Design Distributed Scaffolding for Modeling a Complex System

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Abstract: Based on the expert-novice analysis, we developed a distributed scaffolding curriculum for modeling air quality (DSCMAQ) to facilitate high school students' model-based reasoning in a technology-enhanced learning environment (APoME) which provided the Modeling Air Quality (MAQ) software associated with gradual complex learning tasks. Three studies had conducted to evaluate the effects of DSCMAQ on students' modeling practices. In these three studies, students worked in a small group to complete DSCMAQ and their modeling abilities were improved after DSCMAQ.

Introduction

In current science education reform, models and modeling have been regarded as necessary to scientific literacy (National Research Council, 1996; AAAS, 1993; Gilbert, 1991; Linn & Muilenberg, 1996; Perkins, 1986). As constructivist epistemology becomes more widely adopted, most science educators now agree that scaffolding students by building models to help them understand scientific phenomena is an effective instructional method (Sins, Savelsbergh, and Joolingen, 2005; Jonassen, Strobel, and Gottdenker, 2005). However, researchers have pointed out that students face a variety of problems during the model-building process (Coll, & Treagust, 2001; Kawasaki, Herrenkohl, and Yeary, 2004; Sins, Savelsbergh, and Joolingen, 2005) so scaffolds are needed for model-based learning. Since there are multiple students with different zone of proximal development (ZPD) in a classroom context, a single teacher can't provide scaffolds for all students at the same time (Brown, Ash, Rutherford, Nakaguwa, Gordon, and Campione, 1993). A software-based support (Guzdial, 1995) was suggested to embed several kinds of supports in software such as building blocks for building a model & visualizing the connections between pieces of a model (Guzdial, 1995), evidence hints & metacognitive hints to support students' scientific reasoning (Knowledge Integration Environment, KIE, Linn, 1995; Davis, 2003), and supportive, reflective & intrinsic prompts (Model-It, Jackson, Krajcik, and Soloway, 2000).

Distributed Scaffolding for Modeling –Based Learning

According to a scaffolding design framework proposed by Quintana, Reiser, Davis, Krajcik, Fretz, Duncan, Kyza, Edelson, and Soloway (2004), the Modeling Air Quality (MAQ) software included the following features: (1) a visual conceptual organizer (the advance organizer in the building phase, see Figure 1); (2) an expert guidance for applying science content and modeling practices (supportive prompts in the testing and applying phases, see the right corner in Figure 1); (3) explicit disciplinary strategies for students' creating artifacts (data analysis tools); (4) representations to reveal underlying properties of data (viewing data from horizontal distribution, vertical profiles, trend graphs, difference graphs, and a one-hour interval loop of pollution density figures); (5) multiple views of the same data (viewing data horizontally and vertically) and malleable representations (everywhere in the MAQ software); (6) restricting a complex tasks by setting useful boundaries and using ordered & unordered task decompositions (the complexity of the tasks increasing from the testing to applying and evaluating phases); (7) constraining the space of activities by using functional modes (constraining the space of activities in the four phases of the MAQ software) and automating nonsalient portions of tasks to reduce cognitive demands (the computer program is in charge of calculating pollutant density associated with variables and distances from pollutant sources); (8) facilitating navigation among tools and activities (the interface designs allow students to navigate among data analysis tools, the advance organizer, supportive prompts, setting of inputs, and the result for each trail).

Finally, we developed a distributed scaffolding curriculum for modeling air quality (DSCMAQ) including two parts: background knowledge (unit 1 and 2) of air quality and model-based reasoning in a technology-enhanced learning environment (APoME) which provided a MAQ software and learning activities from unit 3 to 5 with gradual complex tasks to facilitate students' modeling practices. We conducted a series of studies to examine the effects of scaffolds. In these studies, students worked in a small group to complete DSCMAQ so that they could gain more learning supports from peer discussions and whole-class discussions when sharing ideas or responding to the teacher's questions.

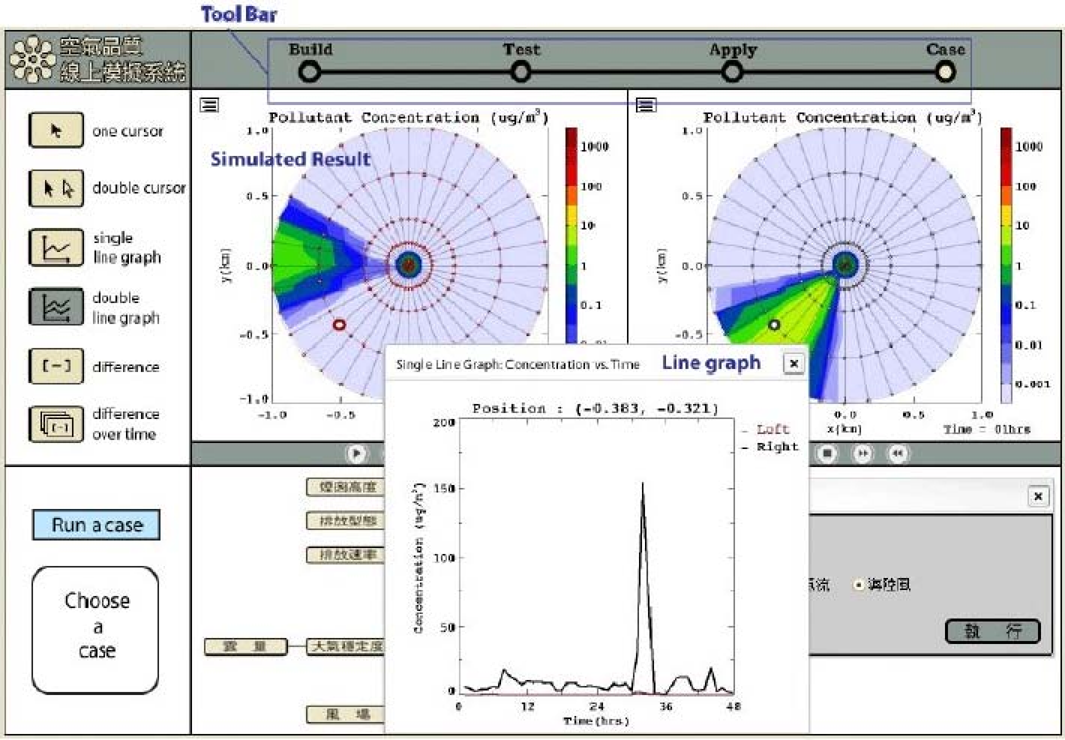

Figure 1: Interface of the MAQ software

Methods

In order to examine the effect of distributed scaffolding, design-based research is used to conduct a series of studies with various scaffolds and instructional design. For study 1, 28 tenth graders were grouped into 8 groups (4 groups selected randomly as the focus groups) to complete the first version of the MAQ software which provided an advance organizer to help students identify and connect major variables related to air quality. After revising the MAQ software based on the findings of Study 1, we conducted Study 2 (34 senior high school students in 10 groups) in order to promote students' abilities in planning, experimental design and identifying relations. After adding explicit prompts with inquiry cycles in activity sheets, Study 3 (24 tenth graders in 12 groups) was used to explore how students identified relations and modeled air quality.

Results

The interviews of the focus groups in Study 1 showed that most students' ability in making conclusions was improved distinctly but slightly in planning, experimental design, and identifying relations after the intervention. Students in Study 1 made significantly progress in conceptual comprehension ($t=3.319$, $p<0.003$). Study 2 showed that students' modeling abilities were improved significantly ($t=3.841$, $p<0.001$) after the intervention; especially, in planning and experimental design but still slightly improved in identifying relations (see Table 1). Study 3 using explicit prompts in inquiry cycles helped students verify learning tasks during modeling air quality so students' overall modeling ability were improved significantly after the intervention ($t=4.832$, $p<0.000$); especially in identifying relations (see Table 2). It is hoped that the present study can at the very least serve as a foundation for future research in identifying and explaining the elements and functions of model-based teaching and learning (MBTL).

Table 1: Summary table of paired-t test in Study 2 Table 2: Summary table of paired-t test in Study 3

	Pre-test		Post-test		t	P
	mean	S.D.	mean	S.D.		
Planning	0.88	0.66	1.5	0.622	4.706	.000**
Experimental design	1.09	1.279	2.22	1.539	3.588	.001**
Identifying relations	2.22	1.913	2.56	1.703	0.938	0.355
Total	4.19	3.021	6.28	3.040	3.841	.001**

	Pre-test		Post-test		t	P
	mean	S.D.	mean	S.D.		
Planning	1.35	0.573	1.35	0.573	.000	1
Experimental design	1.78	1.476	2.35	1.027	1.769	0.91
Identifying relations	2.35	1.191	5.22	3.059	4.513	.000**
Total	5.48	2.626	8.91	3.088	4.832	.000**

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