SCAFFOLDED FLEXIBILITY MODEL

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Introduction

According to the 1999 release of the Third International Math and Science Study-Repeat (TIMSS-R), scientific and mathematical conceptual understanding and problem solving are still lacking in K-12 education (International Study Center, 1999). This study, along with the original TIMSS report in 1995, illustrated how students in the United States have fallen significantly behind those in other countries in science and math education (International Study Center, 1995). The results from these studies are consistent with reports published by the National Assessment of Educational Progress (NAEP) that compare student achievement against national standards. According to this Nation’s Report Card, 3% of the nation's students reached the advanced level for science in fourth, eighth, and twelfth grades. Twenty-three percent of fourth graders, 25% of eighth graders, and 43% of twelfth graders performed below the basic level in science. Although math scores have improved from 1990 to 1996, a large percentage of students are still not performing at the basic level for math. Thirty-six percent of fourth graders, 38% of eighth graders, and 42% of twelfth graders did not meet the basic level (O'Sullivan, Reese, & Mazzeo, 1997).

These mathematical and scientific skills and understandings are critical for many fields such as medicine, engineering, and business. According to the American Association for the Advancement of Science (1990), the future of our industrial nation and the global community depends on the education of individuals in science, math, and technology.

In order to support young learners in solving complex scientific and mathematical problems, I developed a new instructional strategy called the scaffolded flexibility model

(SFM). This model builds on the cognitive flexibility theory (CFT) and incorporates situated cases and scaffolding elements from a variety of constructivist theories and models. To demonstrate how SFM can be used to design learning environments, a prototype of an environment based on SFM was developed.

In this program, the students take on the role of an intern for an environmental consulting firm. They are given a client who is facing a number of environmental issues and are asked to do research about these issues and come up with recommendations for the company. Their final recommendation to the client must include a cost/benefit analysis. To do this research, the students will "interview" experts and "conduct" site visits. The students will get to hear multiple perspectives on these topics so they can wrestle with these issues and draw their own conclusions.

The program is divided into two parts, the problem introduction and the situated problem-solving environment. During the problem introduction, students will become acquainted with the case they will work with during the course. They will meet their internship supervisor, who acts as a coach throughout the program, and their client, who explains the problematic situation that his company is facing.

The situated problem-solving environment will provide students with the tools necessary to solve the problem. It will also present the expert interviews as individual cases that offer various perspectives on the solution to the problem. These experts discuss their approach for solving the problem, and the criteria they use to determine if the outcome is successful, as well as offer war stories from their past experiences.

Conceptual Framework: Scaffolded Flexibility Model

In order to design a program for younger learners, this environment employs a new instructional strategy called the scaffolded flexibility model (SFM) that builds on the cognitive flexibility theory (CFT). In addition to CFT, SFM situates the learning environment within an authentic scenario and employs a range of scaffolding techniques selected to provide additional structure and support while still allowing the learners to develop flexible knowledge structures about complex issues.

Cognitive Flexibility Theory

The main theoretical framework used in the development of this model is the cognitive flexibility theory. CFT is a theory that was developed by Spiro and his colleagues at the University of Illinois's Center for the Study of Reading in the late 1980's. This theory specifically addresses the deficiencies of advanced knowledge acquisition. Spiro, Coulson, Feltovich, and Anderson (1988) hypothesized that many of the learner failures came about because complex knowledge was oversimplified and consequently learners developed misconceptions. To counteract these learning failures, they developed a theory "that emphasizes the real-world complexity and ill-structuredness of many knowledge domains" (Spiro, Feltovich, Jacobson, & Anderson, 1991, p. 24). Out of this theory, they developed a set of recommendations for the development of hypertext learning environments. These recommendations are to incorporate multiple representations, include case examples, avoid oversimplification, utilize the web-like nature of knowledge, and provide opportunities for knowledge assembly.

Multiple Representations. “Cognitive flexibility is dependent upon having a diversified repertoire of ways of thinking about a conceptual topic” (Spiro et al., 1988, p. 5). To represent more accurately the “multifaceted” complexity of knowledge, CFT recommends using multiple themes, schemas, analogies, or intellectual points of view in instructional activities (Jacobson & Spiro, 1995). Spiro and his colleagues use a metaphor of the ill-structured domain as a complex landscape. An explorer of this landscape cannot begin to understand all of its hills and valleys through one traversal. One must cross the landscape via multiple paths to gain an understanding of its complexity (Spiro et al., 1988). In this learning environment, the student will have the opportunity to interview experts from various fields. After hearing these experts’ different perspectives, students will develop their own ideas on the best approach for solving this problem. By wrestling with these conflicting viewpoints, they will develop flexible knowledge structures around “real world” issues.

Case Examples. Instead of presenting knowledge in a decontextualized format, CFT recommends presenting abstract concepts within multiple cases to provide a variety of contexts and uses of that knowledge. These cases can illustrate the intricacies of the ill-structured domain. In this theory, “the cases are key -- examples are necessary, and not just nice” (Spiro et al., 1988, p. 7). Case examples are used in this program for each expert’s viewpoint. Each expert presents a separate case that will interpret the student’s case from a different perspective.

Avoid Oversimplification. Instead of simplifying complex knowledge domains, CFT recommends that the learning environment highlight the complexities and irregularities of the subject during the introduction of the instruction (Spiro et al., 1988).

This prepares the learner for deeper study “that is not qualitatively different from the earlier introduction” (Jacobson & Spiro, 1995, p. 304). In the problem introduction, the students learn that this case can be examined from multiple perspectives and that they need to integrate these different perspectives into their recommendations in the final report.

Interrelated or web-like nature of knowledge. There is a tendency to separate complex domains into separate chapters. As an alternative, CFT proposes that the learning environment stress the interconnectedness of the multiple domains of knowledge. Rather than compartmentalizing topics, the environment should demonstrate how the domains overlap. Multiple paths should be established to enable the learner to “criss-cross” the “conceptual landscape” through different paths (Spiro et al., 1988, p. 8). In this program, the cases are interrelated to information presented in the resource books, which provide links to relevant web sites. The telephone, the help system in this application, can help the students make connections between the various sources of information.

Knowledge Assembly. In order to create flexible knowledge structures that enable the transfer of information, CFT stresses that learning environments provide opportunities for learners to combine and synthesize multiple sources of information in different ways to solve various problems (Spiro et al., 1988). In this environment, analyzing the various alternatives to the problem and synthesizing this information into a final report will help the students develop their own recommendations for the client’s situation.

Situated Problem

SFM prescribes that the ill-structured domain be situated in a meaningful context, which is not necessarily the case with CFT.

> While cognitive flexibility theory does not particularly prescribe that the cases for the student to criss-cross should be authentic real life cases, it is not difficult to see that cognitive flexibility theory can go hand in hand with situated learning in case-based environments, especially when the domain of instruction is illstructured and the use of domain knowledge is often expected in real life situations. (Li & Jonassen, p. 425)

Situated problems address the issue of students learning concepts decontextualized from how they are used by practitioners. For example, the way an engineer uses a math formula is very different from how students use this formula in school. In school, "it is common for students to acquire algorithms, routines, and decontextualized definitions that they cannot use and that, therefore, lie inert" (Brown, Collins, & Duguid, 1989, p. 33). Instead of learning authentic applications of science and mathematical concepts, they learn how to use these concepts in relation to the culture of the school environment. "Thus, students may pass exams (a distinctive part of school cultures) but still not be able to use a domain's conceptual tools in authentic practice" (Brown et al., p. 34). If students are learning material primarily for a test, they soon forget the material because they have not made connections between the new information and its applications. When asked to apply this knowledge to a similar situation on another exam or even later in life, the students have difficulty retrieving this "inert" knowledge. One way to counteract this problem is to create authentic activities so that students can simulate "real world" uses in the classroom. To that end, this learning environment uses real experts within its cases who share their actual experiences with the learners.

Scaffolding

The scaffolding strategies in SFM use elements from constructivism, analogical reasoning, problem-based learning (PBL) model, metacognition, and cognitive apprenticeship. As shown in Figure 1, the scaffolding in the problem introduction is required (i.e. the learners cannot bypass the scaffold) and its timing is controlled by the system. In the situated problem-solving environment, only the time management scaffold is both required and controlled by the system. The organization and higher order thinking scaffolds are required, but the learners have control over when they access them. On the other hand, modeling and coaching are completely optional in the problem-solving environment.

Prior Knowledge Connections

To help bring out students' prior knowledge about the case, analogies and questioning are used in the problem introduction.

Analogies. "One mechanism that has been recognized by scientists, philosophers, and psychologists alike as having the potential of bringing prior knowledge to bear on the acquisition of, sometimes, radically new information is analogy" (Vosniadou, 1989, p. 413). In this program, an analogy will be used to teach students the problem-solving approach required to write a proposal. This analogy will compare the proposal writing to a laboratory experiment in a science class.

Questioning. Questions "provide the starting point for the processes through which we integrate new information into our memory, tie old information together in new ways, and correct our faulty generalizations. It is probably not too strong to say that until we ask a question we are unable to integrate an answer into our memories" (Schank, 1995, p. 41). In the problem introduction, the supervisor asks the interns questions about what they currently know about the problem and what they need to know in order to solve the problem. There are pauses in the program for the classroom teacher to facilitate discussions to evoke students' prior knowledge about this topic and to get them to talk about what they need to learn in order to solve the problem.

Time Management

An important part of problem solving is time management. Problem solvers must learn how to work within time constraints, to meet a final deadline by defining smaller deadlines, and to work at a fairly even pace rather than leaving all the tasks until the last minute. In this project, deadlines are given to keep students on track with completing the final report.

Organization

Closely associated with time management is organization. In order to solve a problem, a problem solver must break the problem into smaller problems and divide the overall task into subtasks. The organizational scaffolding is based mainly on the PBL model. In the PBL model, students are encouraged to articulate the problem, develop a hypothesis, gather information to solve the problem, re-examine the problem, and revise the hypothesis as needed. At the end of the process, students abstract the knowledge they have learned and summarize their findings (Savery & Duffy, 1996). The design of the research notebook is based on principles from the PBL model. This notebook provides students with a template to break down the problem and organize their tasks.

Higher Order Thinking

Metacognition is a higher-level thinking task that occurs when experts solve problems. It is the ability to be aware of oneself as a problem-solver combined with the ability to monitor one's mental processes. This higher-level thinking allows problem-solvers to recognize what they do not know and to judge when the problem is solved (Winn & Snyder, 1996). To prompt this type of thinking, reflection and self-assessment methods were employed in the design.

Reflection. "Reflection refers to students looking back over what they did and analyzing their performance" (Collins, 1991, p. 130). This type of "assessment enables learners to focus not only on performance outcomes, but on diagnosing the cognitive processing components, strategies, and knowledge structures that underlie performance" (Choi & Hannafin, 1995, p. 64). In this program, students will be asked to reflect on what they have learned and what questions they still have as they move through the process. One way to "provoke reflection [is] by periodically posing questions that possess deeper conceptual significance" (Chee 1994, p. 496). These questions are posed to the student when the supervisor asks for a status report on their research.

Self-assessment. Authentic assessment naturally arises as part of an authentic activity. In authentic assessment, it is very important to replicate an actual situation. "Proponents of authentic assessment seek to estimate learning within specific contexts that approximate the ill-defined, uncontrollable aspects of the real world, a world in which the much vaunted generalizability of standardized tests may have little relevance" (Reeves & Okey, 1998, p. 193). Since an intern would not be asked to take a test in the workplace, it would not make sense to create a test within this program. The products developed by the students simulate actual products that they would create at work.

Supportive Guidance

Coaching. "Coaching is the thread that runs through the entire apprenticeship experience" (Collins, 1991, p. 8-9). The coach provides hints and scaffolding, challenges students, offers encouragement, and gives feedback. The coach acts "as [a] model[] for performing learning tasks and as advisor[] to students on how to improve their performance" (Winn, 1993, p. 18). In this application, the student will take on the role of an intern for a consulting company and ostensibly becomes the apprentice of the internship supervisor. The supervisor will offer examples from previous clients and provide advice or "hints" to the student as to how to approach the problem.

Modeling. "Modeling is showing how a process unfolds, and explaining involves giving reasons why it happens that way. It is the showing and telling that is so characteristic of apprenticeship" (Collins, 1991, p. 124). In this program, modeling will be used to show students an effective way to take notes. Although students take notes in school on a daily basis, they are rarely shown how to take notes effectively. Sample reports will also be provided as a model for students to follow.

Conclusion

In summary, the scaffolded flexibility model builds on elements of the cognitive flexibility theory by situating the learning environment within an authentic scenario and by providing additional structure through scaffolding elements. This instructional model will provide support for young learners as they solve complex scientific and mathematical problems.

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Figures

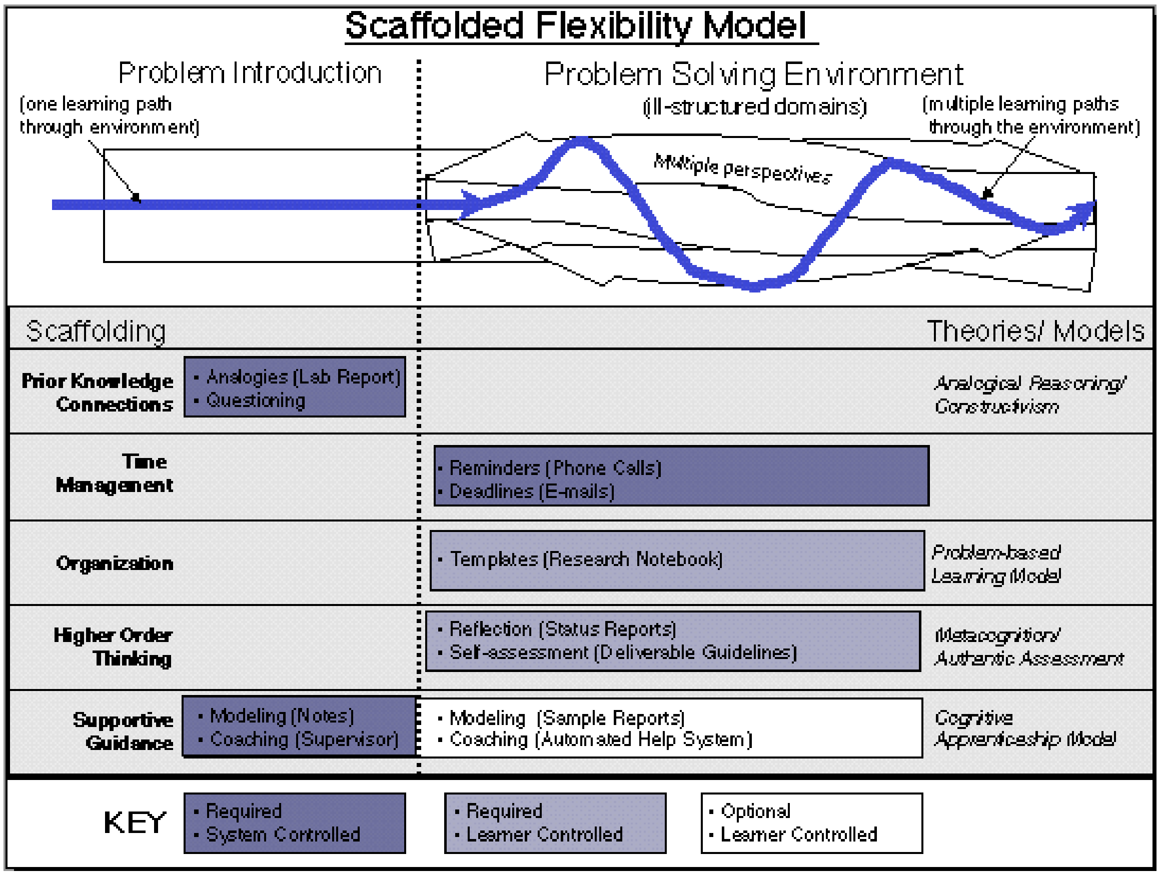

Figure 1. Diagram of Scaffolded Flexibility Model