

STUDENTS DEFINING COMPLEX PROBLEMS THROUGH QUESTIONING:
THE EFFECTIVENESS OF SCAFFOLDING IN A MULTIMEDIA PROGRAM

Janet Mannheimer Zydney

New York University
Program in Educational Communication and Technology
Department of Administration, Leadership, and Technology

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INTRODUCTION

As Supreme Court Justice Frankfurter once said, “The likelihood of getting on the road to [the] right answers ... is very slim unless the right questions are asked” (Frankfurter, 1951, p. 1023). Asking good questions is critical in defining the problem that one eventually hopes to solve. However, the problem remains that “children everywhere are schooled to become masters at answering questions and to remain novices at asking them” (Dillon, 1990, p. 7). This problem becomes even more evident in research conducted by Rowell, Gustafson, and Guilbert (1999). When the researchers asked these engineers how they learned to solve technological problems, many responded that defining the problem was the hardest part for them to learn because it was not a skill they learned in school. One engineer noted that the most difficult aspect was developing the research questions. The necessity to promote these skills has been recognized by the National Academy of Science in their emphasis on scientific inquiry in the National Science Education Standards (National Academies Press, n.d.). Given this need, my study focused on the activities involved in problem finding, the early stages of problem solving.

In recent years, researchers have studied the various aspects of problem finding. Problem finding encompasses a wide range of activities ranging from problem recognition to problem invention (Runco & Nemiro, 1994). Formulating questions can help students invent new problems or define a given problem. Researchers have found that the nature of these questions varies at different stages of this process (Silver & Cai, 1996). For example, some studies have concentrated on the nature of questions asked by students when defining a problem (Chin, Brown, & Bruce, 2002; Czarnik & Hickey, 1997; Dori & Herscovitz, 1999; Olsher & Dreyfus, 1999), and other studies have investigated the nature of questions asked by students planning their own investigations (Cuccio-Schirripa & Steiner, 2000; Keys, 1998). Closely linked to students’ questioning is their underlying knowledge about the problem because in order “to ask a question, one must know enough to know what is not known” (Miyake & Norman, 1979, p. 357). Thus, several researchers have also investigated students’ knowledge acquisition in addition to their questions (Dori & Herscovitz; Olsher & Dreyfus). Based on this earlier research, my study examined students’ ability to formulate questions as well as their knowledge

acquisition of the complex problem.

In order to assist students in defining a complex problem, different types of scaffolding were tested to determine which was most effective in helping students with this task. Scaffolding that focuses on assisting students with cognitive processing was thought to be the most critical for students to define the problem because this stage of problem solving requires that students gather, organize, and synthesize information about the problem. Different categories of scaffolds that support cognitive processing were found in the literature. These categorizations were based on a cognitive tool classification developed by Iiyoshi and Hannafin (1998). Organizational scaffolds that are designed to help students break down tasks into subtasks have been found to improve the overall quality of students' work (Davis & Linn, 2000). Higher-order thinking scaffolds that are designed to help students use reflective strategies to process content more deeply have been found to improve students' knowledge integration (Davis, 2003; Davis & Linn; Wolf & Brush, 2000). Thus, my study investigated the use of organization and higher-order thinking scaffolds in helping students define a complex problem.

CONCEPTUAL FRAMEWORK AND LEARNING ENVIRONMENT

In order to support students in defining problems, I developed a learning environment called *Pollution Solution* specifically for this research. In this environment, the students take on the role of an intern for an environmental consulting firm. They are given a client who explains the symptoms of his company's legal problem involving air pollution, and they are asked to do research in order to construct the problem and come up with recommendations for a solution. To do this research, the students "interview" experts and "conduct" site visits. The students get to hear multiple perspectives on these topics so they can wrestle with these issues and draw their own conclusions.

The design of the complex, ill-structured problem presented to the students in *Pollution Solution* is based on principles from the cognitive flexibility theory (CFT) and situated learning theory. For example, this learning environment employs aspects of CFT by presenting students with different expert viewpoints on the problem, providing multiple cases, stressing the interconnections between related disciplines, and offering opportunities for knowledge synthesis (Jacobson & Spiro, 1995). Situated learning theory complements CFT by drawing on cases from the real world that are inevitably richer and more complex than ones that are fabricated (Li & Jonassen, 1996). Layers of scaffolding were added to *Pollution Solution* through an iterative

design-and-development process, including formative evaluations with teachers and students, over a 3-year period. As a result of this process, I conceptualized a new instructional model that builds on CFT and incorporates situated cases and scaffolding elements from a variety of constructivist theories and models. This scaffolding helps foster students' cognitive processes, provides modeling and coaching, and helps students with time management. For the purposes of this discussion, this model will be referred to as the scaffolded flexibility model (SFM) (see Zydney 2003a for further details on this model).

DESIGN OF THE STUDY

This study investigated the effectiveness of different types of scaffolding in an SFM environment for helping students define a complex problem situated in an environmental context. Specifically, this study examined how different scaffolding affected students' knowledge acquisition and ability to formulate questions about the problem. In order to determine this, different treatment conditions of the software were developed with varying amounts of scaffolding to support the learners. The overarching question was, what is the effect of scaffolding type in a multimedia program on students' knowledge acquisition of the problem and their ability to formulate investigative questions?

Sample

The students who participated in this study attended 10th-grade science classes at a New York City public school with a diverse student body representative of an urban area along cultural and socio-economic lines. Seventy-nine students ranging from 15 to 16 years of age participated in this study. The students were randomly divided into four biology classes that were all taught by the same teacher. In the discussion of the findings, the results from this study are compared to a similar pilot study conducted the previous year (Zydney, 2003a). The pilot study was conducted with 60 eighth-grade students from four earth science classes in a different public school in New York City.

Independent Variables

Treatment. The treatment was the problem-definition phase of a problem-solving project about the environment. Using the *Pollution Solution* software, the students defined the problem that they had to solve over the course of the project. Through this software, the students were assigned a client, a fictitious utility company that was sued by the Justice Department on behalf of the Environmental Protection Agency for defying anti-pollution regulations and illegally

contaminating the air. During a virtual interview (through a video clip) with the Vice President of the utility company, the symptoms of the problem were presented to the students, and it was their job to construct the problem and figure out exactly what had happened. Why was the client sued? What caused the environmental activists to hold protests outside their offices? Why were the company's stock prices plummeting? In order to define this problem, the students were asked to write descriptions of the problem and formulate investigative questions that would help them eventually solve the problem.

The classes were randomly assigned to one of four conditions of the treatment. All students in the same classroom received the same condition. Each condition utilized a slightly different version of the software. All versions explained the problem scenario through opening videos with the internship supervisor and client and also provided resources for the students to solve the problem. However, the different treatment conditions included varying types of scaffolding to help students define the problem. Condition 1 was the control group and provided students with directions to write the research plan. Condition 2 included the organization scaffold, the research plan template, which provided the students with the same directions to write the research plan as in Condition 1, but also included headings and focusing questions to help students organize their research. Condition 3 included the higher-order thinking scaffold, a status report. The status report gave the students reflective, higher-order thinking questions to help them integrate their new ideas with their prior knowledge. Condition 4 was a combination of Conditions 2 and 3 and included the research plan template and the status report.

Divergent-thinking Ability

Researchers have shown that divergent-thinking ability is related to problem finding (Hoover, 1994; Hoover & Feldhusen, 1990). The construct of fluency was most relevant to this study because students were asked to generate questions about the problem. Fluency was measured by the Topics Test (reliability = .81) (Ekstrom, French, & Harman, 1992). The reliability of this instrument was retested for this study ($\alpha = .86$).

Computer-treatment Time

The computer-treatment time is the total time students spent using *Pollution Solution*. A log file recorded the start and stop time of each student's session, and the duration of time was computed. The computer-treatment time was the sum of the session times. In some cases, the end time of one of the sessions in the log file was not recorded because students' computers

crashed at some point during the week. The end time for these sessions was estimated as the last recorded time in the log file.

Dependent Measures

The dependent measures were students' knowledge acquisition about the problem and their ability to formulate questions about the problem (as measured by their frequency, type, and specificity). All dependent measures were assessed through rubrics, which an earth science teacher reviewed to confirm their validity. Two evaluators rated each of the dependent measures independently and then came together again to discuss discrepancies. Inter-rater reliabilities are reported in the sections describing each variable.

Knowledge Acquisition

The students were asked to write a research plan that included a description of the problem that they were trying to solve. In order to demonstrate a strong understanding of the problem, the students needed to describe the legal, environmental, economic, and public relations factors about the problem in their research plans. A student received 1 point for each possible factor. Knowledge-acquisition scores ranged from 0 to 6 points. No one received a 7, the highest possible knowledge-acquisition score. The inter-rater reliability was .81.

Ability to formulate questions

After the treatment, the students were asked to generate questions about the complex environmental problem and the reason for asking the question. The students' ability to formulate these questions was measured by frequency, type, and specificity.

Question Frequency. Since researchers have found that students who are more familiar with a problem ask a greater number of questions (Dori & Herscovitz, 1999), the number of questions asked by each student was computed.

Question Type. Students with increased expertise in a problem have been found to ask more questions related to the problem domain (Czarnik & Hickey, 1997) and its solution (Dori & Herscovitz, 1999). Thus, students' questions were evaluated to determine whether they were subject oriented, problem oriented, or solution oriented. Subject-oriented questions were ones dealing with general subject matter associated with the problem such as economics, environmental science, law, or engineering. For example, a subject-oriented question was "what is the Clean Air Act?" Problem-oriented questions dealt with factors connected with the client's objectives and goals. These factors include the political and legal considerations of the problem,

environmental factors, economic aspects, ethical issues, or the public relations problem. An example of a problem-oriented question was “what is the standard sulfur dioxide emission level according to the EPA?” Solution-oriented questions asked about the different alternative solutions to the problem. “How much can solar powered energy cost?” was an example of a solution-oriented question. The number of questions for each type was computed, and the percentages of each question type was calculated based on the total number of questions generated. The raters agreed on 94.6% of these ratings.

Question Specificity. Previous research has also shown that students with increased expertise about the problem ask more specific questions (Czarnik & Hickey, 1997). Thus, the students' questions were also coded for level of specificity. Unclear question were statements that were ambiguous or contained misconceptions. General questions dealt with general content knowledge such as “What are some clean air technologies?” An example of a specific question was “How much do clean air technologies cost?” A specific question elicited data required to solve the problem, but required further questions to get to a more precise answer; whereas, a very specific question did not require any further questions. For example, in the previous question, the student would need to know how the different types of clean air technologies work. A very specific question dealing with this same topic could be “what would be the exact cost and sellable value (of the byproduct) of the sulfur dioxide recovery system?”

Unclear questions were coded a 0, general questions were given a 1, specific questions were rated a 2, and very specific questions were coded a 3. A mean question-specificity score was calculated for each student. To obtain this score, the total number of questions generated by the student in each category was multiplied by the value of that category. The sum of these calculated values was divided by the total number of questions generated by the student in order to compute his or her mean question-specificity score. For example, if a student generated one unclear question, five general questions, two specific questions, and two very specific questions, his or her mean question-specificity score would be 1.5. The inter-rater reliability was .91.

Procedures

During six 60-minute class periods, the students participated in the study. During the first session, students were given their code numbers and completed the Topics tests. During the second session, the class watched the introductory videos where they met their supervisor and saw an acid rain overview video. After the overview, the class met their client and learned about

the acid rain problem faced by the company. During the third session, the class discussed what they needed to know in order to solve the problem. Then, the teacher distributed the laptop computers to the students. After a brief demonstration of the software, the students explored the interface of the software. During the fourth session, the students independently researched and took notes about the problem. At the end of the day, the students with the higher-order thinking scaffold and the combination scaffold completed their status reports. The next day, the students started writing their research plans, which they finished during the final session. All groups had the same amount of time to use the computer resources and to write their research plans.

After completing their research plans, the students completed a 20-minute questioning assessment and final survey on the computer. For this assessment, the students generated as many questions as they could think of that would help them to solve the problem and explained their reasoning for asking each question. At the end of this assessment, the students answered a few survey questions to determine if they were absent, worked at home, lost any data during the study, or discussed their work outside of class. After completion of the study, the students continued to use the software and participate in class activities to solve the environmental problem.

RESULTS

Controls

Potential factors that might affect the results of the study were collected. These factors included students' number of absences during the study, amount of time worked at home, level of discussion outside of class, amount of technical problems/ loss of work, computer-treatment time, and prior divergent-thinking ability.

Although there was a high absentee rate over the duration of the study (including 17 students who were absent for 1 day and 5 students who were absent for more than 2 days of the study), the impact of this factor was minimized by requiring students to make up all the work that they missed. Only 4 students reported to have worked at home during the study. Temporarily removing these students from the analyses did not change the results; thus, these factors did not appear to have affected the results. There was a concern that students might talk outside of class and find out that they were using different versions of the software, but this turned out not to be a problem. Most of the students (82%) reported they either never or rarely spoke about the software outside of class. This result was confirmed through classroom

observations and field notes taken during the study.

Although there were some technical problems during the study (both hardware and software related), the number of students who lost a portion of their work (e.g. a note) was similar across the classes. These technical problems caused some students to have less time to use the computer. In addition, time variations were caused by students who came late to class. Although the amount of time spent on the computer ranged from about 2 hours to 3 hours and 20 minutes, the students' time using the computer did not significantly vary among the classes. In addition, this variable was used as a covariate in the analyses to control for time differences within the classes. This study also controlled for students' prior divergent-thinking abilities. A one-way ANOVA was performed on the Topic test scores with scaffolding type as the between-subjects factor. This analysis did not produce significant results; thus, prior to the treatment, the classes were found to be equivalent across this measure.

Effect of Scaffolding Type on Students' Knowledge Acquisition

To examine the effectiveness of the scaffolding in an SFM environment on students' understanding of the problem, an ANCOVA was computed with knowledge acquisition as the dependent measure, scaffolding type as the between-subjects factor, and computer-treatment time as the covariate.

After adjusting for computer-treatment time, students' knowledge acquisition of the problem varied significantly for different treatments ($F(3,74) = 3.58, p = .02$). The scaffolding type had a medium effect ($\eta^2 = .13$) on the differences between these scores. The magnitude of this effect size was estimated from Cohen's (1988) classification, which categorized effect sizes as small (.01), medium (.09) and large (.25) (as cited in Weinberg & Abramowitz, 2002). Pairwise comparisons revealed that the students who used the organization scaffold had a significantly higher understanding of the problem than the control group ($p = .02$). No significant differences between the other pairs were found. Table 1 shows the differences in knowledge acquisition for the different treatment conditions.

Table 1
Means and Standard Deviations for Knowledge acquisition for Different Treatment Conditions

Treatment conditions	<i>N</i>	<i>M</i>	<i>SD</i>
Control	21	1.38	0.82
Organization	20	2.40	1.32
Higher-order thinking	18	1.57	0.80

Combination	20	1.78	1.01
Total	79	1.78	1.07

As shown in Table 1, the students who used the combination scaffold tended to have the next highest knowledge-acquisition score after the organization scaffold group, followed by the higher-order thinking group and then the control group.

Effect of Scaffolding on Students' Ability to Formulate Questions

Questions were assessed for their frequency, type, and specificity.

Question Frequency

Each student generated between 1 and 10 questions/explanations. To analyze the differences in number of questions generated by students for different scaffolding types, an ANCOVA was computed with scaffolding type as a between-subjects factor and the covariates, computer-treatment time and divergent-thinking ability (fluency construct). One case was identified as a multivariate outlier, and this case was eliminated. After adjusting for the fluency construct of divergent-thinking ability and students' computer-treatment time, the number of questions generated by the students was found to be significantly different ($F(3,71) = 4.85, p < .01$) for the different treatment conditions. Scaffolding type had a medium to large effect ($\eta^2 = .17$) on the variance between scores. Pairwise comparisons, with a Bonferonni adjustment, revealed that students who used the higher-order thinking scaffold asked significantly more questions than the control group ($p < .01$), the students who used the organization scaffold ($p = .01$), or the students who used the combination scaffold ($p = .02$). Table 2 depicts the differences between the mean number of questions generated for the different treatment conditions.

Table 2

Means and Standard Deviations for Number of Questions for Different Treatments Conditions

Treatment conditions	<i>N</i>	<i>M</i>	<i>SD</i>
Control	21	4.20	1.94
Organization	20	4.25	1.21
Higher-order thinking	18	5.24	2.05
Combination	20	4.25	1.67
Total	79	4.45	1.75

Question Type

Students' questions were judged for whether they were subject oriented, problem oriented, solution oriented, or unclear. Since these data violated the normality assumptions of

the ANCOVA, a nonparametric equivalent for an ANCOVA was computed (Bathke & Brunner, 2003). After controlling for computer-treatment time, scaffolding type did not have a significant effect on the type of question asked by the student. Figure 1 shows how the mean percentage of questions in each type differed among the treatment conditions. Although not significant, students who used the organization scaffold and the combination scaffold tended to ask a higher percentage of problem-oriented questions; whereas, the students who used the higher-order thinking scaffold and the control group tended to ask a higher percentage of solution-oriented questions. The percentage of subject-oriented questions tended to be very similar for the different groups. In addition, the percentage of unclear questions tended to be little smaller for the organization scaffold group.

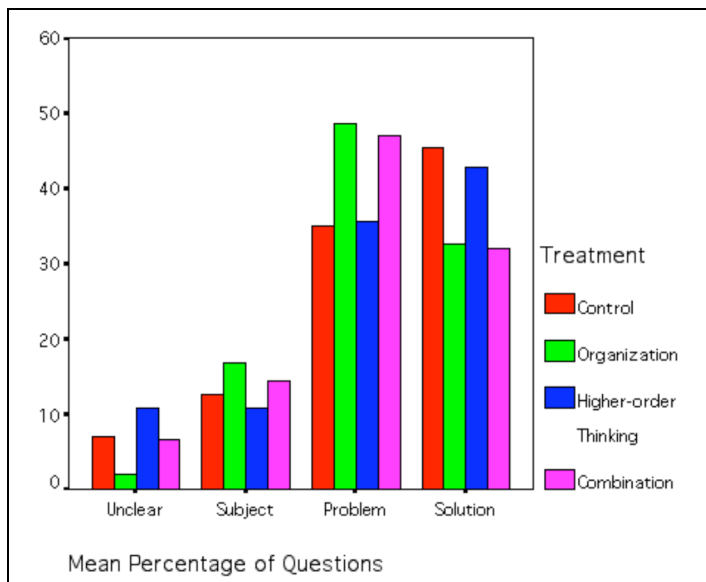


Figure 1. Mean percentage of questions in each question type for different treatment conditions.

As a follow-up to this analysis, planned comparisons were employed to investigate the opposing trends of the problem-oriented and solution-oriented questions. The treatments were regrouped into scaffolds that include the organization scaffold (i.e. the organization scaffold and the combination scaffold) and scaffolds that did not include the organization scaffold (i.e. the control group and the higher-order thinking scaffold). Then, a Mann Whitney U analysis was computed to compare the differences between the percentage of problem-oriented and solution-oriented questions for treatments with and without the organization scaffold. This analysis revealed that there were significantly more ($Z = -2.10, p = .04$) problem-oriented questions for

treatments with the organization scaffold than without the organization scaffold. In addition, there were significantly more ($Z = -2.19, p = .03$) solution-oriented questions for treatments without the organization scaffold than with the organization scaffold.

Question Specificity

To examine the effectiveness of the scaffolding on increasing the specificity of questions asked by students, an ANCOVA was performed with scaffolding type as a between-subjects factor and computer-treatment time as a covariate. There was no significant treatment effect on question specificity. Table 3 displays the differences in means and standard deviations for the different treatment conditions of the software.

Table 3

Means and Standard Deviations for Question Specificity for Different Treatment Conditions

Treatment conditions	<i>N</i>	<i>M</i>	<i>SD</i>
Control	21	1.48	0.43
Organization	20	1.59	0.54
Higher-order thinking	18	1.42	0.52
Combination	20	1.69	0.43
Total	79	1.54	0.48

There was a tendency for students who used the combination scaffold to ask the most specific questions, followed by the organization scaffold group.

DISCUSSION OF THE FINDINGS

Effect of Scaffolding

Each class was randomly assigned to one of four treatment conditions of the software. One class received the organization scaffold, a template with headings and focusing questions to organize their research. Another class was given the higher-order thinking scaffold, which contained reflective questions to help them process their knowledge more deeply. One class received both types of scaffolds, and another class (i.e. the control group) received neither scaffold.

Organization Scaffold

Prior to the study, students who used the organization scaffold were expected to have improved understanding of the problem and ask specific questions relevant to the problem. These expectations grew out of the cognitive tool classification developed by Iiyoshi and Hannafin (1998) that was used in the development of the SFM model. The organization scaffold

was designed to help learners “interpret, connect, and organize the represented information meaningfully” (Iiyoshi & Hannafin, p. 3). By assisting learners in connecting new information with their prior knowledge and conceptually organizing this information, the organization scaffold should improve students' understanding of the problem. Increased knowledge acquisition about the problem should lead to students asking better questions that are more specific and related to the problem (Czarnik & Hickey, 1997).

After analyzing the results, students who were given the organization scaffold were found to have a significantly higher knowledge acquisition than the control group and to ask significantly more questions related to the problem (as opposed to the solution) compared to the other groups. Students who used this scaffold also tended to ask questions that were more specific than the higher-order thinking or control groups, but they tended not to do quite as well as the combination scaffold group on this measure.

Some of the findings confirmed or improved upon the results found in the pilot study. Both studies found that the organization scaffold significantly helped students understand the problem. While the pilot study only showed a trend for the organization scaffold to assist students in asking questions related to the problem (Zydney, 2003a), this trend became a statistically significant finding in this study. Although grade level could be a possible factor in explaining this change, it was more likely due to the fact that 48 questions needed to be eliminated in the pilot study because of a problem with rating these questions. To alleviate this issue, an enhancement was added to the program used in this study that required students to provide an explanation for why they asked a question. This explanation made it easier to rate the questions, and, as a result, most of the questions were able to be used in the analysis of the data. In addition, this study categorized the questions into finer classifications than the pilot study. The pilot study classified questions as either inside or outside the problem domain; whereas, this study broke those categories down further. Questions outside the problem domain were separated into subject-oriented and unclear questions, and questions inside the problem domain were divided into problem-oriented and solution-oriented questions. In observing the students, I noted that they were naturally inclined to rush to find a solution. It is likely that the organization scaffold helped students focus on the problem, increasing their knowledge acquisition, and, in doing so, helped them to ask more questions related to the problem.

On the other hand, one finding that was statistically significant in the pilot study was only

a trend in this study. In the pilot study, the organization scaffold also significantly helped students ask questions that were more specific (Zydney 2003a); whereas, in this study, there was only a tendency for students who used the organization scaffold to ask more specific questions than the higher-order thinking and control groups. A possible explanation for this change was that the students in the pilot study were part of an environmental class that had been immersed in studying similar topics throughout the year; thus, these students had much more prior knowledge on the subject from which to draw upon. This may indicate that the organization scaffold is more powerful when students have a greater knowledge base with which to make connections to the new information presented. It is also important to note that, although the organization scaffold improved students' knowledge acquisition over the control group, the knowledge-acquisition scores were, on the whole, lower in this study than in the pilot study. In order for students to ask questions that were more specific, it may be that they need to go beyond a certain threshold of understanding.

The partially, statistically significant findings in this study reflect the mixed results seen in the literature on the use of scaffolds that support students in organizing information at a detailed level. Wolf and Brush (2000) found that this scaffolding significantly improved students' reports; however, their study used a combination of supports; thus, it is difficult to determine whether it was the organizational scaffolding that was responsible for this positive outcome. Other studies found the organization scaffolds were either not used or not used effectively by the students; however, these studies did not require the use of these scaffolds (Brush & Saye, 2001; Oliver & Hannafin, 2000). One explanation for the partial success of the organization scaffold used in this study may have been that students were required to use it prior to moving on to the next task. In addition, this scaffold may be more effective for students with greater prior knowledge. This finding is in line with earlier research conducted by Iiyoshi and Hannafin (1998) who found that organization tools were used more often by students with higher prior knowledge; however, they did not report on the effectiveness of this increased usage. Thus, future research is necessary to determine whether prior knowledge increases the effectiveness of the organization scaffold.

Higher-order thinking scaffold

Prior to the study, the students who used the higher-order thinking scaffold were expected to ask many questions and begin analyzing alternative solutions. These expectations stemmed

from the underlying theory of how the higher-order thinking scaffold is designed to work within an SFM learning environment. This scaffold utilizes metacognitive strategies that help learners “monitor knowledge construction process as well as their knowledge status” (Iiyoshi & Hannafin, 1998, p. 3). In assisting learners to reflect on the problem, this scaffold is designed to help learners in thinking about what they do know about the problem, thereby prompting them to ask more questions.

The students who received the higher-order thinking scaffold asked significantly more questions than the other groups. When this group was combined with the control group, the two groups together asked significantly more questions related to the solution than the groups with the organization scaffold. However, the students who used the higher-order thinking scaffold tended to ask a lower percentage of solution-oriented questions than the control group. Thus, it may not have been the higher-order thinking scaffold that prompted students to think more about the solution, but a natural inclination for students to rush to the end of the problem. One speculation is that it may be the lack of organization scaffold that caused students to lose focus on the problem they were trying to solve, allowing them to concentrate more on the solution. However, without a strong understanding of the problem, they often chose ineffective solutions to the problem. For example, after the study ended, many students in their final presentations picked solutions that might have been effective solutions elsewhere but not for this specific situation. Many students recommended using solar energy, but it turns out that the fictitious company in *Pollution Solution* is located in one of the cloudiest cities in the United States; therefore, solar panels would not be a viable solution for this particular case.

The findings from this study confirmed many of the results from the pilot. The pilot also found that students who used the higher-order thinking scaffold asked significantly more questions (Zydney, 2003b). On the other hand, the pilot did not classify the questions into problem and solution oriented, so the finding that students asked more solution-oriented questions was specific to this study.

The partially, statistically significant findings from this study were not entirely surprising given the varied results found in several recent studies on higher-order thinking scaffolds. As mentioned earlier, some studies found that higher-order thinking scaffolds improved students’ knowledge integration (Davis, 2003; Davis & Linn, 2000) as well as declarative knowledge for younger students (Nelson, Watson, Ching, & Barrow, 1996). Other studies also had similar

outcomes, but because they combined different types of scaffolding (Ge & Land, 2003; Wolf & Brush, 2000), it was difficult to determine which scaffolding type was affecting the results. On the other hand, two studies that examined several types of higher-order thinking supports found that not all are equally effective in assisting students with knowledge integration (Davis; Davis & Linn). For example, Davis found that generically worded prompts were more effective than prompts with more specific directions. Moreover, some studies found the scaffolding was either not used or not used effectively (Brush & Saye, 2001; Oliver & Hannafin, 2000); however, the scaffolding in these applications was not required. Given the findings from earlier research, it is possible that rewording the higher-order thinking scaffold (Davis), changing the timing/location of the scaffold (Davis), or providing more time to use the scaffold (Brush & Saye) may have produced more statistically significant results.

Combination (organization and higher-order thinking) scaffold

Prior to the study, students who used the combination scaffolding were expected to excel across all measures. Thus, these students should have had a solid understanding of the problem and asked very specific questions related to the problem. Based on the SFM model, one would expect that combining the organization and higher-order thinking scaffolds would combine the effects of the individual scaffolds and would produce outcomes that were the same or better than those obtained with the scaffolds separately.

The students who used the combination scaffold did not perform as well as expected. Although they had a tendency to do slightly better than the organization scaffold group in asking questions that were more specific, they tended to have slightly lower knowledge acquisition than the organization scaffold group, and as result, did not ask as high a percentage of problem-oriented questions. Moreover, these students tended not to ask as many questions as the higher-order thinking group.

One explanation for the discrepancy between expected and actual results could be that this class was observed to have more behavioral issues than the other classes; however, another explanation may have been a confusion caused by the similar formats of the organization and higher-order thinking scaffolds. In the classes that received the higher-order thinking scaffolds, several students had difficulty discerning the difference between the status report (i.e. the higher ordering thinking scaffold) and the research plan (i.e. the organization scaffold) and asked, “Didn’t we already do this activity?” The teacher had to bring up the status report to show these

students how it differed from the research plan. Since this confusion took place early on in the study, it is possible that it caused them to not do as well with activities in the beginning, but once this confusion dissipated and they gained clarity on the task, they were able to do better on some of the later tasks.

The results in this study are an improvement over the pilot study. In the pilot study, the students who used the combined scaffolding tended to do worse than the individual scaffolds across all measures (Zydney, 2003a). The positive change in this study was most likely due to an enhancement in the design of the study. In the pilot study, students with the combination scaffold had less time to complete the research plan than students who did not have to respond to the reflective questions posed in the status report. For this study, in order to give all the treatment groups the same amount of time to complete the tasks, the order of the tasks was changed. Before writing the research plan, the students with the higher-order thinking scaffolds completed the reflective questions first while the students who did not have this scaffolding continued to do their research. Thus, all students started writing their research plan at the same time and had the same amount of time to complete it. In addition, the amount of time students spent on the computer was included as a covariate in the analyses in order to account for any individual differences in the amount of computer time.

The results from this study were somewhat surprising given the positive findings from the majority of recent studies on the use of combined organization and higher-order thinking scaffolds (Davis & Linn, 2000; Ge & Land, 2003; Wolf & Brush, 2000). Only one study found these scaffolds to not be effective (Brush & Saye, 2001), but this may be a result of the fact that the scaffolding was not a required element of the software. None of the previous studies tested both the individual effects of each scaffold and then the combined effect of both. This study raised some questions about whether combining scaffolds will add the effects of these individual scaffolds. Future studies will need to confirm whether these results were due to the behavioral issues of this particular class or perhaps the confusion caused by the similarity between the scaffolds. One solution may be to use a generic sentence prompt instead of the directed questions for the higher-order thinking scaffold as recommended by Davis (2003).

Control Group

This class did not perform as well as the other classes across the various measured outcomes. The control group performed as expected because they did not receive either the

organization or higher-order thinking scaffold to support their learning. It is important to note that this group was statistically equivalent to the other groups on the pretest, and according to their teacher, performed academically as well as the other classes. The findings from this study also confirm the results found in the pilot study (Zydney, 2003a).

CONCLUSION

This study investigated which scaffolding type most effectively helped students define a complex, ill-structured problem. The findings indicated that the organization scaffold was most effective in helping students understand the problem and ask more specific questions related to the problem. The higher-order thinking scaffold was most effective at helping students generate a greater number of questions. Although the combination scaffold tended to be able to assist students more than the organization scaffold in asking questions that were more specific, it did not do as well as the individual scaffolds across the other measures. This study raised some questions about whether utilizing two scaffolds will add the effects of these individual scaffolds. The findings from this study could be influential in helping educators and instructional designers create learning environments that assist students in defining and eventually solving complex problems.

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