SCIENTIFIC REPRESENTATION AND DESIGN IN COLLABORATIVE LEARNING

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Keywords: scientific representation, designing, models, collaborative learning

INTRODUCTION

The paper aimed to introduce the usage of scientific representation and design in collaborative network-based environment as promising methods for developing students’ understanding about scientific problems. The influence of exploratory and expressive learning in synchronous environment was investigated regarding to the development of students’ mental models of floatation process.

Johnson-Laird (1989) has proposed that whenever people understand a phenomenon, they have a mental representation of it that is like the working model. The main role of a mental model is to allow its builder to explain and make predictions about the physical system represented by it (Greca & Moreira, 2000). The sources of mental models are observation (aided by knowledge), other people’s explanations, and our ability to construct models for ourselves either from a set of basic components or from analogous models we already possess (Johnson-Laird, 1989). From mental representations of phenomena people construct external representations – they express what they have understood by giving narrative explanations or by designing material artefacts, visual images and models. Any external representation can be based on predictions or it may reside upon theoretical knowledge. Scientists, teachers, engineers, etc., construct scientific representations – conceptual models, which facilitate the comprehension or the teaching of systems or states of affairs in the world (Greca & Moreira, 2000). Derived from the activities of scientists, science teaching has aimed to increase students’ ability of explaining phenomena through the use of conceptual models or by designing scientific representations. In the context of scientific practice, the development of personal understanding should be assisted by activities in which communication about scientific concepts and their interrelationships is integral (Sizmur & Osborne, 1997). These considerations can be implemented to practice by combining modelling environments with collaborative learning environments.

It is possible to categorize the learning environments in terms of modelling capabilities as exploratory or expressive (Chalk, 2000). Working with exploratory environments, such as simulations, students can study the effects of changing variable values on the model, which supports scientific reasoning and step-by-step approaches to investigate the phenomena. Conceptual models serve as external representations for making inferences, finding characteristics, and structuring the problem solving (Reinhard, et al., 1997). By means of manipulating the model, learners obtain a direct feeling for the underlying structure of the represented content that is often hard to achieve with conceptual reasoning alone (Cheng, 1993). The expressive modelling tools, like argument graphs, mind-maps, etc., on whiteboards, enhance learning through designing or explaining integrated models involving
model-based reasoning. Designing refers not only to the activities of producing artefacts, but also to the process of arranging elements to form systems (Roth, 2001). The traditional perspective of designing has the meaning of application of rational knowledge and it is recommended that learners should have obtained all the principles of science before actually being engaged in design activity. The second perspective views designing as a social process in which rational knowledge serves as one of the resources, but is secondary in importance to the norms and practices in a particular community. According to this perspective, there is much to be learned when students engage collective design activities and acquire standard knowledge on an as-needed and just-in-time fashion (Roth, 2001). By creating artifacts designing can occur in the world rather than in the head of participants. They serve as anchors that ground specific utterances, which appear unclear to participants (Roth, 2001).

Effective problem solving requires the construction and coordination of valid problem representations. The elements by which a problem situation can be explained in internal and external representations are objects or processes in systems and the structural relationships between these (Jonassen, 1995). The objects and processes are concepts or nodes, and the relationships are links or verbs that state the nature of the relationship between entities. By combining the ‘object’ and ‘process’ entities, the relations can be formed between two objects or two processes, and between a process and an object. Each of these relationships enables to describe the problem situation scientifically with different extent of complexity. These node-link combinations form networks of relationships that describe the domain of knowledge represented by a mental model (Jonassen, 1995). Models can also be expressed at different levels of formalization and abstraction. One of the frameworks originally proposed for chemistry describes the stages of understanding science at macroscopic, microscopic and symbolic levels (Johnstone, 1991). The macroscopic level is sensory and deals with tangible and visible objects and phenomena with their properties; the microscopic level involves with objects and processes at particulate level by using scientific narrative explanations; the symbolic level represents objects and processes in terms of formulas and equations. For giving profound explanations of scientific phenomena the different combinations of relationships between the problem representation’ elements should be explained by macroscopic, microscopic and symbolic means (Pata & Sarapuu, 2003).

Residing on these theoretical considerations, the question about how learning by expressive or exploratory modelling activity would influence the development of students’ problem representations of the scientific phenomenon of floatation, was highlighted.

METHODS

87 Estonian basic school students from the grades of 8-9 were divided randomly into the groups of 3-7 learners. They worked in the collaborative learning environment Collaborative Virtual Workplace (CVW) where 44 students used the simulation model and 43 worked with the visual problem representation on a whiteboard. The activity was supported by an online-tutor.

The activities presented to the students consisted of individual and collaborative tasks. First, the students’ had to write a short essay about the problem why toy-cubes either float, sink or hover in water. Next, they logged into the CVW and were introduced to the topic about washing toy-cubes. They were asked to discuss why objects behaved differently in water and what it was caused by. After short discussion the students had to make their first joint decision about the problem. As they were not supported with any additional information about floatation, only pre-knowledge could be used for predictions. Before the second part of the discussion started, a short overview of theoretical background about buoyancy was presented.
on a web page and the students had to work collaboratively with expressive or exploratory tools in order to reformulate their decisions. The groups that worked in expressive learning environment had to use a whiteboard with the background image ‘Toy-cubes’ in order to model their problem representation by adding texts and arrows. The groups that worked in exploratory environment had to apply the analogy principle by using the web-based model of buoyancy that enabled to test object floating and changes in physical parameters of objects and liquid. After individual testing and collaborative discussions the teams had to formulate a written decision about the problem. The following day the students were asked to write again a short essay about the problem that they had solved in the first essay. The changes in the structure of students’ problem representations in pre- and post-essays were analyzed in the perspective of connectedness of elements ‘object-object’, ‘process-object’, and ‘process-process’ relationship considering macroscopic, microscopic and symbolic levels of explanation.

RESULTS AND THE DISCUSSION

The results indicated that collaborative activity changed significantly (p<0.001) students’ understanding of floatation of objects. It appeared that there was a certain hierarchical sequence by which their ability to construct problem representation models developed. Before collaborative modelling, the ‘object-object’ and ‘process-object’ relationships prevailed (e.g. the bigger cube is heavier, floatation depends on the density of the cube) and the processes were seldom explained through other processes (e.g. the gravitational force is balancing the upwards force), also there were numerous wrong or partly correct macroscopic and microscopic explanations. Modelling on whiteboard and with floatation model shifted the structure of problem representations towards using fewer the ‘object-object’ and ‘process-object’ relationships at macroscopic level, and more at microscopic level. The usage of ‘process-process’ relationships increased by using both the microscopic and symbolic level explanations.

Figure 1. ‘Object-object’ (upper left), ‘process-object’ (upper right) and ‘process-process’ (below right) relationships in students’ problem representations before and after the activity.
The comparison of the effects of exploratory and expressive learning showed that in both environments the correct symbolic level explanations were used for ‘process-process’ relationships. The significant (p<0.01) difference appeared in the usage of symbolic level descriptions for ‘process-object’ relationships. By expressive modelling students started to use symbols for describing processes through objects and their properties, but these phrases appeared to be wrong. In exploratory environment ‘process-object’ category was not described by symbols. These tendencies could be explained by the nature of the modelling activity. When completing the template model on whiteboard, the students got information about symbolic level only by reading the supplementary material. This presented figures where symbols of forces were related with images of toy-cubes, which could have caused the confusion in understanding, if the students did not read the accompanying text thoroughly. Working with the floatation model, the same supplementary text was available, but in addition, the model itself offered several symbolic variables. The students had to relate certain objects’ property values to the symbols of these properties that started the simulation of floatation. They could control their hypotheses about the reasons of floatation by calculating the amount of forces through the use of formulas. This highlighted the ‘process-object’ and ‘process-process’ relationships by using the symbolic level and could have enhanced the correct usage of symbolic phrases in the post-essays. To conclude, both the collaborative activities – scientific representation and inquiry with models – appeared to develop the structure of students’ understanding towards abstract and formalized explanations.

ACKNOWLEDGEMENTS

This research was supported by the ESF grant 4473 and MER funding 0182542s05.

REFERENCES


