

# Chapter XIV

## Scaffolding Problem–Solving and Inquiry: From Instructional Design to a “Bridge Model”

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### ABSTRACT

*The study examines cognitive support for science learning in a computerized environment. The research was carried out with junior high school students, who used a problem-solving computerized environment in science. For this purpose, four support components were identified - structural, reflection, subject-matter, and enrichment components. These components were used to construct four computerized cognitive support models based on human teaching. The effects of these support models on achievement, on cognitive and meta-cognitive skills, and on reflective behavior are compared to one another and to a control group. The results led to the construction of a theoretical-functional “Bridge Model”. The model elucidates the functions of the structural, reflective and subject-matter components upon the cognitive system, and offers an explanation of the research findings. The study and its main results are presented, as well as a theoretical description of the Bridge Model.*

### INTRODUCTION

Instructional design is the technology of creating learning experiences and learning environments, which in turn, promote instructional activities such as directing students to appropriate learning activ-

ities, guiding students to appropriate knowledge, or helping students to process information (Merril, 2006). The recent widespread use of open-ended computerized environments such as simulation, discovery learning and problem-solving learning environments has raised several theoretical and

educational issues that should be answered to fully exploit their potential (Azevedo, 2005; Mayer, 2004). Due to their open character--which places a great emphasis on learners' activities and the high cognitive and meta-cognitive demands they pose upon the learners--*such environments do not elicit productive learning by and of themselves* (De Corte, 2000). *Guidance is crucial*. Consequently, pedagogical approaches have to be incorporated into the learning and teaching environments (Webb, 2005), appropriately embedded with sufficient support and scaffolding (instructional support) (de Jong & van Joolingen, 1998). Quintana et al. (2004) argue that "advances in the field [of scaffolding] require an empirically grounded consensus about successful scaffolding methods" (p. 339). At the same time, there is a need for further research concerning which "pedagogical approaches are effective in supporting learners" (ibid., p.376) as also are tailored to the demands of the learning task. Similarly, De Corte (2000) calls for further elaboration and testing of principles for the design of powerful computer-supported learning environments as a challenging joint task for researchers and practitioners. Sweller et al. (2007) encourage a deeper consideration and explication of the required amount and type of instructional "guidance" through the careful design of systemic instructional experiments. Careful attention and research investigation is needed to implement effective open-ended computerized activities as well as *to find appropriate and effective scaffolding approaches* (Azevedo, 2005; Hmelo-Silver et al., 2007). In the current study, we engaged these challenges. Our design was followed by large-scale school implementation and empirically grounded examination of the learning outcomes. Some design approaches are presented as follows.

### **DESIGN APPROACHES**

A number of scaffolding studies have adopted a *strategies-oriented support* approach (Hmelo-

Silver et al., 2007; Zhang et al., 2004). Some of these, support learners in accomplishing specific tasks--such as generating hypotheses--in simulation-based discovery learning (Njoo & de Jong, 1993), or developing causal or evidence-based explanations (Hmelo-Silver et al., 2007); others focus on the impact of specific support strategies (de Jong, 2006; de Jong & van Joolingen, 1998). Quintana et al. (2004) organize their scaffolding design framework around three constituent processes of inquiry: *sense making* (the basic operations of testing hypotheses and interpreting data); *process management* (the strategic decisions involved in controlling the inquiry process); and *articulation and reflection* (the process of constructing, evaluating, and articulating what has been learned). De Jong (2006) reviews scaffolding of inquiry learning, organized around each of the learning processes involved – *orientation, hypothesis generation, experimentation, drawing conclusions and making evaluations*. Although in the study we used a teacher oriented approach for scaffolding (see the following), we included some detailed categorization of computerized science problem-solving skills (Fund, 2003; Method, the COSPROS Scheme, experiment B, and Table 2).

The current on-going research project approaches the challenge of the scaffolding's design from a teacher oriented perspective. It is based on the three "idealized teacher models" described by Scardamalia and Bereiter (1991). The scaffolding programs of the current research are constructed on these platforms. The models were implemented appropriately by the following support programs – *Operative, Integrated and Strategic* (see Method section). We used four support components previously found effective in computerized learning environments – *structure, reflection, subject-matter, and enrichment* – in different configurations. The programs were implemented by appropriate *worksheets* (for each student, for each problem). These were found to be suitable for scaffolding students in both overall structure and in specific reasoning steps (Njoo & De Jong 1993; Vreman-de

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