SIMULATION IN COMPLEX LEARNING DOMAIN: GREENHOUSE EFFECT

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Abstract:
The greenhouse effect is one of the most complex topics in the Finnish national core curriculum, and understanding of it requires knowledge of many science concepts like radiation as well as the role of atmosphere, clouds and gases. Research has indicated that students' misconceptions or alternative conceptions are a formidable challenge in the enactment of instruction for students' understanding of an increased greenhouse effect. In this study it has been noticed that the instruction including simulation has motivated the pupils to study, and that there was a clear increase in the amount of concepts between pre and post test related into the mechanisms of the greenhouse effect. However, the planning and the enactment of instruction of this topic is a challenge also to the teacher, and it may still be so that pupils who normally are good in science understand also the greenhouse effect better than the peers.

Keywords: greenhouse effect; complex topic; simulation

1. Introduction

Substances around us in the Finnish national core curriculum include the topics composition of air and the atmosphere [1]. When studying these issues generally also greenhouse effect is discussed. The greenhouse effect is a complex topic and therefore understanding of it requires knowledge of many science concepts like radiation as well as the role of atmosphere, clouds and gases. Therefore we felt that it would be reasonable to assume that use of simulations could be valuable aid for pupils while studying this topic. The teacher students, who participated into VccSSe-project related course, translated the English simulation into the Finnish language. This version of the simulation was available to be utilized in fifth graders' classroom experimentation.

Model-based learning in the simulation context was characterized by Gobert and Tinker [2] as dynamic recursive process, in which learners are offered an interactive opportunity to

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build and refine their mental models of the topic. During the interactive process of working with the simulation model the learners are interacting with the causal and dynamic aspects of complex phenomena, in this case it was the model of greenhouse effect. Chang et al. [3] offer an impressive list of studies on the advantages of simulation-based learning, but they also offer a list of prerequisites. These prerequisites are much related with the construction of the mental models, and the learning process includes reasoning of affects of different parameters to the phenomena in study. Setting the parameters on the simulation requires some preliminary knowledge. During the simulation a parallel process of setting the parameters and making of hypothesis is needed, and this should lead to refinement of the mental and conceptual models of the learners. These processes may be overwhelming to students without teachers´ careful preparation of the learning situation (or sequence). The teaching-learning process should fulfill the following prerequisites listed by Chang et al. [3]: 1) the provision of sufficient background-knowledge, 2) help in the forming of the appropriate hypothesis, 3) helping the learners to make the experiments and direct the focus on building understanding instead of just completing the tasks, 4) helping the students to interpret data and the results of their observations and 5) supporting learners self-monitoring and regulation, while working in the simulation environment.

Research examining students' understanding of an increased greenhouse effect has indicated that students' misconceptions or alternative conceptions are a formidable challenge to content understanding [4, 5]. For example the study of Koulaidis and Christidou [5] showed that the Primary school students had some misunderstanding concerning e.g. ultraviolet and other forms of solar radiation and terrestrial radiation. Also they had limited understanding of ozone layer and greenhouse gases in the atmosphere. The nearly same findings have been stated in the study of Rebic and Gautier [6] who examined undergraduates.

2. Greenhouse effect simulation intervention

In order to assure the relevant background knowledge there was several lessons before the simulation session. The first lesson (45 minutes) was about atmosphere, clouds and the greenhouse effect. At the end of the lesson, the teacher and student teacher discussed these phenomena with the pupils, and assembled one common mind map on the greenhouse effect: *"What comes into your mind about clouds, the atmosphere and the greenhouse effect?"*

During the second pair of lessons (90 minutes), the pupils searched for answers to questions concerning layers of the atmosphere and the water cycle in nature. Working in small groups and using the internet, they tried to find out what are the gases in the atmosphere, what are clouds and how are they formed. Finally, there was a discussion concerning the main topics: What kind of gases does the atmosphere consist of? What are the chemical elements and their proportions in the atmosphere? What are the layers of the atmosphere? What does a cloud consist of? How do the clouds affect life? What is the composition of the Earths' atmosphere?

During the third session (45 min), the pupils read a scientific article concerning the greenhouse effect. Working in small groups and using the internet, pupils tried to find out information about carbon in nature (soil, atmosphere, the cycle of carbon and the human impact on the cycle of carbon). Again at the end of the lesson, there was a discussion about the studies.

The fourth session was the actual simulation session (90 minutes). The teacher students' translated version of the greenhouse effect simulation from the University of Colorado PhET (http://phet.colorado.edu) collection was used. The greenhouse effect simulation tries to introduce the mechanisms of turning radiation from the Sun into heat (infrared radiation) and the effect of gas particles in keeping infrared radiation in the atmosphere. In the simulation it is possible to compare the effects of differentiation of greenhouse gases and clouds into ways the radiation behaves and to observe these effects into changes of the temperature. Pupils' studying process was scaffolded with a document planned by the teacher and student teacher and asking to find out what are the differences: when there are no greenhouse gases, when there are lots of greenhouse gases, and the effect of clouds. What are the differences in the way how sunlight and infrared photons behave, and what the consequence to temperature is. Furthermore, pupils were asked to simulate and write down the main differences between the Ice Age, the pre-industrial era and contemporary time. At the end of the session the results were compared and discussed among the groups.

3. The follow-up study

The participants were pupils aged 11 to 12 from two classes (groups of 22 and 18 pupils) in a rural Primary school. Pupils' ideas in the first group were examined in the context of seven lessons in chemistry and physics described above and which were supervised by a student teacher and a Primary school teacher. The second group worked similarly during a one school day in supervision of another Primary school teacher. Prior to instruction, the pupils of the first group were asked to draw and write down the things that came to their minds when they thought on the atmosphere, clouds and the greenhouse effect. If needed they were given some questions to help them in the writing process.

After the instruction period, the same pupils were once again asked to draw and write what came into their minds when they thought on the greenhouse effect. Finally, the teacher and student teacher had a discussion with the pupils and assembled one common mind map on the greenhouse effect. For both of the two groups the VccSSe-project questionnaire was administered after the experimentation.

4. Some remarks on the results

Analysis of the pupils' drawings and writings, from the first group, about the greenhouse effect, before and after instructional intervention, produced 151 descriptions which were classified into 30 categories. The descriptions and themes were divided into six categories: source of the greenhouse effect, consequence of the greenhouse effect,

mechanism of the greenhouse effect, prevention of the greenhouse effect, distribution and personal opinion. The results show that although there were misconceptions fifth graders appear to have some previous understanding of the greenhouse effect. Pupils' started by describing the major sources of greenhouse gases and the influence of greenhouse effect. Most descriptions in the drawings and writings were grouped into three main categories: source, consequence and mechanism. Here we report only some concepts related to the mechanism, and try to find possible effects of the simulation. The more detailed analysis of the drawings and writings of the first group pupils will be found in Kärkkäinen et al. [7].

Analysis of pupils' descriptions concerning different mechanisms of the greenhouse effect led to the construction of the following categories: clouds, heat radiation, insolation, gases, infrared radiation, atmosphere, heat evaporation, red and yellow balls (Table 1).

After simulation, drawings included red and yellow balls and pupils explained them as being: *"infrared radiation"* and *"heat radiation"*. Only one of the pupils drew and write in pre instructional drawing, about the mechanism of the greenhouse effect. He wrote about carbon dioxide and explained: *"Carbon dioxide is not filtered in the Earth."* Afterwards the same pupil wrote: *"…the visible light is transformed into heat and re-radiates in the form of invisible infrared radiation."*

After simulation, many of the pupils drew and wrote about radiation. They also used the concepts: atmosphere, soil, clouds and gases, which are required for understanding. Most of the pupils' explanations were correct but some explanations were purely tautological.

Table 1. Pupils' descriptions of the different mechanisms of the greenhouse effect before and after simulation.

Category	Number of descriptions prior to instruction	Number of descriptions after instruction	Total
Clouds	0	10	10
Heat radiation	1	8	9
Insolation	0	13	13
Gases	0	3	3
Infrared radiation	0	8	8
Atmosphere	0	3	3
Heat evaporation	0	1	1
Red and yellow balls	0	1	1
Total	1	47	48

The VccSSe pupils questionnaire was delivered for both of the groups (N=40, table 2) and the results seem to indicate that in both groups pupils have liked the ability to explore the issue and to find out influences by changing of different variables. Two thirds of the pupils in both groups claim that the simulation helped them in understanding the science

concepts. Even thought there were only two pupils not wanting to have simulations used again, the most of the pupils would like to have them only sometimes, not often. The pupils commented the experiment that it was nice and that they liked it as a way to learn.

Table 2. Pupils answers in the VccSSe-project questionnaire

Class 1 (N=22), 5th grade, 11-12 years old	**Category**	**Number**
1. What did you like most?	To change variables	8
	To explore the influences	6
	One method mentioned	3
	Easy to construct from picture	2
	Almost all, new, nice or difficult	5
2. What did you like less?	I liked everything	9
	Repeating, writing, tasks, searching Information, difficult, long, mismatch, limited working	one utterance in each
3. Did the VI help you in understanding the science concepts?	Yes	16
	In some extent	6
	Not	0
4. Would you like to use VI once again?	Yes, often	8
	Yes, sometimes	14
	No	0
5. Please comment the use of virtual experiments?	Nice	7
	I learned a lot	5
	Easier than learning by reading a book	5
	Nice to play	4
	Different	4
	Good experiments, computer good for searching information, more often	one in each
Class 2 (N=18), 5th grade, 11-12 years old	**Category**	**Number**
1. What did you like most?	Simulations	9
	Being by computer	3
	Changes and effects	3
	Experiments	1
2. What did you like less?	Everything was nice	3
	Filling the papers	3
	Boring, long, not enough time	one in each
3. Did the VI help you in understanding the science concepts?	Yes	12
	In some extent	6
	Not	0
4. Would you like to use VI once again?	Yes, often	8
	Yes, sometimes	8
	No	2
5. Please comment the use of virtual experiments?	Nice	7
	Nice way to learn	3
	Good experiments, I could good, I did not inspire, nice to experiment	one in each

5. Discussion

Simulation of the greenhouse effect could provide an opportunity for pupils and teachers to explore and analyse a complex phenomena related to the natural world from a system-based perspective. The teaching-learning process which was planned for the base in this study fulfilled the prerequisites presented by Chang et al. [3]. The provision of sufficient background-knowledge was arranged before the simulation unit, the teachers helped if needed in the forming of the appropriate hypothesis and in the experiments. The tasks were planned to direct the focus on building understanding instead of just completing the tasks and the tasks also required the students to interpret data and the results of their observations as well supported learners self-monitor and regulate their working in the simulation environment.

In this study it has been noticed that there was a clear increase in the amount of concepts between pre and post test related into the mechanisms of the greenhouse effect. Perhaps most clear was the increase in taking account the role of the clouds in the process. The pupils used the concepts in quite a right way.

During the classroom work with the simulation the pupils had the opportunity to share their ideas with the pair and test them together, to make observations by changing the parameters in simulation, and hopefully recognize the causal relationships concerning the greenhouse effect. The pupils were familiar with the working with computers, and the Finnish pupils in general are used to work with ICT. Virtual instrumentation also probably is them familiar via many games they play in their leisure time. Those pupils who normally were good in science, according to the teacher, seemed also to understand the greenhouse effect in this study better than the peers. However, they also seemed to benefit of the use of simulation. For some of the pupils the visual presentation in the simulation was most impressive, thus they had remembered the red and yellow balls, but not necessary understood their meaning.

In conclusion, the instruction including simulation has motivated the pupils to study. They also have learned to use more relevant concepts and understood some causal relationships. The results encourage us to use more simulations in Science.

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