Towards a framework for scaffolding learning science by design

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Design is a powerful vehicle to teach school children science and math (Harel 1991; Kafai, 1994; Lehrer & Romberg, 1996). Design provides a natural environment for discovering reasons why science concepts need to be learned, for seeing the contexts in which those concepts are put to use, for using those concepts to solve meaningful problems, and for engaging in meaningful reflection and thinking. Our conception of Learning by Design (Hmelo, Narayanan, Kolodner, 1995) is that a design problem is posed to children, who then collaborate, with the teacher acting as a facilitator, to propose solutions, decide what they need to learn to follow through or decide between proposed alternatives, seek out that knowledge, and incrementally construct, try out, analyze results, and revise ideas and designs. In our first implementations, we trained teachers at being facilitators and helped them learn about the particular design problems their students would work on. Based on our analyses of these experiences, we discovered some of the specific difficulties students had and designed paper scaffolding to address some of these difficulties. Experience with the paper scaffolding showed us how much more fine-grained and problem-specific the scaffolding needs to be.

Lessons Learned

We found that students needed help not only at the level of the main phases of the design process but also to successfully execute the activities within each phase. Moreover, it was clear that the support should integrate the science and the design activities in such a way that students carried out the design related activities in the pursuit of science knowledge. We are working on a framework for a model that will help us provide better scaffolding for children in LBD classrooms.

The framework that we are working on is an attempt to help us design the scaffolding at three levels and to integrate the support in such a way that the science is more integrated with the design process. From our analysis, three levels of support have been identified a *macro* level (the main phases), a micro level (the activities within each phase) and a *metacognitive* level (links between and within phases).

We describe the design process as consisting of four main stages at the macro level - analysis, description, synthesis and evaluation (macro-level). Each stage consists of numerous activities at the micro-level. Analysis consists of exploratory activities such as identifying the objectives, breaking the problem into sub problems, brainstorming, identifying issues for research, etc. The description stage involves further understanding of the problem, literature search, refining the problem specification, establishing criteria for evaluation and other activities that help in clarifying the situation. In the third stage, that of synthesis, the knowledge for the earlier two stages is combined. It is the stage in which a solution is chosen and a prototype is implemented. The final stage, evaluation, is characterized by a stepping back and reflecting. It involves evaluating the design with respect to the criteria, and identifying aspects for improvement and redesign.

Although we describe four distinct stages, they are not mutually exclusive and students traverse through different levels in the space. The task then, is to guide the students through the space defined by processes and representations along three dimensions. The first dimension defines the stage in the design process, the second dimension specifies whether it is a metacognitive, a macro or a micro activity, and the last dimension defines the representational level -- structure, function or behavior -- on which the design processes operate. An example will make the relationships clear. Suppose a student has built a prototype and is evaluating (macro) her model. While evaluating, she would have to go back (metacognitive) to the criteria (micro) that will help her to evaluate her artifact. The criteria should enable her to judge whether her prototype fulfills function (s) that was proposed, and if not whether the structure needs to be changed. Thus each activity in the process required students to reason about the science.

We are attempting to formalize this framework into a model (the propeller) and base our scaffolding efforts on it.

References

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