a table of results and a text input field for asking questions.

| Question | Quiz Answer | Current Answer |
|---|-------------|----------------|
| 1. If waste increases, what happens to plants? | A decrease | A decrease |
| 2. If waste increases, what happens to bacteria? | An increase | -- |
| 3. If bacteria increase, what happens to nutrients? | An increase | -- |
| 4. If nutrients increase, what happens to crowded plants? | An increase | -- |
| ...ens to sunlight? | A decrease | -- |
| ...o plants? | A decrease | -- |

Figure 8. Screenshot of Betty's quiz result. The results of the questions are shown by happy or unhappy smileys. The student is also able to ask her a specific quiz question afterwards and compare her current answer with her old answer.

3.3.1.4 Mr. Davis office

When the student encounters problems teaching Betty the student may turn to Mr. Davis for help (see figure 9). Mr. Davis provides information of where the student finds the online resources and how the student should teach Betty. He also tells the student how to be a good learner. Mr. Davis also evaluates what the student has taught Betty and depending on the results he gives the student tips about what to do. The information from Mr. Davis also depends on what the student has done. If the student hasn't asked Betty any questions for a long time he may tip the student to do so. Also Mr. Davis doesn't reveal all of his information at once, instead he tries to hint the student in the right direction and if the student comes back without any progress he reveals a bit more information and hints.

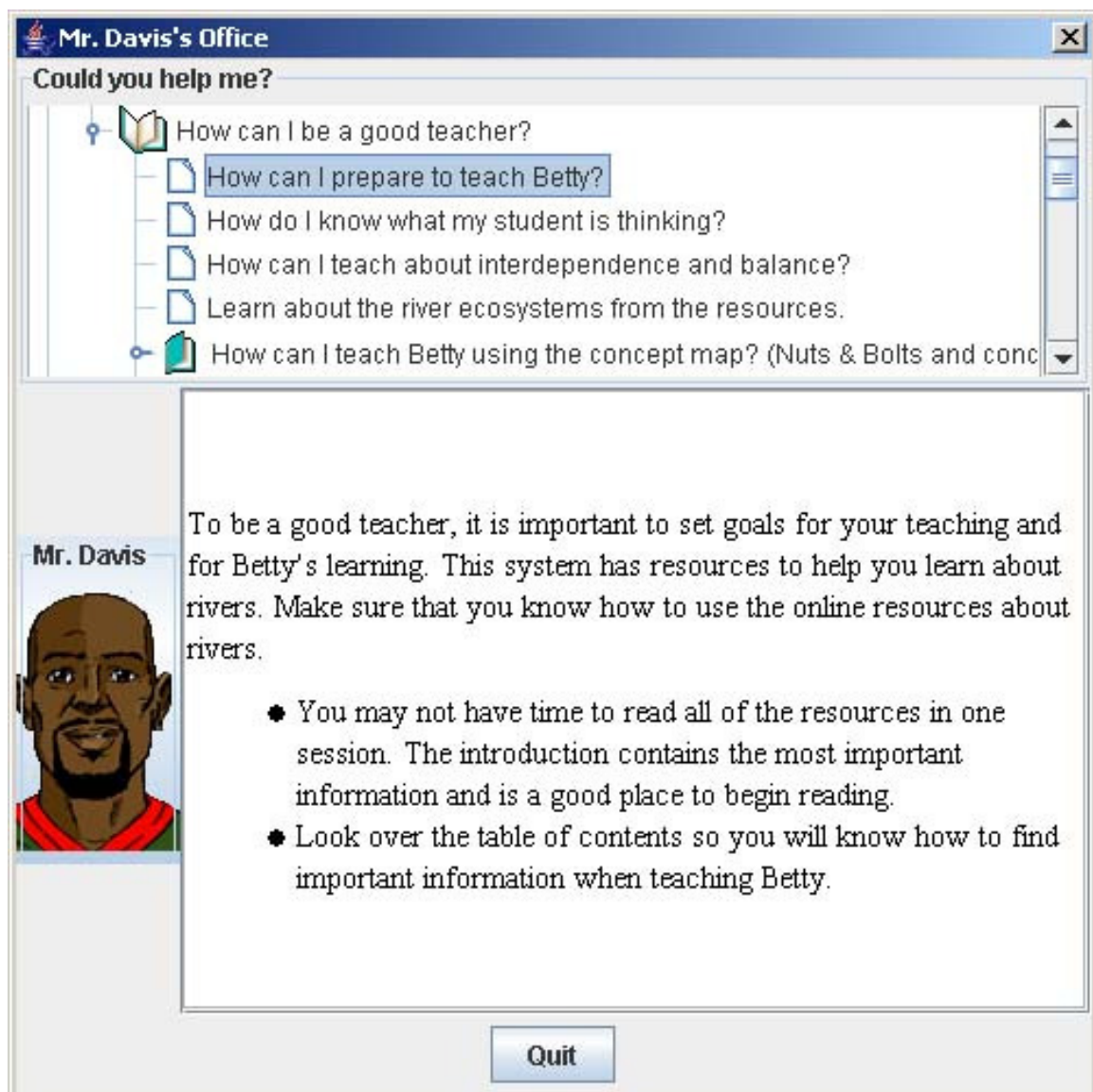


Figure 9. Screenshot of Mr. Davis. Here the students can find information on how to teach Betty.

3.3.2 Studies performed on Betty's brain

Several studies have been done on Betty's brain. Here I will briefly make a summary of some studies. Further reading about the studies can be found in their references.

3.3.2.1 Usability

In early stages of the development of Betty's brain the researchers made a usability test and it showed that it only took about 5 minutes to grasp the graphical user interface (Schwartz et al., 2005). Compared to learning by programming it lowers the programming overhead time considerably. But there are a lot of thoughts which Betty not can be taught. Therefore, Schwartz et al. don't see teachable agents as the only means of instruction, but rather as a way to help novices grasp abstract important structures. Another difference from programming is that the structure is not hidden in code. Instead it is clearly shown for the student as a concept map.

3.3.2.2 Teach, query and quiz study

In one study Biswas et al. divided the students into four groups where one group only could teach Betty, one could both teach and query Betty, one could both teach and quiz Betty and the last could teach, query and quiz Betty (Biswas et al., 2005a). The results from the study shows that both the Query and Quiz features had beneficial effects on students' learning. The query mechanism seems to be helpful to understand and create causal links between the concepts. The quiz mechanism on the other hand helped the students to decide what concepts and relationships that was relevant to teach Betty. The students found out that the concepts which are in the quiz questions were important. The group who could both query and quiz Betty did not generate significantly higher-quality maps than the quiz and the query groups. An investigation of the activity logs revealed a pattern where students' primary focus was to get the quiz questions correct.

3.3.2.3 Co-Mingling Animations with Students' Ideas

Schwartz (2005) conducted a study where they wanted to see if students incorporate Betty's knowledge structure into their own. The result of the study shows that students do incorporate Betty's visual structure into their own thinking when they co-mingle their ideas with the Betty. This incorporation also depends on whether Betty animates her thinking or not (see figure 10).

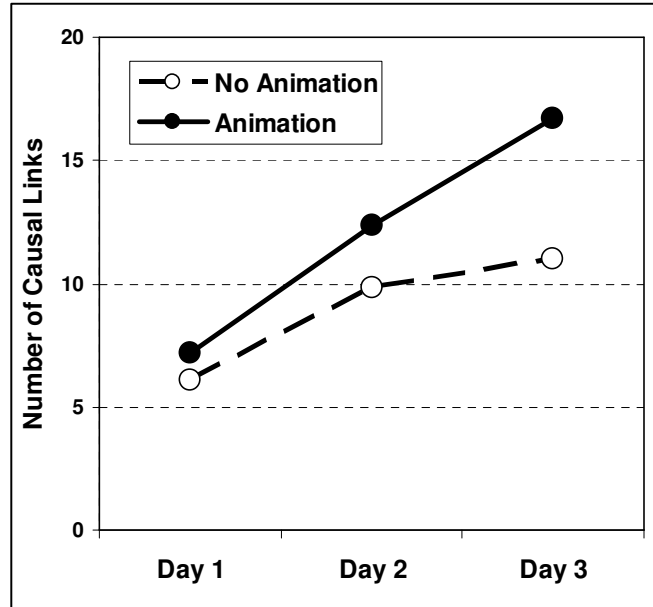


Figure 10. Students who see Betty animate her reasoning add more causal links (Schwartz et al., 2005).

3.3.2.4 Agents' independent performance supports learning

When people teach somebody else who has to perform, they cannot count on their own abilities and “situational smarts” to generate answers on the fly or sidestep challenges as they arise. They need to formalize their knowledge in a clear and unambiguous way for the tutee. Moreover, by seeing how the other person performs, they receive projective feedback about their knowledge as incorporated into the other person. Schwartz (2005) proposal is that we can garner these types of benefits with teachable agents when they perform in a secondary context.

To make this possible they created an extension to Betty which is called Front-of-class (FOC). After the students have taught their agent, the agents are projected in front of the class. There the agents are tested with a quiz simultaneously (see figure 11). Then the agents take initiative in a secondary context where they perform based on how they were taught.

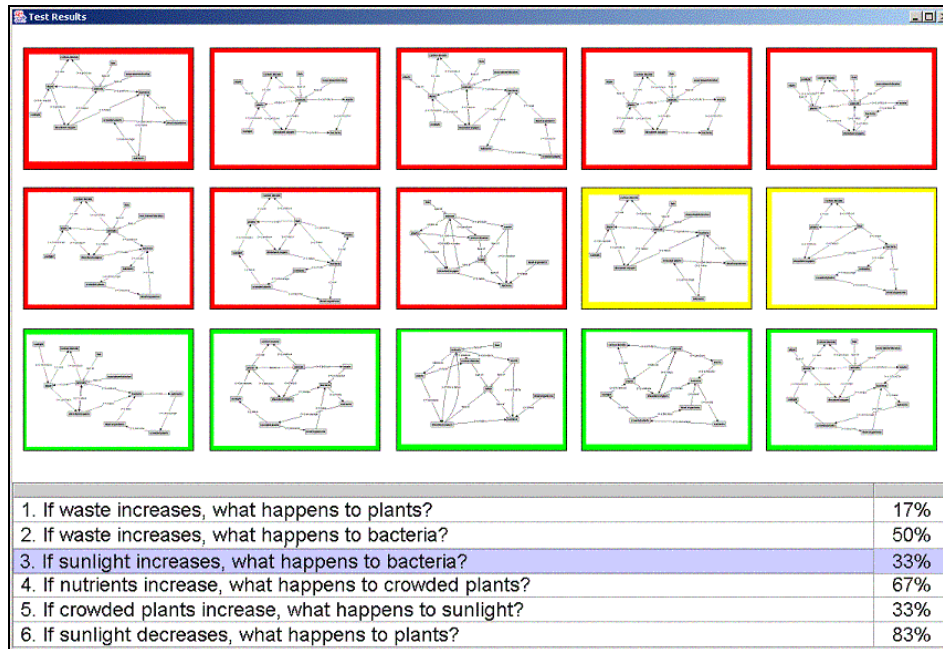


Figure 11. Front of class quiz system for showing agents perform (Schwartz et al., 2005).

Schwartz did a study with one group using FOC and one using solitary agents. After one quiz the students were able to revise their concept maps. Afterwards the FOC group were superior the solitary group (75% versus 63% correct concept maps). Especially good were the FOC group on quiz questions which included more causal links (see figure 12).

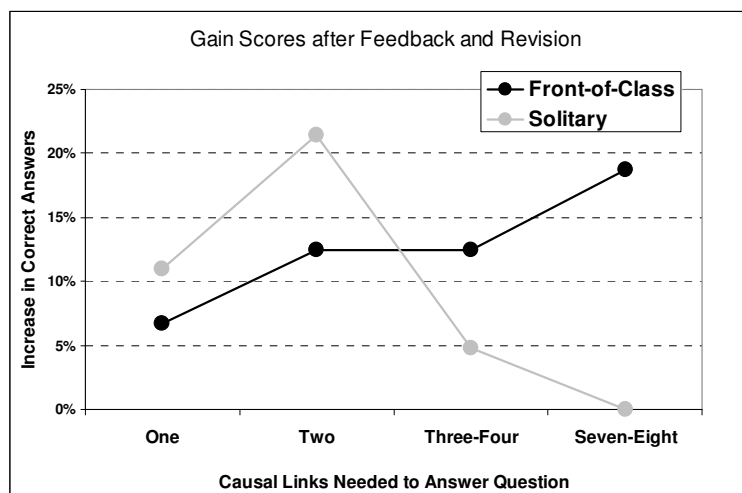


Figure 12. Changes to the quality of Betty maps when assessed by asking all possible questions. Students in both conditions improved their maps after seeing Betty answer a few quiz questions. Students who saw their agents at the front of the class improved the overall structure of their map more (Schwartz et al., 2005).

3.3.2.5 Self regulated learning with mixed initiative

It is shown that tutors gain a deeper understanding when they have interactions with a tutee which include answering tutee questions, explaining materials, and discovering misconceptions (Chi et al., 2001; Graesser, Person, & Magliano, 1995; Uresti, 2000 in Schwartz et al., 2005). Schwartz proposes that by letting Betty sometimes take the initiative in her own learning process the students' will apply this metacognitive strategies when learning new content (Bransford & Schwartz, 1999 in Schwartz et al. 2005). Betty incorporated the metacognitive strategies of monitoring, assessing, goal setting, seeking assistance, and reflecting on feedback.

| Student Action | State of System | Samples of Betty's Dialog |
|--|---|---|
| Tell Betty to take a quiz | Student has not asked Betty a question since the last quiz. | "I still do not feel prepared to take a quiz. I don't understand enough about the causal relationships in the river. Please ask me some causal questions to see if I understand. Mr. Davis can help you learn more about being a good teacher." |
| | Betty's answers have changed since the last quiz | "What you have taught me has changed my thinking. I had some questions right on the quiz, but now I think I would answer them wrong." |
| Add a link to Betty's concept map | First causal link in the session | "Hey! Let me see if I understand this." (Betty reasons with link, and explains her reasoning) |
| | First causal path with two or more links | "OK. I think I know how this works." (Betty reasons with path, and explains her reasoning) |

Table 1. Examples of Betty taking initiative (Schwartz et al., 2005)

To confirm these hypotheses Schwartz (2005) conducted a study where one group of students used a mixed-initiative Betty, one group used a normal Betty (teaching condition) and finally one group used standard computer-based instructions (being taught condition). After their first training session the three different groups had about the same results. One month later the students did a transfer task. During this task they were supposed to create a concept map with help of online resources, a quiz feature, and a mentor agent who only said whether the answers to the quiz were right or wrong. There was no directive feedback, no shared initiative, and no metacognitive guidance. The results of the transfer task showed that using a mixed-initiative agent led to significant gains in abilities to learn. The other two groups didn't learn how to use resources to support their learning or how to monitor their understanding.

3.3.3 Further development of Betty

The development of Betty continues. She is now also able to be a competitor in a game show (see figure 13).

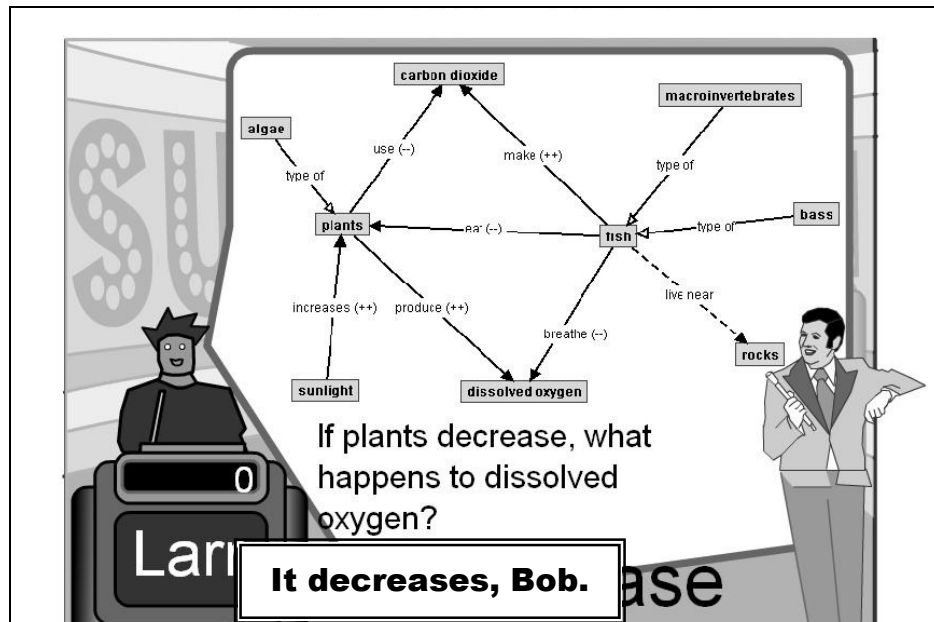


Figure 13. A customized agent performs in an on-line game show with other agents (Schwartz et al. 2005).

The students are able to go home and teach their Betty and afterwards they can upload their taught agent to a game show. They can customize the looks of their own agent and compete against other agents. The game host asks agents to answer questions and show their thinking. There is also a chat where the students can cheer for their agent and communicate with the other competitors. Schwartz (2005) hopes that students will find this both engaging and educative by using this system to prepare themselves for their lessons in school the next day.

3.3.3.1 Temporal reasoning

In the latest version Betty has also been equipped with temporal reasoning. Her qualitative reasoning mechanisms have been extended so that she can reason with cycles and determine how entities change over time. Also a simulation environment has been built (see figure 14) where the students can simulate the river ecosystem. The idea is to let the students first learn about dynamic behavior in a simulation and then teach Betty their new knowledge (Biswas et al. 2005b).

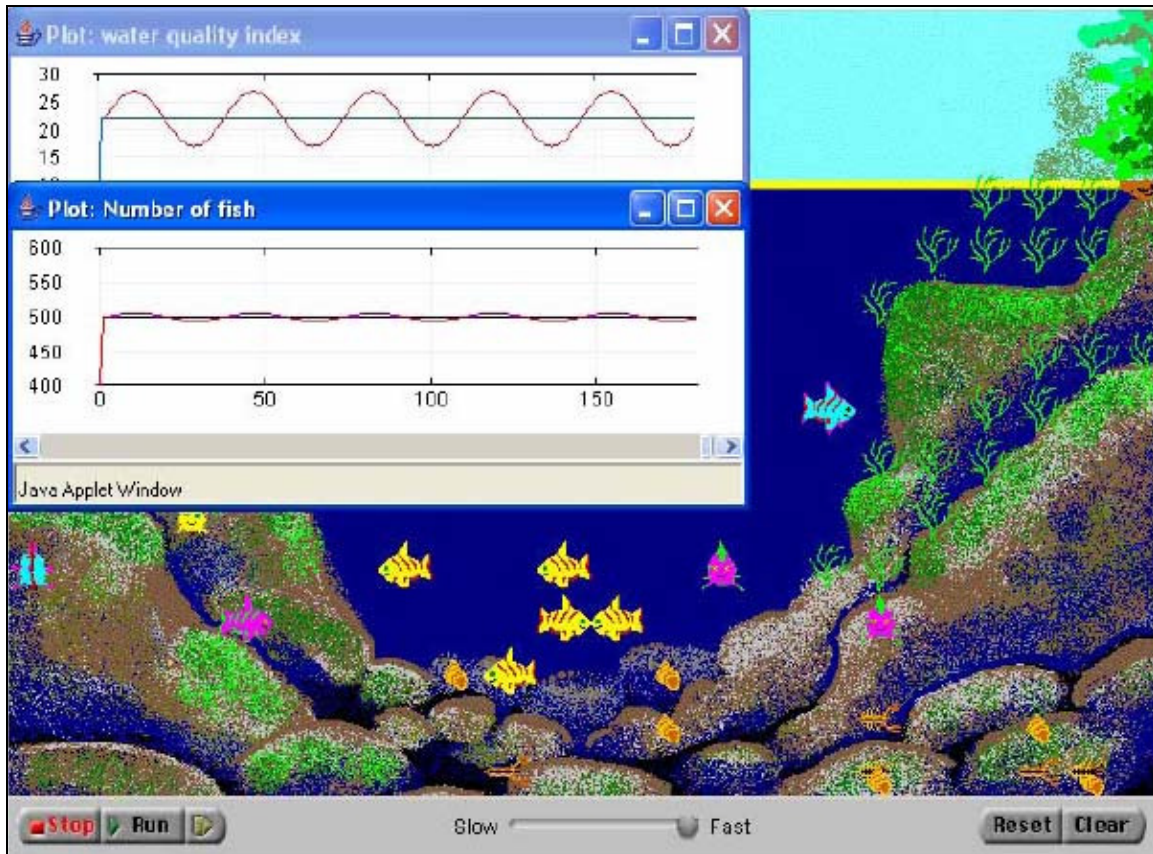


Figure 14. Screenshot from the simulation environment (Biswas et al., 2005b).

3.3.4 Other teachable agents

Betty is not the only teachable agent. The AAA-lab at Stanford has also Moby, Milo, Orbo, J-Mole and Hobbies (AAA-lab homepage, 2005). Before Betty there was also a teachable agent called Billy (Katzlberger et al., 2001). Billy was an animated character who was capable to be taught. For example you could draw a graph to teach him the relationship between distance and time at different speeds.

4 Method and performance

I decided to carry out my study according to the following steps:

1. A pretest
2. The training session
3. A posttest
4. An evaluation
5. Interviews

First of all I let the students take a pretest (see appendix 1) with some questions about the gas laws. This was made a week in advance because I wanted the students to forget what the questions were. After the training session they did the same test again as a posttest, which made it easy for me to see their progress of their training. To get more information about how they experienced the training I also let them answer to an evaluation (see appendix 2). After analyzing my results I decided to have interviews with two students since their results was specifically interesting.

4.1 Preparations

Since I wanted my study both to give me interesting results and also learn the students something new I had to prepare myself a lot. First of all it was very difficult to find a section in physics which was well suited for teaching by modeling. I started to model a swinging pendulum. It worked but there were too few parameters which were dependent on each other. This made the model uninteresting to teach Betty. I had to find a subject with a lot of causal relationships. Preferably also with concepts which are dependent of each other in several ways. Chains of relationships are extra interesting.

After a tip from the teacher I switched subject to the ideal gas law. Even with this subject I had problems making the model interesting enough. With just the gas laws the model contains three independent systems where only two concepts are depending on each other and the third concept is constant. But by inserting one of the systems into a practical environment I could create a model which would give the students some meaningful knowledge.

4.2 The content

For creating my content I received some textbooks from the teacher and also some exercise books. Of course I also browsed the web for more information about the gas laws. First I started describing what the training session contained and then I continued about the gas laws. I described each state of the gas law, when the volume is constant, when the temperature is constant and finally when the pressure is constant. Further I wrote about the ideal gas law and finally I ended with describing the practical example which the student were supposed to model or teach Betty. By placing the section about the practical example last I

figured the students would read the theory first. As an extra help for the students I added a glossary which explains the important words in the text. The content is presented in Appendix 3.

4.3 The source code

Later I encountered another problem. When I inserted the new content in Betty I noticed that much of the content in Betty was hard coded – the content was locked inside the application. To be able to insert my content I needed the source code from Vanderbilt University. Fortunately Mr. Biswas was nice to me and sent me the source code so I could continue with my project. When I had the source I could adopt it to suit my needs. The following issues were hard coded in the system and had to be changed in the source code:

1. The number of headlines and also the names of the headlines in the content.
2. All of Mr. Davis feedback to Betty (and the student) after completing a quiz.
3. The help texts which are shown for the students by Mr. Davis about how and what to teach Betty.
4. The response from Betty to the students.
5. The number of links between concepts Betty must know before she is able to take a quiz. Before Betty could take a quiz she had to know four links, but since my concept map was much smaller I allowed Betty to take a quiz with only knowing two links. I figured the students could begin letting Betty take a quiz after only teaching her the relationship between the pressure and the temperature when the volume is constant.

Since the program also compares the concept map taught to Betty and an expert map I had to change the expert map. I did that by only teaching Betty a new map and replace the old one with the new map. I also created new quiz questions and noticed that the quiz questions must be written in lower case characters otherwise the system crashes. The quiz questions are presented in appendix 4.

4.4 Pilot study

Before I made the real study I made up a test session with four students from another department. They were familiar with creating causal loop diagrams (CLD) before, but I wanted to try the setup of my study. Two of the students were using Betty and the other two were creating a CLD on a blank paper, but they had access to the same content. I noticed what was difficult to understand or could be misunderstood. I also gave them the pre- and posttest. One change I had to do was to create more quiz questions for Betty. I only had four questions, but in them I included the whole model. The students tried then to skip some steps and that made them confused. I then decided to create a couple of easy questions just to help the students build the model. I created a question for each concept and almost every link. The students in the pilot study managed to create exactly the correct model in the end. I also noticed what difficulties there were in the graphical user interface in Betty and what I had to present to the students before starting the training session.

4.5 The training session

During the training session I divided the students into two groups. One group was teaching Betty and the other group was creating a causal loop diagram for themselves. I started by introducing myself and the purpose of my study. Then I introduced the basics of creating causal loop diagrams. After that I handed out the content to the CLD group. While they were reading the content I gave a presentation of Betty for the rest of the students. The presentation included:

1. How you find the content inside the application
2. How you teach Betty the content
3. How you ask Betty questions of what you have taught her
4. How you let Betty take a quiz
5. How you receive feedback from the quiz
6. The purpose of the quiz questions
7. How you ask Betty a specific quiz question

Finally I stated that when Betty correctly could complete all quiz questions they were finished with the training session. The training session lasted about 80 minutes, but the students were free to go when they were finished. Both the groups had access to the same content and they were supposed to come up with the same kind of models. But there were also a slight difference (see figure 15 and figure 16). Since it is obvious to a person that a lifting airplane increases in altitude and by turning up the heat the temperature rises, the CLD group could overlook that in their models. Betty on the other hand is totally clueless so the students had to teach her this as well.

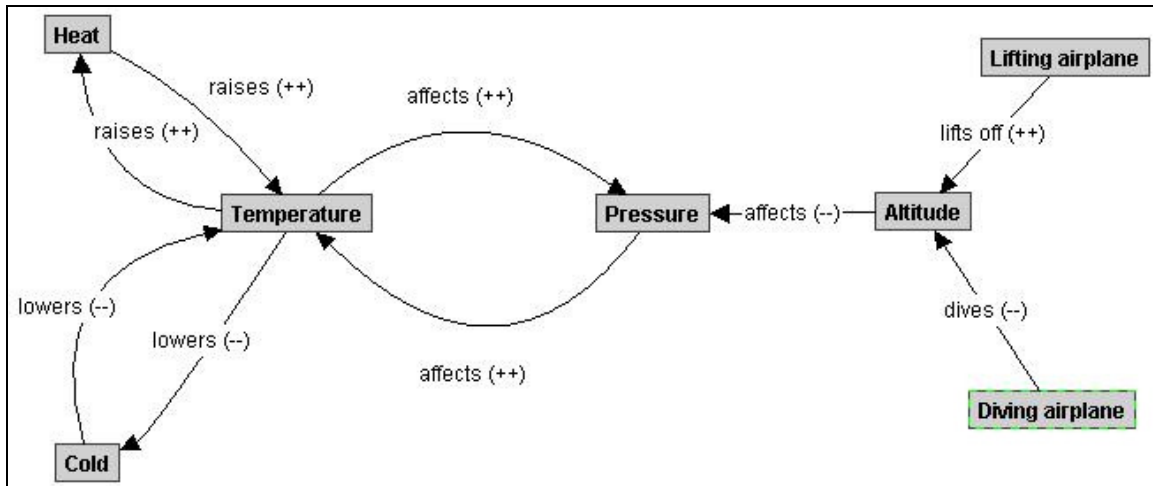


Figure 15. This is the model which the students were supposed to teach Betty.

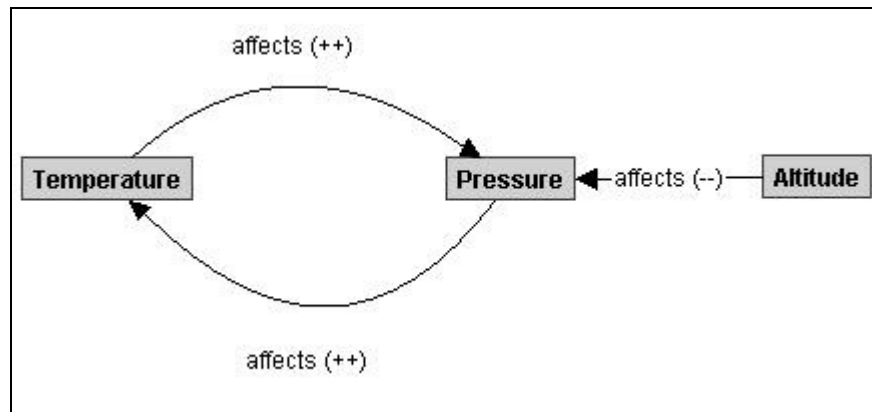


Figure 16. This is the model which the CLD group was supposed to create.

In the presentation of CLD and Betty I used temperature and volume instead of temperature and pressure. By including volume in my presentation almost all students started with including the volume too. I had to explain to them that in their model the volume is constant and doesn't affect any other concept. Some students still wanted to include the volume in their concept maps. After the presentation the students managed to use and teach Betty without much further instructions. During the training session I walked around and helped the students when they encountered problems or difficulties. All the students in the CLD group had to get some help from me, but in the Betty group some students managed without any help.

4.6 Interviews

After my study I also interviewed two students which I found particularly interesting. These two students didn't reflect their knowledge in their concept models. I asked them to describe how they created their concept model. How did they think when they were creating their models? What was difficult to understand? What did the arrows (causal links) mean? Did they use the model when they were answering the questions in the posttest?

5 Results and discussion

It is always difficult to measure knowledge and also how and when the knowledge is perceived. My idea was to try to measure the students' knowledge before and after the training session with a small assessment. By letting the students take the pretest a week before the training session I hoped they would have forgotten the questions during the training session. If I had let them take the pretest immediately before the training session I think that they would have focused on the questions during the session and that would have affected their results. The posttest was on the other hand taken instantly after the training session. The model which the students were supposed to create was a practical example where the volume was constant. But in my assessment I also added questions which tested the rest of the content – the content which the students didn't create a model of.

5.1 The results from the pre- and posttests

The test consisted of seven questions, where Q1, Q2, Q5a and Q6a were connected to the concept model. The answers to the other questions were just mentioned in the content. The students which created the model with Betty are called the Betty group and the other is called the CLD group.

| Questions | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Total |
|----------------------|-----|-----|-----|-----|-----|-----|-------|
| Betty group | | | | | | | |
| Avg. points pretest | 0,4 | 0,6 | 1,2 | 1 | 1 | 1,1 | 5,3 |
| Avg. points posttest | 1,9 | 1,8 | 1,7 | 1,7 | 1,4 | 1,4 | 9,9 |
| Difference | 1,5 | 1,2 | 0,5 | 0,7 | 0,4 | 0,3 | 4,6 |
| Paper group | | | | | | | |
| Avg. points pretest | 0,3 | 0,5 | 1 | 0,8 | 1 | 1,2 | 4,8 |
| Avg. points posttest | 2 | 2 | 2,8 | 2 | 2 | 2 | 12,8 |
| Difference | 1,7 | 1,5 | 1,8 | 1,2 | 1 | 0,8 | 8 |
| Max points | 2 | 2 | 3 | 2 | 2 | 2 | 13 |

Table 2. The results from pre- and posttests.

5.1.1 No difference between the teaching methods

As you can see the CLD group has almost increased their points twice as much compared to the Betty group. But we should mostly focus on the two first questions since they are related to the model which the students were supposed to teach Betty (and learn themselves). There you can see that there is only a slight difference between the groups. Only one student in the Betty group missed the first two questions otherwise all students scored max points on those questions. This shows that both methods are good teaching methods, but you cannot tell that one is better than the other.

5.1.2 Students only learn what they are teaching Betty

An interesting point is that the students using Betty seem only to learn what they are teaching Betty. They did not learn the rest of the content. They focused more on teaching Betty the specific model which probably made them ignore the rest of the content. The CLD students on the other hand seem to have learned the complete content. Everybody but one in that group scored max points on the posttest. One reason might be that those students first tried to make a model of the whole content (all the gas laws) before they started to create the specific practical example. Then they had learned also about the other gas laws, which is reflected in their posttest results.

5.1.3 Communication disadvantages

Another thought is that the CLD group worked in pairs since they didn't use the computer. Then they could discuss their model and their thoughts with each other and that might have affected their results. This might illustrate the difficulties with communication and collaboration with computer based learning. When the student works with the computer, he concentrates and only focus on what happens on the computer screen. If there isn't any communication with the other students through the computer network, the students won't communicate at all. In some cases this might be a benefit since they will not be disturbed by the other students, but in this case I think it was a disadvantage. It is known that you learn from communicating and sharing your thoughts with other students (Vygotsky, 1962). One solution to this could be to have two students on one computer. In software developing this strategy is known as extreme programming.

5.2 Results from the concept models

All the concept models created with Betty were of good quality when they were handed in to me. Some students made shortcut links in their models. Instead of let the chain of links from one concept affect another concept they created a direct link to the concept in the end of the chain. But I think that they created the chain of causal links in their minds when creating the shortcut link. The reason why some students created shortcut links was probably to easily get Betty to answer the quiz questions. It was more difficult to answer questions with a long chain of causal links.

The CLD group also succeeded to create their concept models or causal loop diagrams. Some of the students created three or four diagrams with only two concepts instead of creating one big concept map. But when I asked them about their model they understood that the small models were connected in a big relationship as well. Many of the students in this group also wanted to create a model of the rest of the gas laws before they created a model of the specific example. This group also needed more help from me when they were creating their models, since they had no help or feedback from Betty. Some also had difficulties to understand how the causal links affected the concepts.

5.3 Results from the questionnaire

After the study I let the students answer a questionnaire. The CLD group and the Betty group answered to two different questionnaires but some questions were common. I received answers from ten students in the Betty and seven answers from the CLD group. In the second appendix you will find a full report from the questionnaire. Here I will make a summary with my comments and conclusions.

5.3.1 Common questions

In this summary I will bring up the questions which were common for both of the groups.

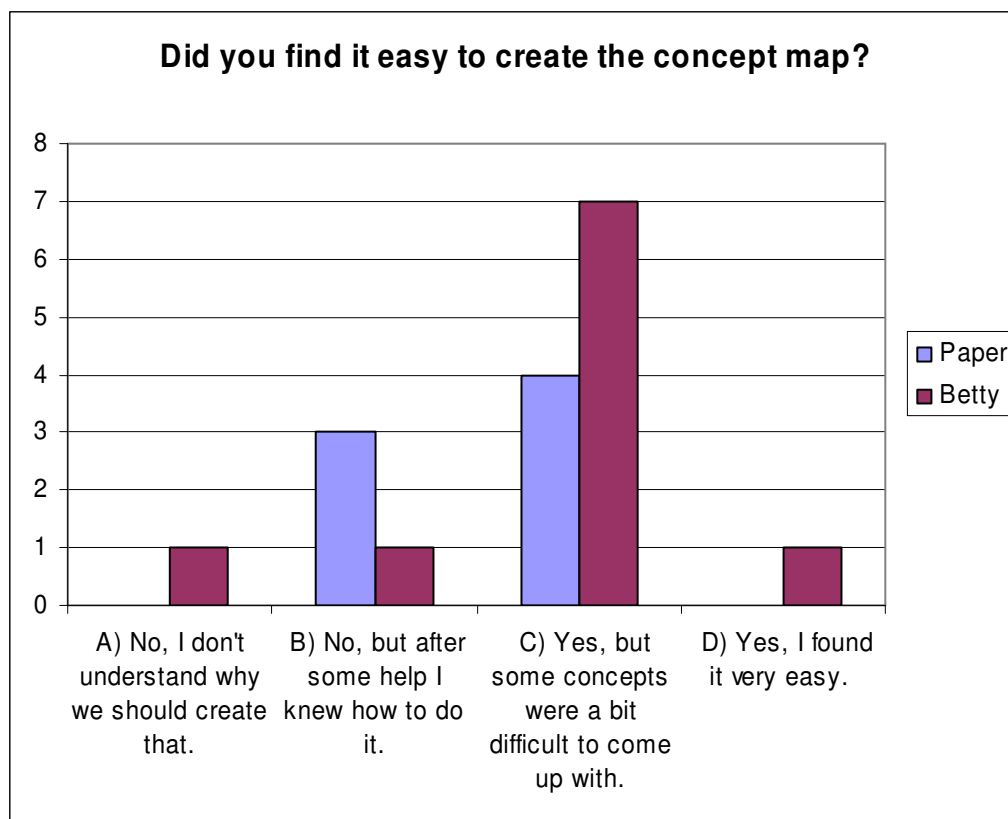


Figure 17.

In figure 17 you can see that the CLD group needed a little bit more help to create their causal loop diagram compared to the Betty group. This was also my impression of the groups during the training session. Some comments from both of the groups were that the links between concepts were a bit difficult to understand.

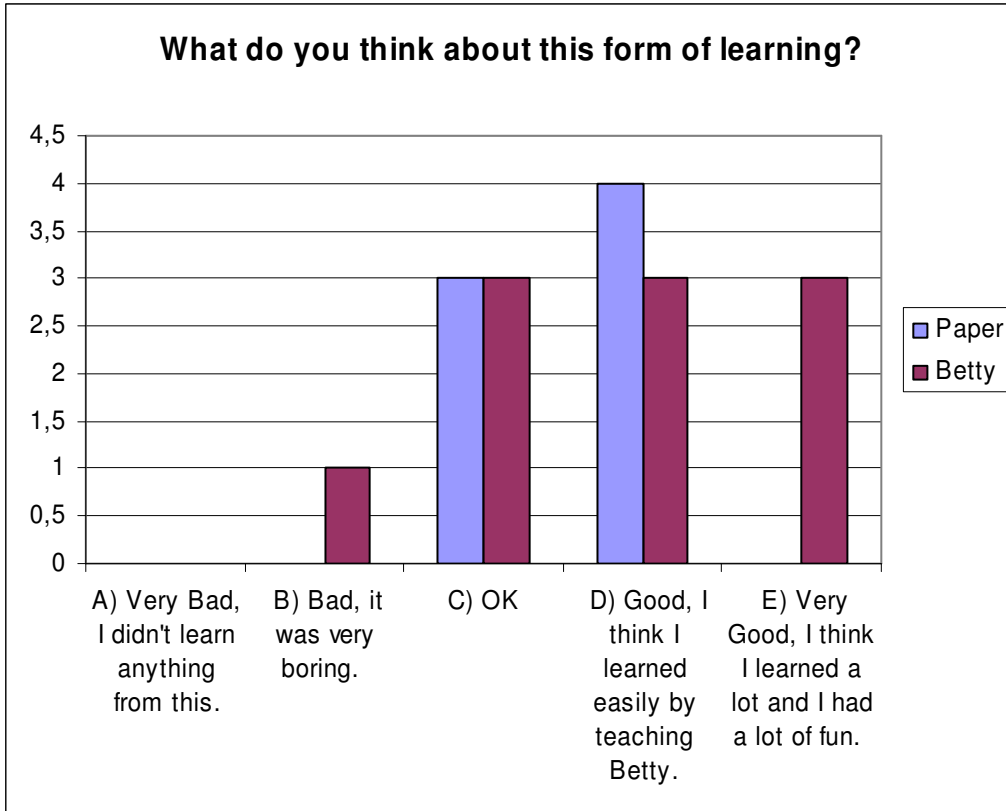


Figure 18.

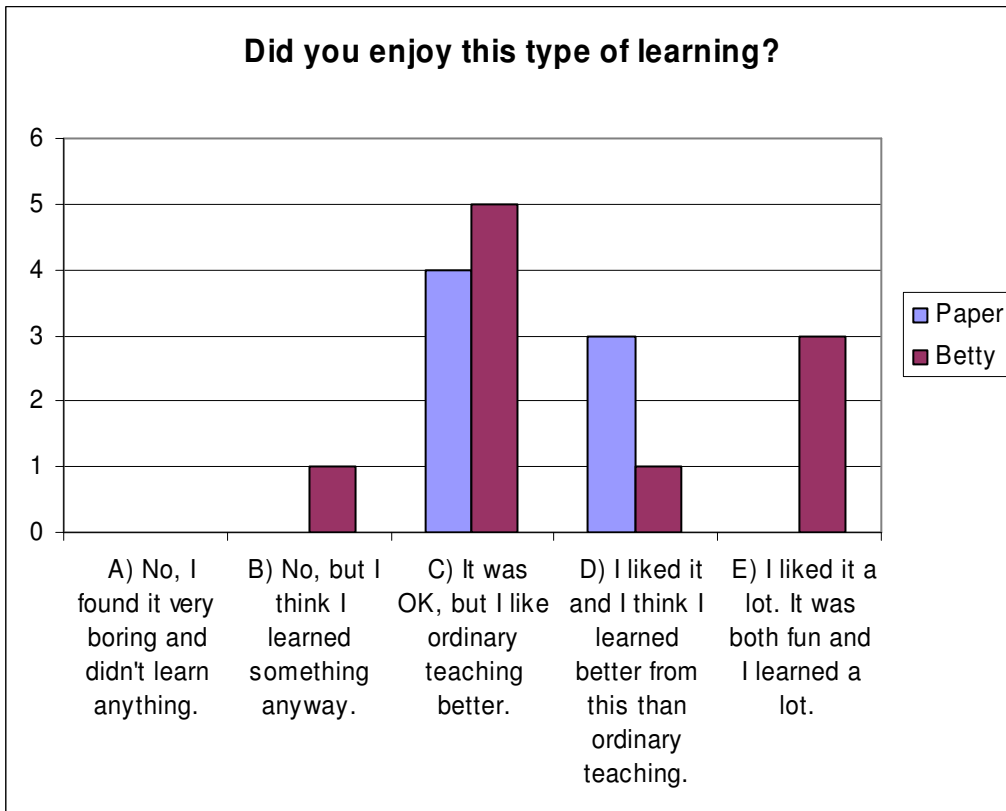


Figure 19.

Both these two questions (figure 18 and figure 19) were very similar and the response from the students was also quite similar. It seems like the Betty group had more fun while learning than the CLD group. Many of the students who chose “C) It was OK, but I like ordinary teaching better” in the Betty group thought that using Betty can’t replace ordinary teaching but might be excellent as a complement. They also noted that Betty can’t be used in all subject domains, but in this domain it worked fine. Some of the students in the Betty group also said that it was a bit difficult to focus on you own learning while using Betty. It seemed like they learned more about how to use Betty than about the subject domain. Some recommended the use of Betty when introducing a new subject since it was easy to understand the new relationships.

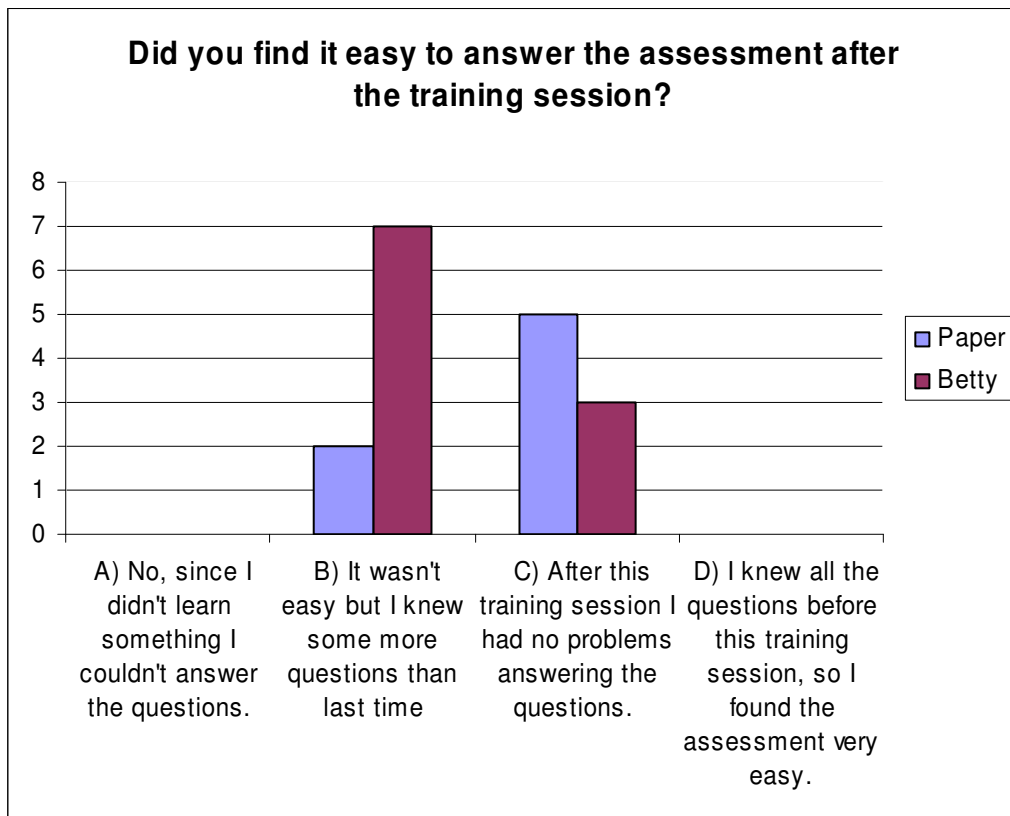


Figure 20.

This question (figure 20) strengthens my results from the pre and post assessments. The students using Betty had more difficulties while taking the post assessment. But this doesn't have to mean that Betty is a worse teaching method than just creating causal loop diagrams on paper. I think it depends on what you are teaching Betty, since the students only seem learn exactly what they are teaching her.

5.3.2 Other comments from the Betty group

Most of the students found it easy to use Betty. They just had some difficulties in the beginning but with my presentation and just a little help from me all of the students understood how to handle Betty. Some students found it difficult using English as language. They all had a lot of fun with Betty's voice, but after a while some of them were tired of her voice and wanted to be able to interrupt her speech. All of them found both the question and quiz features as very useful. The quiz feature was the one which mostly helped the students creating their concept maps. It can be noted that the feedback feature from Mr. Davis wasn't used much. The reasons could be many. Maybe the students didn't find or understand the feature.

5.4 Particularly interesting case

During my analysis I found that two of the students had specifically interesting results. Both of them used Betty during the training session. I choose to refer to these two students as *Student 1* and *Student 2*.

Student 1 created a concept map which was exactly like the expected concept map, but she didn't improve her results at all in the posttest.

Student 2 improved her test results from two to thirteen from the pretest to the posttest. But her concept model was unstructured and contained a lot of extra causal links.

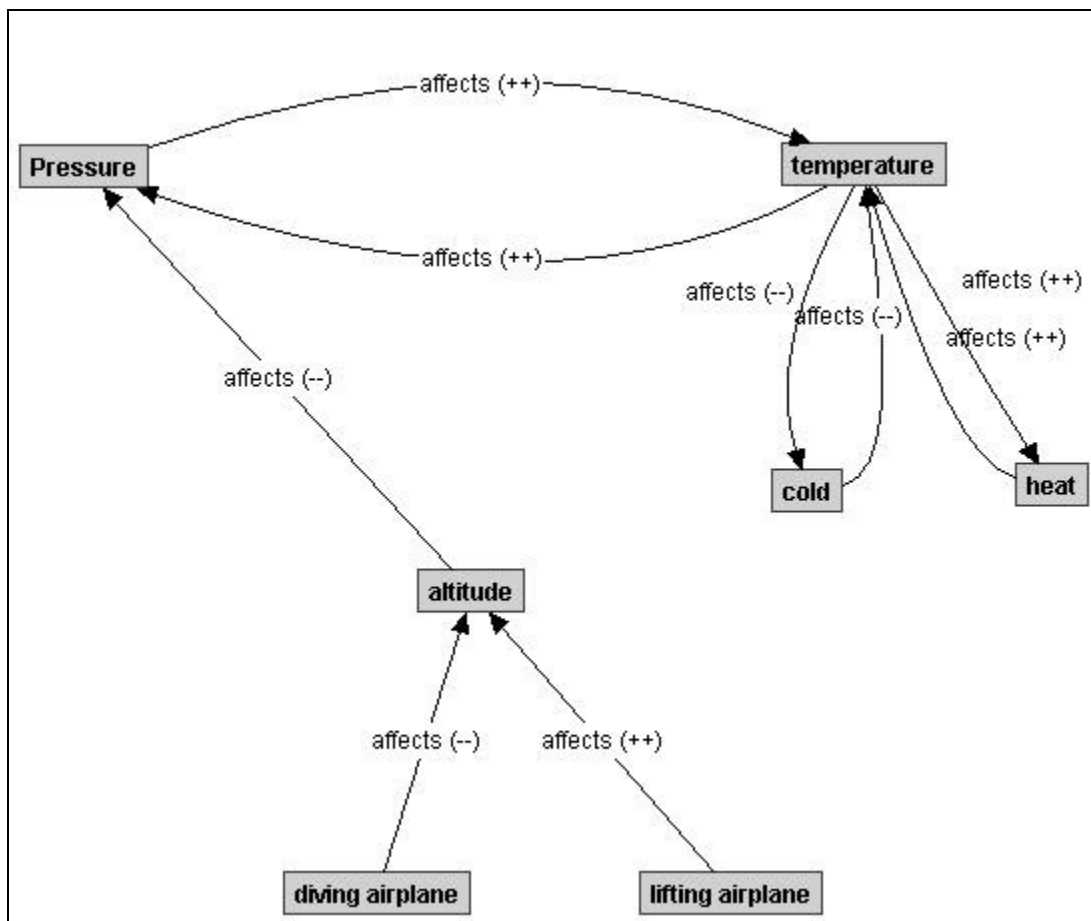


Figure 21. The concept map from *Student 1*.

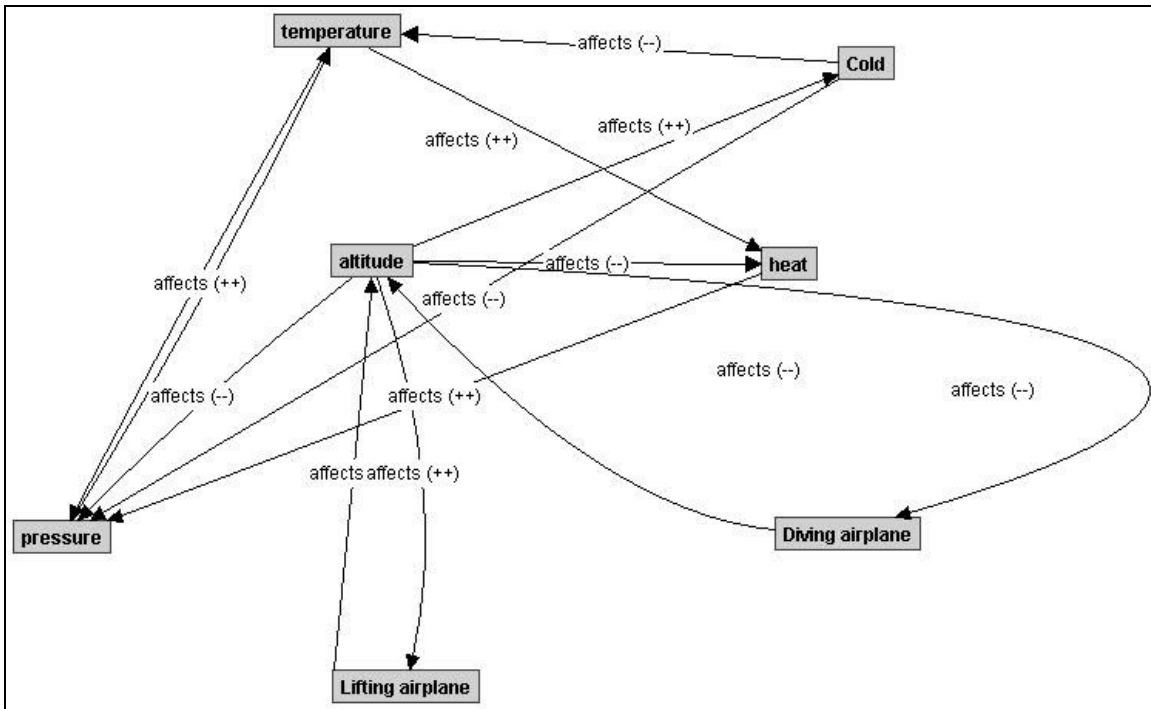


Figure 22. The concept map from *Student 2*.

| Questions | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Total |
|-------------------|----------|----------|-----------|----------|----------|----------|-----------|
| Pretest | 0 | 0 | 3 | 2 | 1 | 1 | 7 |
| Posttest | 1 | 0 | 1 | 2 | 1 | 1 | 6 |
| Difference | 1 | 0 | -2 | 0 | 0 | 0 | -1 |

Table 3. Results from *Student 1*

| Questions | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Total |
|-------------------|----------|----------|----------|----------|----------|----------|-----------|
| Pretest | 0 | 0 | 0 | 1 | 1 | 0 | 2 |
| Posttest | 2 | 2 | 3 | 2 | 2 | 2 | 13 |
| Difference | 2 | 2 | 3 | 1 | 1 | 2 | 11 |

Table 4. Results from *Student 2*

I asked myself if the concept model didn't visually reflect the knowledge of the student. To find out why *Student 1* didn't improve her results and why the *Student 2* did improve hers from two to thirteen points I decided to make an interview with each one of them.

5.4.1 Results from the interviews

1. Student 1 - good map, poor results

First I asked her to describe how she created her concept map. She said that she started to add some concepts and then she let Betty take a quiz. When she noticed that Betty didn't succeed on a quiz question she changed the causal links between the concepts until she answered the quiz questions correctly. I then asked her if she understood the meaning of the arrows (causal links). She found it hard to understand what they were doing to another concept. She wasn't sure what happened to a linked concept when the other concept was increasing. But she tried to think about the model while she was answering the questions during the posttest.

2. Student 2 – poor map, good results

I also asked her how she created her concept map. She also said that she added some concepts and causal links and tried Betty with the quiz. On the basis of Betty's quiz results she changed the causal links. But opposed to the other girl she had no problem to understand what the causal links meant. She found it very easy to understand what to do and how to teach Betty. Another thing was that she misspelled a concept which caused her to trial Betty a lot of extra times. After trying for a long while she asked me (the researcher) what was wrong with her model, since she was sure it was correct. After I corrected the misspelling Betty got all the quiz questions right. The model was indeed working but it was not as clear as the other girl's model. She also said that when she made the pretest she had no clue how to answer the questions, but after the training session she found it easy to take the posttest.

5.4.2 My conclusions from the interviews

My conclusion from this specific case is that both the students were using the trial-and-error method. According to Alexandersson (2001) this method is dangerous in learning contexts. The students are focused on solving the allotted problem by figuring out the computer program instead of learning the subject content. In the first case the student succeeded to create a perfect model without really knowing what she was doing. She figured out that by changing the causal links she managed to change Betty's quiz results. The second student used the same method but she understood the meaning with the causal links. In her model she created shortcuts from one concept to another which made her model look a bit messy. Her test results on the other hand showed that she really had understood the content. Another conclusion is that if the student doesn't understand how the concept map works, she can create a totally perfect map without knowing anything about the domain. One way to solve this might be to ask the students to explain how their concept model works after they feel that they are ready with their model. They must understand the meaning with the causal links and how they affect the concepts.

6 Conclusions

In this chapter I will make a brief summary of my conclusions from the results of my study.

- Since almost all the students scored max points on those two questions which tested what you have taught Betty, *you cannot tell whether learning with Betty was better or worse than learning by just create a model.* Because of this I cannot answer if the teaching element in Betty causes better understanding. According to Schwartz (2005) students using Betty would learn easier next time they should learn something since they get aware of their own learning process.
- *The students only learn what they are teaching Betty.* If the students have a certain task to learn Betty, they will only focus on and learn that specific task. I am pretty sure the students read the rest of the information in the online content, but since they didn't work with the information they didn't learn it either. This can also be seen as the learning advantage with Betty compared to just reading some information.
- *The concept models don't always reflect the student's knowledge.* If the student hasn't fully understood how the concepts and relationships work he or she may create a correct model without really having the corresponding knowledge.
- *Using a trial and error method may result in that the student doesn't learn from teaching Betty.* Some students just tested Betty until she got all quiz questions correct without really thinking about what they changed to get Betty's results better and even worse they didn't understand their changes.
- *Communication disadvantages with Betty's brain.* I think the students in the modeling group benefited from being able to communicate with each other. The students using Betty's brain were very focused on their work and didn't communicate that much. The chat component in the online game show might decrease this disadvantage (Schwartz, 2005). Another solution might be to have two students on one computer.

7 Recommendations and further research

After this case study I can give the following recommendations for teachers who want to try out using Betty's brain for their students:

- Most important is to find a subject domain which works well to create a model of and teach Betty. Especially since the students only learn what they are teaching Betty.
- The students must understand the meaning of the causal links and how they affect the concepts otherwise they can create a model without learning the relationships.
- The quiz questions which Betty should answer must cover the whole subject domain. Even easy links must have a question.
- I think Betty's brain is good suited for introducing new subjects to the students. Betty's brain easily gives a good overview of the subject domain.

Betty's brain is still in a beta version and I look forward to see the full version. Hopefully these study projects will help promoting that. With an editor for creating concept maps, quizzes and content the application could be spread to several subject domains. For example, I think this tool would be perfectly suited for teaching dynamic economic models. I definitely think that teachable agents in some form will be supporting the learning process for future students.

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Appendix 1 – The pre- and posttest

Here is the test which the student took before and after the training session.

Ideal gas laws

Name: _____

You have a gas in a bottle and you are sitting in an airplane on the ground. What happens to the temperature of the gas when the plane reaches 10 000m in altitude. (Motivate you answer) (2p)

On the plane you place your bottle in a champagne cooler. What happens now with the pressure in the bottle? (The plane keeps the same altitude) (Motivate you answer) (2p)

A little kid has bought a balloon filled with helium, but suddenly he drops it and lets the balloon fly away into the atmosphere. What happens with the balloon and why? (Motivate your answer) (3p)

You have a gas in a closed container. What happens to the **temperature** when you...

1. Increase the pressure and the volume is constant (1p) _____
2. Increase the volume and the pressure is constant (1p) _____

You have a gas in a closed container. What happens to the **pressure** when you...

1. Increase the temperature and the volume is constant (1p) _____
2. Increase the volume and the temperature is constant (1p) _____

You have a gas in a closed container. What happens to the **volume** when you...

1. Increase the temperature and the pressure is constant (1p) _____
2. Increase the pressure and the temperature is constant (1p) _____

Appendix 2 – The evaluation

Here you can read a full presentation of the evaluation or questionnaire.

Here you can find the reports online:

The CLD group:

<http://eval.luvit.se/eval/pub/90904/92202/default.asp>

The Betty group:

<http://eval.luvit.se/eval/pub/90128/92201/default.asp>

Here are the reports from the evaluations.

Causal loop diagram – evaluation (CLD group)

Causal loop diagram - evaluation

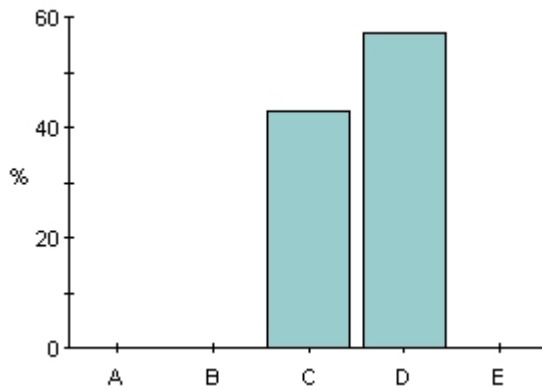
The evaluation was taken right after the post assessment.

| | |
|--------------------------------|----|
| Summary | |
| [REDACTED] | |
| Total number of answers | 7 |
| Filter | no |
| [REDACTED] | |
| Group by question | no |
| [REDACTED] | |

Please answer the following questions.

I would be extra glad if you motivate your answers.

What do you think about this form of learning?



| | % | # |
|--|-------------|----------|
| A) Very Bad, I didn't learn anything from this. | 0% | 0 |
| B) Bad, it was very boring. | 0% | 0 |
| C) OK | 42.9% | 3 |
| D) Good, I think I learned easily by creating a model. | 57.1% | 4 |
| E) Very Good, I think I learned a lot and had a lot of fun. | 0% | 0 |
| Total | 100% | 7 |

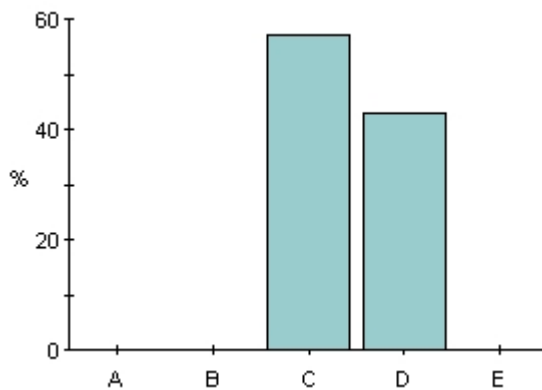
Comment

1 have commented on this question

Good, I think I learned easily by creating a model (one comment)

— First I didn't understood the task, but when I got started I learned a lot

Did you enjoy this type of learning?



| | % | # |
|---|-------------|----------|
| A) No, I found it very boring and didn't learn anything. | | |
| A) No, I found it very boring and didn't learn anything. | 0% | 0 |
| B) No, I think I learned something anyway. | | |
| B) No, I think I learned something anyway. | 0% | 0 |
| C) It was OK, but I like ordinary teaching better. | | |
| C) It was OK, but I like ordinary teaching better. | 57.1% | 4 |
| D) I liked it and I think I learned better from this than ordinary teaching. | | |
| D) I liked it and I think I learned better from this than ordinary teaching. | 42.9% | 3 |
| E) I liked it a lot. It was both fun and I learned a lot. | | |
| E) I liked it a lot. It was both fun and I learned a lot. | 0% | 0 |
| Total | 100% | 7 |

Comment

2 have commented on this question

It was OK, but I like ordinary teaching better. (one comment)

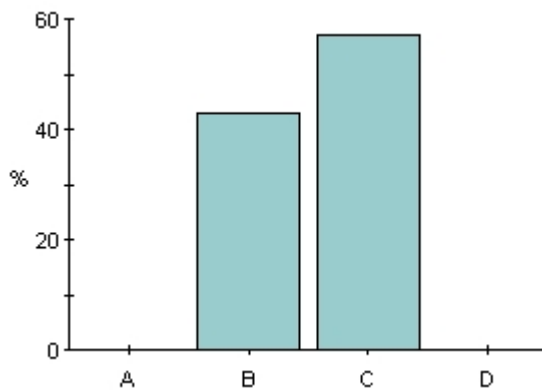
— Just as good as ordinary teaching

I liked it and I think I learned better from this than ordinary teaching.

(one comment)

— It is hard to decide if this is better than ordinary teaching since I have only experienced this type of learning once.

Did you find it easy to create the causal loop diagram?



| | % | # |
|--|-------------|----------|
| A) No, I don't understand why we should create that. | 0% | 0 |
| B) No, but after some help I knew how to do it. | 42.9% | 3 |
| C) Yes, but some concepts were a bit difficult to come up with. | 57.1% | 4 |
| D) Yes, I found it very easy. | 0% | 0 |
| Total | 100% | 7 |

Comment

3 have commented on this question

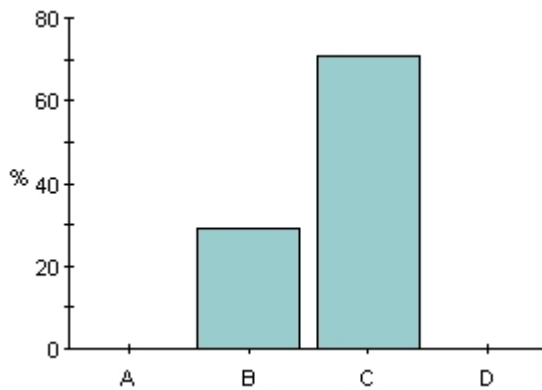
No, but after some help I knew how to do it. (2 comments)

- The links were confusing
- I was confused by the arrows.

Yes, but some concepts were a bit difficult to come up with. (one comment)

- It was a bit hard in the beginning since it was a new way to represent your knowledge.

Did you find it easy to answer the assessment after the training session?



| | % | # |
|---|-------------|----------|
| A) No, since I didn't learn something I couldn't answer the questions. | 0% | 0 |
| B) It wasn't easy but I knew some more questions than last time. | 28.6% | 2 |
| C) After this training session I had no problems answering the questions. | 71.4% | 5 |
| D) I knew all the questions before this training session, so I found the assessment very easy. | 0% | 0 |
| Total | 100% | 7 |

Comment

2 have commented on this question

After this training session I had no problems answering the questions. (2 comments)

- I didn't know so much about gas before and how it is affected by pressure, volume and temperature. So yes, I think the assessment was easier afterwards.
- No difficulties.

What can be done to improve this type of learning?

1 have answered this question

- I would have been easier to understand the task if the presentation before the training session would have been more concrete.

Contact person: Jan Petersen, jan.petersen@luvit.com

Last modified: 15/04/05

Teachable agent – evaluation (Betty group)

Teachable agent - evaluation

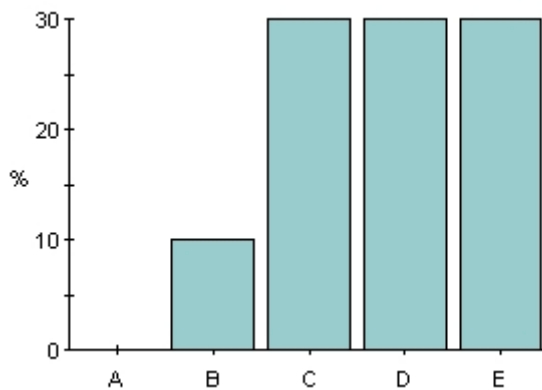
The evaluation was made right after the post assessment.

| Summary | |
|--------------------------------|----|
| Total number of answers | 10 |
| Filter | no |
| Group by question | no |

Please answer the following questions.

I would be extra glad if you motivate your answers.

What do you think about this form of learning?



| | % | # |
|--|-------------|-----------|
| A) Very Bad, I didn't learn anything from this. | 0% | 0 |
| B) Bad, it was very boring. | 10% | 1 |
| C) OK | 30% | 3 |
| D) Good, I think I learned easily by creating a model. | 30% | 3 |
| E) Very Good, I think I learned a lot and had a lot of fun. | 30% | 3 |
| Total | 100% | 10 |

Comment

8 have commented on this question

Bad, it was very boring. (one comment)

— I rather have an ordinary teacher who lectures the class.

OK (3 comments)

— It was annoying when the computer didn't understand even though I was correct

— It was a little bit hard to understand what you were supposed to teach her and also understand that information

— I learned more about betty than about the gas laws, it was hard focusing on your own learning.

Good, I think I learned easily by teaching Betty (one comment)

— A very fun approach to learning, but I don't know if it still is that much fun after a while

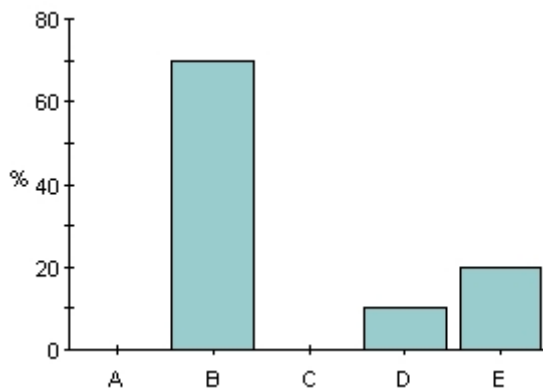
Very Good, I think I learned a lot and I had a lot of fun (3 comments)

— I particularly liked Betty's voice!

— Nice and interesting!

— Good to have for basic learning and to understand relations. I also had some fun while learning.

What was your first impression of this system?



| | % | # |
|--|-------------|-----------|
| A) I didn't have a clue of what to do, even after reading the help texts. | 0% | 0 |
| B) I was a little bit confused, but after a while I understood what to do.. | 70% | 7 |
| C) It wasn't that difficult to understand what to do, especially after reading the help text. | 0% | 0 |
| D) I found it easy to understand. I just needed a little help. | 10% | 1 |
| E) At once I knew what to do, I didn't have to read the help texts. | 20% | 2 |
| Total | 100% | 10 |

Comment

3 have commented on this question

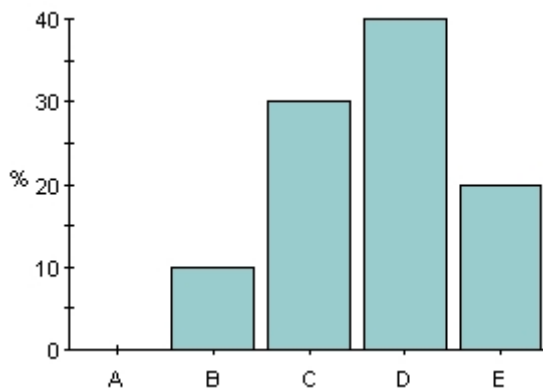
I was a little bit confused, but after a while I understood what to do. (2 comments)

- A bit difficult that everything was written in english
- there was certain things, like you have to ask her questions to be able to do the test, which made me confused. Also that you had to spell everything like the program and draw the lines in the right direction.

I found it easy to understand. I just needed a little help. (one comment)

- Logical program

Was it easy to understand how to teach Betty?



| | % | # |
|--|-------------|-----------|
| A) No, I still don't know how to teach her. | 0% | 0 |
| B) No, but after some help from the researcher I understood how to teach Betty. | 10% | 1 |
| C) Well, after reading the help texts I understood. | 30% | 3 |
| D) Yes, I just needed a little help to understand. | 40% | 4 |
| E) Yes, it was very easy. | 20% | 2 |
| Total | 100% | 10 |

Comment

4 have commented on this question

Well, after reading the help texts I understood. (2 comments)

- but also thanks to the oral presentation before the training session
- It was difficult, but when you had understood how the test-processing worked it became more easy.

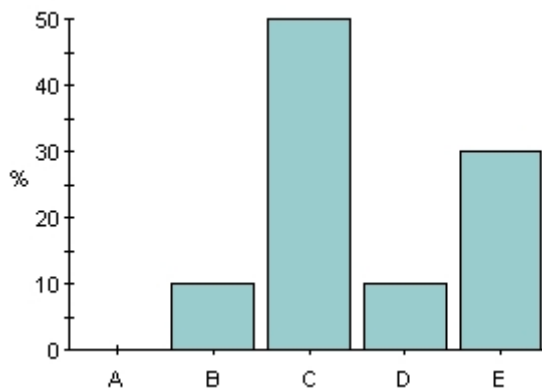
Yes, I just needed a little help to understand. (one comment)

- Just a little help from the researcher, then it was easy!

Yes, it was very easy. (one comment)

- She was a little bit stupid, she couldn't draw easy conclusions.

Did you enjoy this type of learning?



| | % | # |
|---|-------------|-----------|
| A) No, I found it very boring and didn't learn anything. | 0% | 0 |
| B) No, I think I learned something anyway. | 10% | 1 |
| C) It was OK, but I like ordinary teaching better. | 50% | 5 |
| D) I liked it and I think I learned better from this than ordinary teaching. | 10% | 1 |
| E) I liked it a lot. It was both fun and I learned a lot. | 30% | 3 |
| Total | 100% | 10 |

Comment

5 have commented on this question

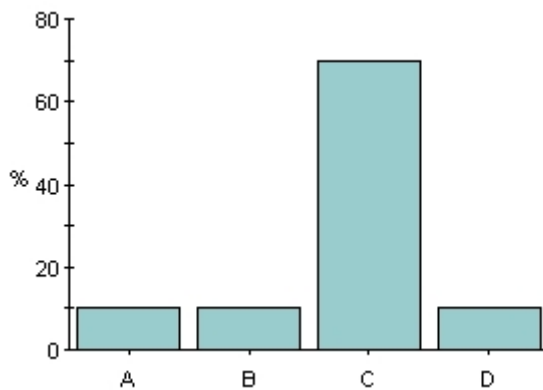
It was OK, but I like ordinary teaching better. (3 comments)

- A bit confusing to learn this way, you can't concentrate on what you are supposed to learn
- Yes and now. It suits this chapter. I think I learned pretty good.
- well, it was fun and could be a good complement to ordinary teaching.

I liked it a lot. It was both fun and I learned a lot. (one comment)

- I think it depends a lot on the subject. The software felt a bit limited, but it is a good way to learn the basics for a new subject.

Did you find it easy to create the concept map?



| | % | # |
|--|------|----|
| | | |
| A) No, I don't understand why we should create that. | 10% | 1 |
| B) No, but after some help I knew how to do it. | 10% | 1 |
| C) Yes, but some concepts were a bit difficult to come up with. | 70% | 7 |
| D) Yes, I found it very easy. | 10% | 1 |
| | | |
| Total | 100% | 10 |

Comment

4 have commented on this question

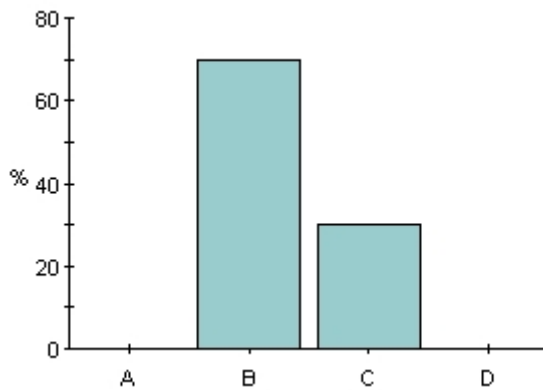
Yes, but some concepts were a bit difficult to come up with. (3 comments)

- You had a good overlook.
- Diving airplane? Lifting airplane?
- a good system, but a bit difficult to understand meaning with all these links

Yes, I found it very easy. (one comment)

- Requires some knowledge about the subject

Did you find it easy to answer the assessment after the training session?



| | % | # |
|---|-------------|-----------|
| A) No, since I didn't learn something I couldn't answer the questions. | 0% | 0 |
| B) It wasn't easy but I knew some more questions than last time. | 70% | 7 |
| C) After this training session I had no problems answering the questions. | 30% | 3 |
| D) I knew all the questions before this training session, so I found the assessment very easy. | 0% | 0 |
| Total | 100% | 10 |

Comment

4 have commented on this question

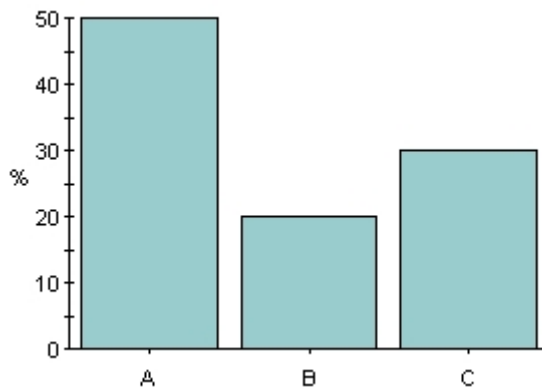
It wasn't easy but I knew some more questions than last time. (3 comments)

- still a bit difficult but it went better than the last time
- still uncertain about some things
- With the formula $PV=CT$ it was pretty easy.

After this training session I had no problems answering the questions. (one comment)

- I had to think of them a bit more

**Do you think this type of learning is more suitable for children?
(Motivate your answer)**



| | % | # |
|---|------|----|
| A) No, I found usable for me | 50% | 5 |
| B) Yes, it was too easy for students in our age. | 20% | 2 |
| C) Yes, I felt that Betty was a bit silly. | 30% | 3 |
| Total | 100% | 10 |

Comment

6 have commented on this question

No, I found usable for me (2 comments)

- If you developed the program it would suit children, and if the facts you had were easier to understand.
- Yes, maybe for children too

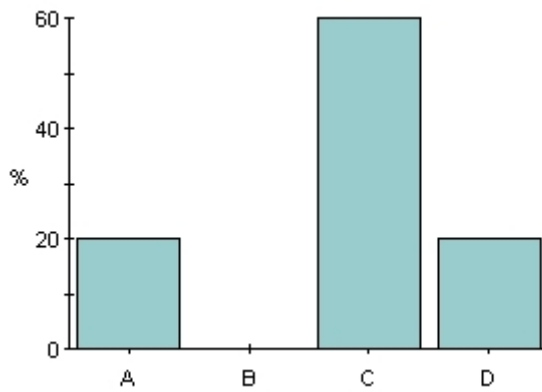
Yes, it was too easy for students in our age (2 comments)

- The technique may even suit younger people, but Betty's brain is probably too difficult
- If you translate the software into Swedish.

Yes, I felt that Betty was a bit silly (2 comments)

- In my age you are expected to automatically draw conclusions. It feels a bit overkill to explain everything to Betty.
- But then you have to make it easier. It was fun entertainment-learning

Did you find it useful to be able to ask Betty questions about her knowledge?



| | % | # |
|--|------|----|
| A) No. | 20% | 2 |
| B) No, since I already knew the answer, why should I ask her? | 0% | 0 |
| C) Yes, it helped me to understand what I was teaching Betty. | 60% | 6 |
| D) Yes. | 20% | 2 |
| Total | 100% | 10 |

Comment

2 have commented on this question

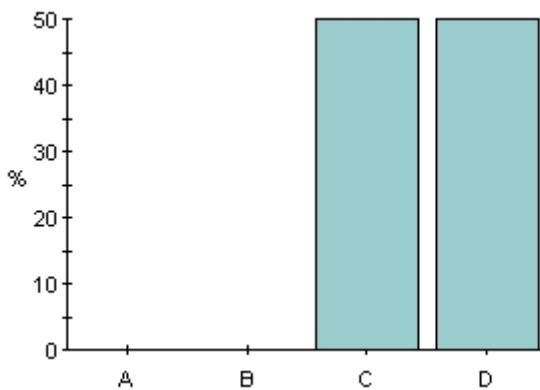
Yes, it helped me to understand what I was teaching Betty. (one comment)

— but her voice was disturbing

Yes. (one comment)

— but sometimes I didn't understand. It would have been easier if it were in Swedish

Did you find it useful to be able to let Betty take a quiz?



| | % | # |
|---|------|----|
| A) No. | 0% | 0 |
| B) No, what do I learn from letting Betty answer to questions? | 0% | 0 |
| C) Yes, it helped me creating the concept map. | 50% | 5 |
| D) Yes. | 50% | 5 |
| Total | 100% | 10 |

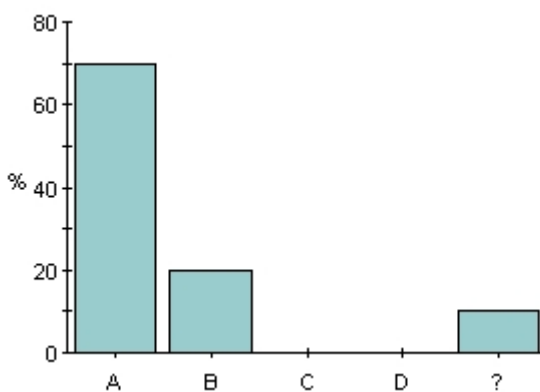
Comment

2 have commented on this question

Yes. (2 comments)

- Much
- very much.

Did you find the feedback from Mr. Davis after the quiz useful?



| | % | # |
|---|------|----|
| A) No. | 70% | 7 |
| B) No, he just confused me more. | 20% | 2 |
| C) Yes, it helped me creating the concept map. | 0% | 0 |
| D) Yes. | 0% | 0 |
| E) ? | 10% | 1 |
| Total | 100% | 10 |

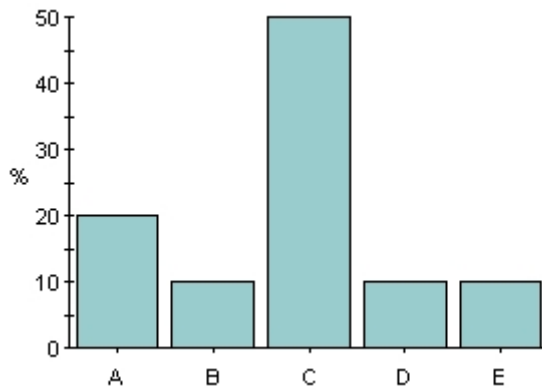
Comment

4 have commented on this question

No. (3 comments)

- What feedback?
- Didn't use that function.
- Rather

What was most helpful when creating the concept map?



| | % | # |
|---|------|----|
| A) The resources. | 20% | 2 |
| B) To be able to ask Betty questions. | 10% | 1 |
| C) To be able to let Betty take a quiz. | 50% | 5 |
| D) The feedback from Mr. Davis after the quiz. | 10% | 1 |
| E) Other. | 10% | 1 |
| Total | 100% | 10 |

Comment

3 have commented on this question

The resources. (one comment)

— the resources should be more easy to understand.

To be able to let Betty take a quiz. (one comment)

— The questions were pretty leading.

Other. (one comment)

— The simplicity with the arrows

What can be done to improve this type of learning?

5 have answered this question

— In Swedish?

— Don' know really. Maybe even more interactive and maybe that she could teach you back?

— You should absolutely be able to stop Betty while she is talking. After a while she is very annoying.

— better explanations of what do and how to do it

— better resources, faster answers from betty and maybe the links should be easier to understand...

Contact person: Jan Petersen, jan.petersen@luvit.com

Last modified: 15/04/05

Appendix 3 – The online content

Here you can read the content which the students had access to during the training session. The texts have links to a glossary which is presented after the main content.

Gas laws

In this laboratory experiment we will examine the relationships between [pressure](#), [volume](#) and [temperature](#) for a gas in a sealed container. The objectives with this experiment are to give you an understanding in the ideal gas law and how the different quantities (volume, pressure and temperature) are related to each other. You should be able to answer to questions like 'What happens to the volume when the pressure is increasing and the temperature is constant?' Read more about the gas laws in the following sections.

With a constant pressure (Charles law)

In 1787, French physicist Jacques Charles observed that the [volume](#) of a gas under constant [pressure](#) increases or decreases with [temperature](#). This behavior was quantified around 1808 by another French scientist, Joseph Gay-Lussac , who measured the thermal expansion of a gas as 1/267 of its original volume per degree Celsius. In 1847, Henri Regnault refined this value to 1/273, and also discovered that many gases violate this rule, which in principle holds only for so-called ideal gases.

Charles' law is represented by the formula

$$V = V_0 \left(1 + \frac{\theta}{273 \text{ K}} \right),$$

where V and V₀ are the final and initial volumes and θ is the change in temperature. More generally, it may be stated that for a gas at constant pressure,

$$V = CT$$

where V is the volume, T is the temperature, and C is a constant.

With a constant temperature (Boyles law)

In 1661 English scientist Robert Boyle found that the [volume](#) of a gas varies inversely with its [pressure](#), if the [temperature](#) is held constant. At constant temperature for gases,

$$\frac{V'}{V} = \frac{P}{P'}$$

where V' and V are the final and initial volumes, and P' and P are the final and initial pressures. This relationship is equivalent to

$$PV = C$$

where V is the volume, P is the pressure, and C is a constant.

With a constant volume (Gay-Lussac's Law)

Gay-Lussac's Law states that the [pressure](#) of a sample of gas at constant [volume](#), is directly proportional to its [temperature](#) in Kelvin.

The formula looks like this:

$$P = CT$$

where P is the Pressure, T is the temperature, and C is a constant.

According to Gay-Lussac's Law:

$$P_1 / T_1 = \text{constant}$$

After the change in pressure and temperature,

$$P_2 / T_2 = \text{constant}$$

Combine the two equations:

$$P_1 / T_1 = P_2 / T_2$$

When any three of the four quantities in the equation are known, the fourth can be calculated. For example, we've known P₁, T₁ and P₂, the T₂ can be:

$$T_2 = P_2 \times T_1 / P_1$$

In other words, as the temperature increases, the pressure increases at a constant volume. (When you put a pickle jar in the refrigerator, the drop in pressure from the trapped air becoming colder makes it hard to open the jar later!)

Ideal gas law

When combining Charles law with the observation by Boyle we arrive at

$$PV = CT,$$

where P is the [pressure](#), V is the [volume](#), T is the [temperature](#) and C is a constant. Combining this formula with Avagadro's hypothesis we get the ideal gas law

$$PV = nRT$$

where R is the [universal gas constant](#) and n is the [number of moles](#) of the gas in the volume V.

Boiling water in an airplane

Your task is to teach Betty how the gas law works in the real world. I want you to teach Betty what happens when you are boiling water in an airplane. At a high altitude the air [pressure](#) is much lower than on the ground. You may also raise or lower the temperature by increasing heat or increase cold.

Betty should be able to answer what happens to the pressure when the [temperature](#) is increasing / decreasing.

Also she should know what happens to the temperature when the airplane is lifting or diving.

Glossary

Pressure:

The force exerted per unit area of surface, typical pressure units are ATM, mmHg and kPa.

Volume:

The measurement of space taken by a substance, it is length cubed, typical units are L, mL and m³.

Temperature:

A measure of the average kinetic energy of the particles in a sample of matter, expressed in terms of units or degrees designated on a standard scale. Typical units are K, F and C.

Density:

The mass of the object divided by its volume. Typical units are g/mL and kg/m³.

Formula Weight / Molecular Weight (MW):

The formula weight of a compound is the sum of all the atomic weights of the elements present in the formula of the compound. Some text also refers it to formula mass. Typical unit is g/mol.

Mass and Mole:

Mass is the amount of a substance in grams, also called weight.

Gas Constant (R):

The constant that appears in the ideal gas equation ($PV=nRT$). It is usually expressed as 0.08206 L x atm/K x mol or 8.314 J/K x mol.

Molality:

The number of moles of solute dissolved in one kilogram of solvent.

Molarity:

The number of moles of solute in one liter of solution.

Appendix 4 – The quiz questions

Here are the quiz questions which Betty had to succeed before the students could finish their training session.

1. If Cold decreases, what happens to Temperature?
2. If Temperature increases, what happens to Heat?
3. If Diving airplane decreases, what happens to Altitude?
4. If Lifting airplane increases, what happens to Altitude?
5. If Altitude increases, what happens to Pressure?
6. If Lifting airplane increases, what happens to Heat?
7. If Altitude decreases, what happens to Cold?
8. If Cold increases, what happens to Pressure?
9. If Heat increases, what happens to Pressure?