Physics education improves when students make their own computer models

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A current trend in secondary science education is for students to learn by discovering for themselves how things work. Computer modelling is a teaching method that fits in nicely with this trend and also with new learning objectives such as scientific literacy, enquiry-based learning and active involvement. Dutch researcher Sylvia van Borkulo has demonstrated that computer modelling is particularly useful for learning complex structures but less effective for learning simple facts.

Van Borkulo compared instruction based on computer modelling with other forms of instruction. The lesson was about the energy of the Earth (the 'domain'). The group of students using computer modelling created a model of the energy of the Earth. In this model they were asked to incorporate variables such as temperature and outgoing thermal radiation. These variables have the following causality: the higher the temperature, the higher the outgoing radiation. The students had to point out this relationship in the model using an arrow and then express it more precisely using a formula.

The students who were given ‘direct instruction' simply received the information about energy in the form of texts and were instructed to complete written assignments. They did not have access to dynamic resources such as simulations and did not make a model.

Finally, in the ‘simulation-based instruction', a group of students studied the concepts with the help of a simulation of the energy of the Earth. In this case the simulation consisted of the Sun shining on the Earth, whereby the students could change the values of different variables, such as reflection of radiation and heat capacity, and then follow the effects on the temperature by studying a graph.

In order to measure the learning outcomes of the computer modelling, the reasoning processes of the students were studied and incorporated into the so-called ACE framework. The researcher divided the students' different types of reasoning skills into the three categories 'Applying' (A), 'Creating' (C) and 'Evaluating' (E). Within the 'complexity' dimension a distinction is made between reasoning in simple and in complex situations. The 'domain-specificity' dimension concerns the influence of the domain (in this case the energy of the Earth) on the reasoning processes and is described as domain-specific or domain-independent.

Constructing models improves acquisition of complex knowledge

The group of students that made computer models performed better on more complex test questions. Their reasoning processes also confirmed the trend that modelling mainly benefits the learning of complex forms of knowledge. The students in the groups receiving direct and simulation-based instruction performed best on test questions requiring the reproduction of simple conceptual knowledge.

Van Borkulo also discovered that when it comes to learning evaluation skills, there is no difference between students who followed the computer modelling approach and students who followed simulation-based instruction. Direct instruction appears to be less effective for acquiring these skills. With respect to the creation skills, no differences were found between the different instruction methods. The fact that the instruction conditions had no effect on acquiring creation skills merits further research.

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