DEEPING OUR UNDERSTANDING THROUGH MULTIPLE PERSPECTIVES:

THE EFFECTIVENESS OF SCAFFOLDING IN A LEARNING ENVIRONMENT

Janet Mannheimer Zydney
New York University[1]

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[1] Janet Mannheimer Zydney is now at the University of Kentucky

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Purpose/ Rationale for Research

“Each of our private lives may seem complete, in itself, just as a field like psychology can seem to explain everything once we are immersed in its methods and its facts. But this sense of completeness is an illusion produced by the limits of our perspective.” (Miller & Spellmeyer, 2003, p. xi). In order to address this problem of learners developing misconceptions by interpreting the world through a single perspective, Spiro and his colleagues developed the cognitive flexibility theory (CFT) (Spiro, Coulson, Feltovich, & Anderson, 1988). This theory recommends strategies for preserving the complexity of an ill-structured domain, such as providing multiple representations and case examples, highlighting the interconnections between related domains of knowledge, and giving students opportunities for knowledge construction (Jacobson & Spiro, 1995).

Although CFT-based applications have been developed for a wide range of subjects, the majority of studies have found positive results. Studies have found that CFT-based applications significantly improved students’ knowledge acquisition (Kraus, Reed, Fitzgerald, 2001), conceptual understanding (Fitzgerald, Wilson, & Semrau, 1997; Jacobson & Archodidou, 2000), knowledge retention (Jacobson & Archodidou) and knowledge transfer (Demetriadis & Pombortsis, 1999; Jacobson, Maouri, Mishra, & Kolar, 1996; Jacobson & Spiro, 1995; Li & Jonassen, 1996). On the other hand, some research has found that CFT applications do not produce these types of learning gains (e.g. Balcytiene, 1999; Niederhauser, Reynolds, Salmen, & Skolmoski, 2000). These findings may be due to the fact that these studies focused mainly on the "criss-crossing" navigational element of CFT (i.e. traversing the domain through multiple paths). Harvey, Godshalk, and Milheim (2001) also found criss-crossing navigation to not have a significant effect on knowledge transfer. Thus, it may be necessary to combine the principle of criss-crossing overlapping domains of knowledge with other aspects of CFT in order for these applications to be effective.

One relatively unexplored area is whether CFT-based environments can be used effectively with young students. Since this theory was developed for advanced (post introductory) knowledge (Spiro, Feltovich, Jacobson, & Coulson, 1991), most of the research has focused on adults. One exception was a study by Jacobson and Archodidou (2000) who examined how a learning environment that utilizes CFT principles affects high school students’ underlying conceptual models of evolution. These researchers added scaffolding to guide students through the environment. Their results hold promise that scaffolding may be effective in supporting young learners in CFT-based environments. However, this study was conducted with a very small sample of students; thus, the researchers recommended that future studies test this concept with larger samples. In addition, the scaffolding in their study was in the form of modeling and coaching. Thus, there has not been research on the use of other kinds of scaffolds in this type of environment.

My study investigated the effectiveness of scaffolding in a CFT-based environment in helping young learners understand a complex problem. The overarching question was: what is the effect of scaffolding type in a multimedia program on students' problem understanding, misconceptions, and consideration of multiple perspectives?

Theoretical Framework

In order to design a program for young learners, a new instructional model called the scaffolded flexibility model (SFM) was developed that builds on the principles of CFT (Zydney, 2005). Based on CFT, this learning environment presents students with multiple perspectives on the problem, offers a variety of cases, highlights the relationships between different disciplines, and provides students with the opportunity to integrate knowledge (Jacobson & Spiro, 1995). In addition to CFT, SFM situates the learning environment within an authentic scenario and employs a range of scaffolding techniques selected to provide additional support while still allowing the learners to develop flexible knowledge structures about complex issues. As the students progress through the learning environment, this scaffolding fades and offers students more control over their use. The scaffolding in the SFM environment is designed to foster students' cognitive processes, provide modeling and coaching, and help students with time management. The cognitive processing scaffolds were thought to be the most critical for understanding a complex problem because they help students organize/synthesize information about the problem; thus, these scaffolds became the focus of my study.

Methods

Sample

Seventy-nine 10th-grade students (15 to 16 years old) from an urban public school participated in this study. The ethnic breakdown of the students at this school was: 39.4% White, 18% Black, 22.4% Hispanic, and 20.3 % Asian and others including Pacific Islanders, Alaskan Natives, and Native Americans. There were slightly more males (53.5%) than females (46.5%) (New York City Department of Education, n.d.).

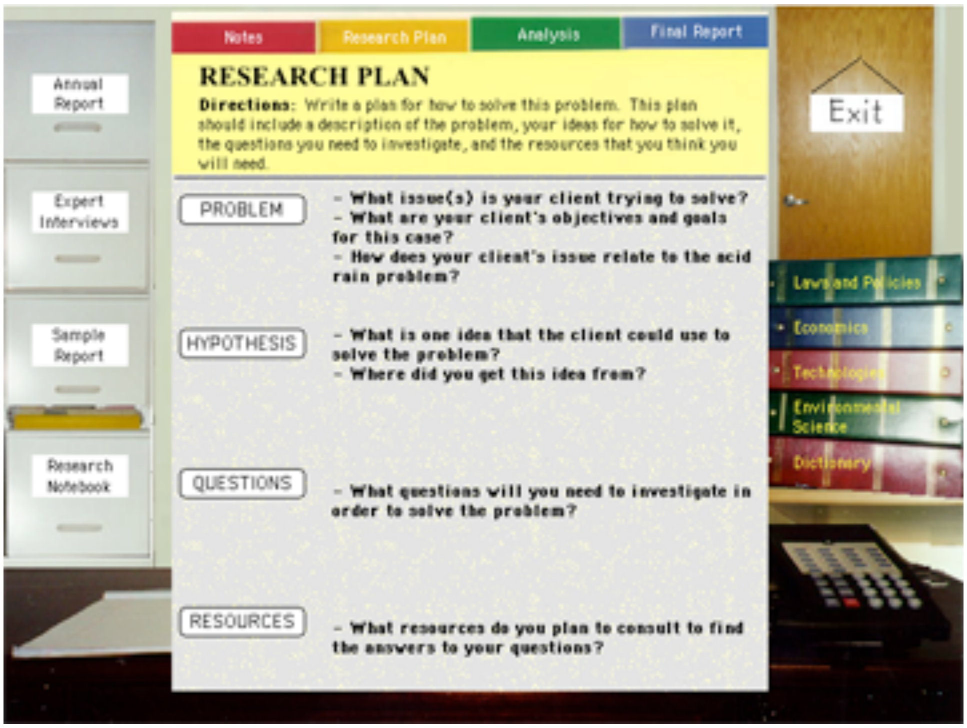
Independent Variables

Treatment. A program called *Pollution Solution,* which was based on the SFM model, was developed specifically for this research. During the first part of the program, the students learned about the problem they were going to solve. The problem scenario involved a legal case concerning air pollution. 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. As a result of the lawsuit, environmental activists began protesting outside the corporate offices. Consequently, the company's public image was tarnished and their stock prices began to fall. While the students were researching the problem, they were introduced to various experts (through digital video clips) who had very different perspectives on the nature of the problem and, thus, how it should be solved.

The students needed to wrestle with these divergent perspectives in order to draw their own conclusions.

To research the problem, students were given a virtual office, which included filing cabinets, research notebook, and reference manuals as well as a phone, e-mail, and notepad. Different versions of this office environment were developed to create different scaffolded versions of this learning artifact. Then, these scaffolded learning artifacts were compared through a scaffolding analysis, designed to isolate the effect of the different scaffolds on the performance of students (Sherin, Reiser, & Edelson, 2004). All scaffolded versions included the basic cognitive processing scaffold. This scaffolding consisted of tools, such as a notepad and reference books, which are designed to help learners retrieve their prior knowledge as well as discover new information. Condition 1 (the control group) provided only the basic scaffolding. Condition 2 included a research plan template (shown in Figure 1), an organizational scaffold, which provided headings and focusing questions. Condition 3 included a status report (shown in Figure 2), a higher-order thinking scaffold, which presented students with a series of reflective questions to assist them in processing the content more deeply. Condition 4 was a combination of Conditions 2 and 3. All groups received the same directions on how to write the research plan.

The four intact classes were randomly assigned to one of the four conditions. All students in the same classroom received the same condition, and the same teacher taught all four classes. Although it was logistically necessary to assign classes (as opposed to students) to treatment condition, the students were randomly assigned to these classes at the beginning of the academic year.



RESEARCH PLAN

Directions: Write a plan for how to solve this problem. This plan should include a description of the problem, your ideas for how to solve it, the questions you need to investigate, and the resources that you think you will need.

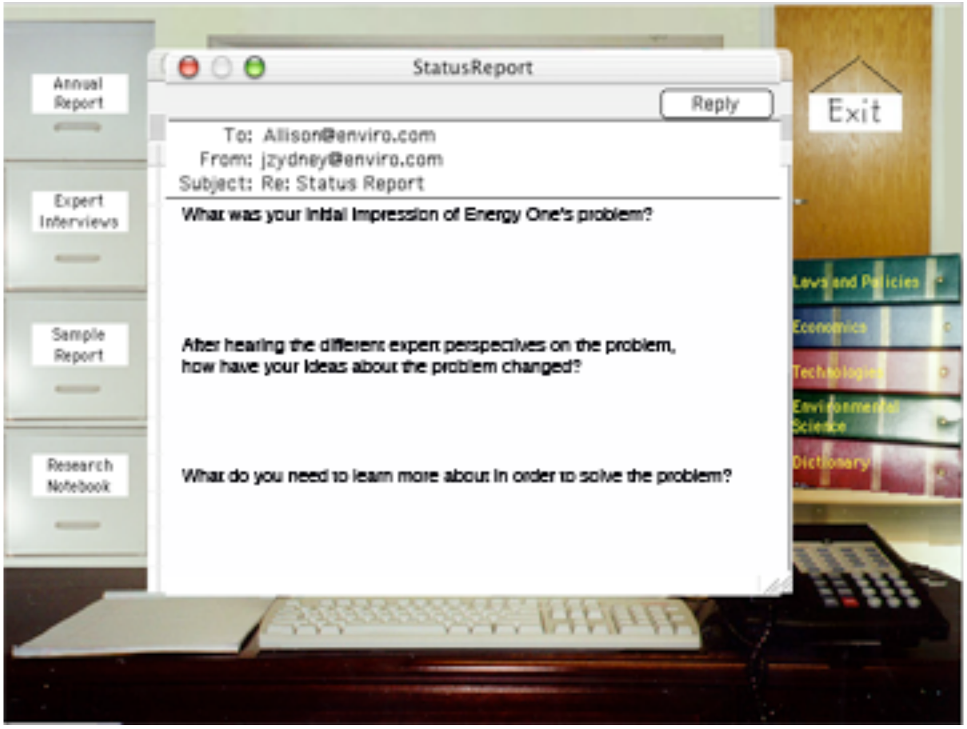
PROBLEM
- What issue(s) is your client trying to solve?
- What are your client's objectives and goals for this case?
- How does your client's issue relate to the acid rain problem?

HYPOTHESIS
- What is one idea that the client could use to solve the problem?
- Where did you get this idea from?

QUESTIONS
- What questions will you need to investigate in order to solve the problem?

RESOURCES
- What resources do you plan to consult to find the answers to your questions?

Figure 1. A screenshot of the research plan template.



To: Allison@enviro.com
From: jzydney@enviro.com
Subject: Re: Status Report

What was your initial impression of Energy One's problem?

After hearing the different expert perspectives on the problem,
how have your ideas about the problem changed?

What do you need to learn more about in order to solve the problem?

Figure 2. A screenshot of the status report.

Problem-solving ability. Since research has found that improved problem solving results from material being presented from multiple perspectives (Fitzgerald, Wilson, & Semrau, 1997), it was hypothesized that students' problem-solving abilities might influence their understanding of the different perspectives on the problem. Students' prior problem-solving abilities were measured by a problem-solving test comprised of one section of the 61-item instrument (K-R 20 = .86) used by Reed and Palumbo (1992). Since only one section of this test was used, the reliability of this instrument was retested and was found to be .55.

Computer-treatment time. The computer-treatment time was 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

All dependent measures were assessed through rubrics. An earth science teacher reviewed these rubrics to confirm their validity. Two raters scored these measures independently from one another and then came together again to discuss discrepancies. The evaluators were blind to the treatment condition the students had used. In addition, students' work was randomly mixed to prevent the raters from detecting the students' assigned condition. Inter-rater reliabilities are reported in the sections describing each individual variable.

Multiple Perspectives. One important aspect of CFT is that the ill-structured domain has multiple perspectives (Spiro et. al., 1988). Since research has shown that students' questions can be an effective measure for assessing their understanding of complex topics (e.g. Miyake & Norman, 1979), students' questions were analyzed for their inclusion of multiple perspectives. Each question was judged to determine which perspectives (e.g. economic, legal, technical, environmental) were present. One point was awarded for each perspective. A student could receive one additional point for providing an extra perspective not presented in the software. Question-perspective scores ranged from 0 to 5 points. The inter-rater reliability for this score was .82

A mean question-perspective score was calculated for each student. To obtain this score, the question-perspective scores were added and then divided by the total number of questions generated by the student. In addition, the total number of perspectives represented by the questions was calculated. To calculate the total perspectives, students received 1 point for each perspective found in any of their questions. Students received up to 1 additional point for specifying a valid perspective not provided in the software. The total perspectives ranged from 0 to 5 points. Thus, if a student had two legal questions, three economic questions, one question that had both environmental and legal perspectives, and no questions with either an engineering or other perspective, he or she would receive 3 points for number of perspectives (1 point for legal, 1 point for economic, and 1 point for environmental).

Problem understanding. Scaffolding in the SFM environment is designed to improve students' understanding of ill-structured problems; thus, students' descriptions of the problem were assessed. In order to demonstrate a strong understanding of the problem, students needed to describe the legal, environmental, economic, and public relations factors about the problem in their research plans. Each factor was worth 1 point. Scores ranged from 0 to 6 points. The inter-rater reliability was .81.

Misconceptions. Another objective of CFT is to lower learners' misconceptions. Students received 1 point for each misconception in their research plans. For example, several students had the misconception that the power plant emitted acid rain. This statement indicated that these students neither understood the byproducts of energy production nor the chemistry of how acid rain is formed from these byproducts. Students received 1 point for each misconception included in the research plan. Simple errors or mistakes (e.g. the wrong date for the Clean Air Act) were not counted. The inter-rater reliability was .93.

Procedures

During six 60-minute class periods, the students participated in the study. During the first session, students completed the problem-solving test. In the next session, the class was introduced to the problem scenario, and, in the third session, the students learned how to use the software. During the fourth session, the students 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 wrote their status reports. During the last two sessions, the students completed their research plans. 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 15-minute questioning assessment and final survey on the computer. For this assessment, the students generated as many investigative questions as they could within the allotted timeframe. In addition, for each question, students were required to explain how this question would help them to solve the problem. 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 the study ended, the students continued to use the software to analyze the problem and write their recommendations.

Results

Pretest

A one-way ANOVA was performed on the problem-solving 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 in prior problem-solving ability.

Multiple Perspectives

Overall, students' ability to consider the problem's multiple perspectives was high. The average number of total perspectives represented in the student questions was 3.24 (SD = 0.98). Approximately 77% of the students considered at least three perspectives in total. On a more stringent measure, the average of students' mean question perspectives was 1.57 (SD = 0.42). To determine if there was a difference in multiple perspectives for different treatment conditions, an ANCOVA was performed with scaffolding type as a between-subjects factor and computer-treatment time and problem-solving ability as covariates.

As shown in Table 1 and 2, the total perspectives and the mean question perspectives was not found to be significantly different among the comparison groups.

Table 1

Analysis of Covariance for Total Perspectives

Source	Type III *SS*	*df*	*MS*	*F*	*p*	$\square^2$
Scaffolding type	1.45	3	0.49	0.62	.60	.03
Problem-solving ability	2.84	1	2.84	3.65	.06	.05
Computer-treatment time	10.49	1	10.49	13.48	<.01	.16
Error	56.81	73	0.78			

Table 2

Analysis of Covariance for Mean Question Perspectives

Source	Type III *SS*	*df*	*MS*	*F*	*p*	$\square^2$
Scaffolding type	0.31	3	0.10	0.59	.62	.02
Problem-solving ability	0.18	1	0.18	1.03	.31	.01
Computer-treatment time	0.33	1	0.33	1.86	.18	.03
Error	12.79	73	0.18			

The means and standard deviations for total perspectives and mean question perspectives for the different comparison groups are provided in Table 3.

Table 3

Means and Standard Deviations for Total Perspectives and Mean Question Perspectives for Different Treatment Conditions

	Total perspectives			Mean question perspectives		
Treatment conditions	*N*	*M*	*SD*	*N*	*M*	*SD*
Control	21	3.24	1.09	21	1.60	0.43
Organization	20	3.45	1.15	20	1.56	0.33
Higher-order thinking	18	3.22	0.88	18	1.64	0.53
Combination	20	3.05	0.76	20	1.46	0.39
Total	79	3.24	0.98	79	1.57	0.42

Problem Understanding

To examine the effectiveness of the scaffolding in an SFM environment on students' problem understanding, an ANCOVA was computed with problem understanding as the dependent measure, scaffolding type as the between-subjects factor and computer-treatment time as the covariate. Students' problem-solving scores were not found to covary with their problem understanding, and, thus, this covariate was dropped from the model.

After adjusting for computer-treatment time, the students' understanding of the problem varied significantly for different treatment conditions ($F(3,74) = 3.58$, $p = .02$, $\square^2 = .13$). See Table 4 for the results of this analysis.

Table 4

Analysis of Covariance for Problem Understanding

Source	Type III *SS*	*df*	*MS*	*F*	*p*	$\square^2$
Scaffolding type	10.57	3	3.53	3.58	.02	.13
Computer-treatment time	4.11	1	4.11	4.18	.05	.05
Error	72.85	74	0.99			

Pairwise comparisons, with a Bonferonni adjustment, revealed that the students who used the organization scaffold had a significantly higher problem understanding than the control group (*p* = .02). No significant differences between the other pairs were found. Table 5 shows the differences in problem understanding for the different treatment conditions.

Table 5

Means and Standard Deviations for Problem Understanding for Different Treatment Conditions

Treatment conditions	*N*	*M*	*SD*
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 5, the students who used the combination scaffold tended to have the next highest problem-understanding score after the organization scaffold group, followed by the higher-order thinking group and then the control group.

In order to examine the possible interaction between the organization and higher-order thinking scaffold in the combination scaffold group, a two-way ANCOVA was computed with problem understanding as the dependent measure, the organization and higher-order thinking scaffolds as factors, and computer-treatment time as the covariate. The results from this analysis are provided in Table 6.

Table 6

Two-Way Analysis of Covariance for Problem Understanding

Source	Type III *SS*	*df*	*MS*	*F*	*p*	η^2
Org. scaffold	4.64	1	4.64	5.09	.03	.06
HO scaffold	0.46	1	0.46	0.51	.48	.01
Org. * HO	3.79	1	3.79	4.16	.05	.05
Computer-treatment time	4.26	1	4.26	4.68	.03	.06
Error	67.45	74	0.91			

Note. Org. = Organization; HO = Higher-order thinking

Table 6 shows that there is a significant interaction (*p* = .05) between the organization and higher-order thinking scaffolds. Pairwise comparisons with a Bonferonni adjustment were computed to explore this interaction further.

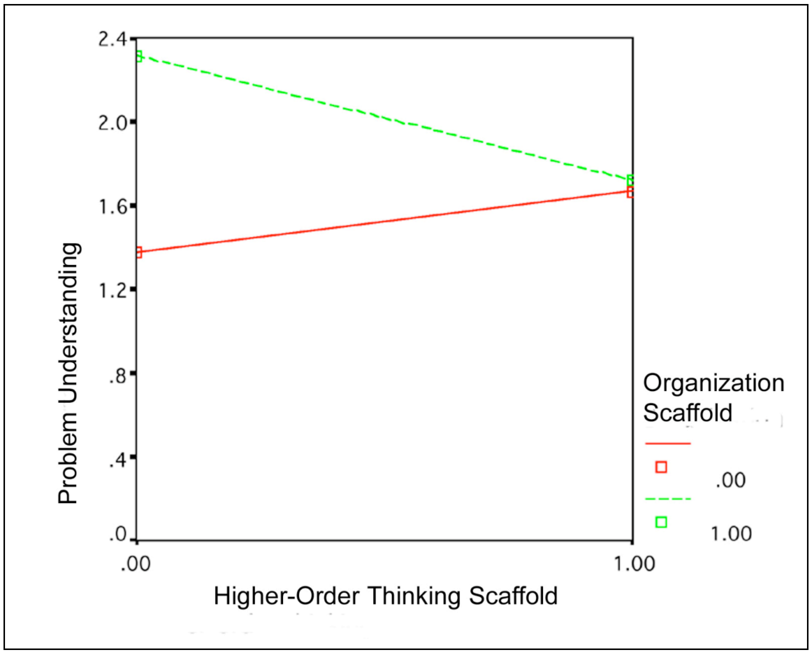


Figure 3. Estimated marginal means of problem understanding.

As shown by the interaction in Figure 3, in the absence of the higher-order thinking scaffold, there was a significant increase in problem understanding scores (*p* < .01) when the organization scaffold was present. However, in the presence of the higher-order thinking scaffold, there was no difference in problem understanding scores regardless of whether the organization scaffold was present or not. Moreover, additional pairwise comparisons revealed that in the presence of the organization scaffold, problem understanding was significantly higher (*p* = .05) if the higher-order thinking scaffold was not included. Thus, it appears that the higher-order thinking scaffold had a moderating effect on the organization scaffold 's effectiveness in improving students' problem understanding.

Number of Misconceptions

Overall, students' misconceptions were minor. The majority of the students (61%) did not have any misconceptions, and most of those students who had misconceptions had two or fewer (98%). No one had more than three misconceptions.

The misconception scores were recoded into two categories: zero or one misconception and two or more misconceptions, and a binary logistic regression was employed. This analysis, as shown in Table 7, revealed that none of the treatment conditions were significantly more likely to contain misconceptions.

Table 7

Logistic Regression Analysis of Level of Misconception as a Function of Treatment

Variables	*B*	Wald Test	*p*	Odds Ratio
Control		3.77	.29	
Organization	-1.50	1.65	.20	0.22
Higher-order thinking	0.19	0.06	.81	1.21
Combination	-1.50	1.65	.20	0.22
(Constant)	-1.45	6.78	<.01	0.24

Table 8 depicts the number and percentage of misconceptions for the different conditions.

Table 8

Number and Percentage of Misconceptions for Different Treatment Conditions

Treatment conditions	Zero or one misconception	Two or more misconceptions
Control	17 (81%)	4 (19%)
Organization	19 (95%)	1 (5%)
Higher-order thinking	14 (78%)	4 (22%)
Combination	19 (95%)	1 (5%)

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, and computer-treatment time.

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 appeared not to have affected the results. There was a concern that students might talk outside of class and find out that they were using different treatment conditions 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 these time variations.

Discussion

Multiple Perspectives

One of the main goals of an SFM environment is to help learners see issues from multiple perspectives. This objective stemmed from CFT, the main theoretical framework used in the SFM model. This theory recommends that the environment provide learners with different intellectual viewpoints and multiple paths through the environment (Spiro et al., 1988).

On the whole, students did very well in considering the different perspectives of the problem. Prior to using the software, the students had not been exposed to this environmental problem or its different perspectives in their curriculum. While using the software, students were presented with four different perspectives. After using the software, over three-quarters of the students included at least three of these perspectives in their questions. Moreover, on average, students were able to integrate more than one perspective within a given question. There was some concern that the additional structure from the scaffolding might curtail students’ ability to develop flexible knowledge structures about a complex issue; however, the findings from this study did not substantiate this concern. The fact that students performed so well on this measure indicates that the scaffolding did not impede students’ ability in this area. In addition, the control group (without the scaffolds) did statistically the same as the other groups on these measures. In fact, there was some evidence that the higher-order thinking scaffold tended to assist students in integrating multiple perspectives into their questions. This trend was also seen in the pilot study (Zydney, 2005).

There was a considerable improvement in students’ consideration of multiple perspectives from what happened previously in a pilot study, conducted the previous year with eighth-grade students. The pilot data revealed that only 16% of the eighth-grade students considered at least three perspectives in their questions (Zydney, 2003). This may have been due to the fact that the students in this study were two grades older than the students in the pilot study. Since CFT was designed for advanced knowledge acquisition, perhaps grade level is a relevant factor. However, this feature was enhanced from what was used in the pilot, and students were asked to explain their reason for asking the question. This explanation helped the raters determine what perspectives were included within a question. Future research is necessary to determine whether grade level is a factor to consider when assessing students' ability to grapple with multiple perspectives or whether the enhancement was the reason for the increase in perspectives.

Problem Understanding

The scaffolding in the SFM model was designed to improve students' problem understanding. The organization scaffold was designed to help learners connect new information with their prior knowledge and conceptually organize this information, thereby improving students' understanding of the problem (Iiyoshi & Hannafin, 1998). The higher-order thinking scaffold was designed to assist learners in reflecting on the problem, which in turn would help them uncover gaps in their understandings. However, since learners might not fully understand the problem without the organization scaffold, it was not expected that the higher-order thinking scaffold by itself would improve students' understanding. On the other hand, one would expect that combining the higher-order thinking scaffold with the organization scaffold would further improve students' understanding of the problem.

This study found that different scaffolding types have varying effects on students' problem understanding. The organization scaffold group had significantly higher understanding than the control group. Moreover, this group also had a tendency to score higher on this measure than the combination and higher-order thinking scaffold groups. Thus, the combination scaffold group did not perform as well as expected.

One explanation for the discrepancy between expected and actual results was the interaction found between the organization and higher-order thinking scaffolds. The effectiveness of the organization scaffold in improving students' problem understanding may have been moderated by the higher-order thinking scaffold. However, this explanation should be interpreted with caution because this group was observed to have behavioral issues and may not have produced the most reliable data. Although future research is needed to confirm whether these finding were due to an interaction or the behavioral issues observed, it is important to note that the combined scaffolding in the pilot study was also found not to be as effective as the individual scaffolds (Zydney, 2005).

Misconceptions

Another objective of an SFM environment is to lower the number of students' misconceptions. CFT recommends that learning environments emphasize the complexity of the issue instead of oversimplifying the material (Spiro et al., 1988). In addition, since the design features associated with CFT were consistent for all four comparison groups, it was expected that the number of misconceptions would be similar for the different groups.

Overall, the number of student misconceptions was very low. None of the students had more than three misconceptions, and the majority of students did not have any misconceptions. In addition, there was no significant difference between the different scaffolding types in the number of misconceptions held by the students. The pilot data also showed that the number of misconceptions was very low (93% had no more than one misconception) and did not significantly differ between treatment conditions (Zydney, 2003).

Conclusions and Implications

One relatively unexplored area was the use of scaffolding within a learning environment that employs principles from CFT in supporting young learners in understanding complex problems. Only one study by Jacobson and Archodidou (2000) previously studied high school students' use of scaffolding in a hypermedia program that utilizes CFT principles; however, this study was done with a very small sample size. My study offers encouraging results that scaffolding used in conjunction with CFT principles does not hinder students’ ability to consider multiple perspectives or cause an increase in misconceptions. Despite these encouraging findings on the use of scaffolding for young learners, this study also raised some questions as to whether grade level might affect students’ ability to grapple with a problem’s multiple perspectives. Future research that compares the same software in two different grade levels is needed to answer this question.

My study found that the organization scaffold helped increase students’ problem understanding. This finding is in line with findings from other studies. For example, Bell (2004) found that scaffolding designed to support students in organizing information into opposing scientific theories, increased students' integrated understanding of different perspectives on an issue. This finding also builds on the research outside the computer field on the use of writing frames to improve students' understanding of scientific procedures (Warwick, Stephenson, & Webster, 2003). My study showed that, in certain situations, writing frames or templates, can be used as an organizational scaffold in multimedia applications.

The findings from my study also showed that combined scaffolding was not as effective as the organization scaffold in improving students’ problem understanding. The results from this study reflect the mixed findings in the literature on the use of combined organization and higher-order thinking scaffolds. Wolf and Brush (2000) found that this combination of scaffolds is effective in assisting students in writing reports. Other studies found combined scaffolds to not be effective (Brush & Saye, 2001; Oliver & Hannafin, 2000), but this may be a result of the fact that the scaffolds in these studies were not a required element of the software. In addition, there may be certain conditions, such as when learner background knowledge is low, which may limit the effectiveness of combined scaffolding (Land & Zembal-Saul, 2003). My study along with the results from the earlier pilot study (Zydney, 2005) raised questions about whether individual scaffolds may interact with one another and modify the overall effect of the combined scaffolding. These findings highlight the importance of testing the effects of individual scaffolds in addition to testing the overall effect of the combined scaffolding.

My study lends support to Reiser's (2004) notion that scaffolding can provide additional structure to support students in solving the problem, while, at the same time, can help students to "problematize" an issue. By providing a framework to describe the problem, scaffolding can assist students in articulating their understanding of their goals in connection with the underlying concept of acid rain. Moreover, presenting the issue through multiple perspectives encourages students to contend with divergent perspectives on the problem. Thus, scaffolding used in conjunction with CFT can provide support for young learners in understanding a real-world issue without oversimplifying the problem, thereby allowing them to grapple with its complexity.

References

Balcytiene, A. (1999). Exploring individual processes of knowledge construction with hypertext. *Instructional Science, 27*(3-4), 303-328.

Bell, P. (2004). Argument construction and collaborative debate. In Linn, M. C., Davis, E. A. & P. Bell (Eds.). *Internet environments for science education* (pp. 115 - 143). Mahway, NJ: Lawrence Erlbaum Associates.

Brush, T., & Saye, J. (2001). The use of embedded scaffolds with hypermedia-supported student-centered learning. *Journal of Educational Multimedia and Hypermedia, 10*(4), 333-356.

Demetriadis, S., & Pombortsis, A. (1999). Novice student learning in case based hypermedia environment: A quantitative study. *Journal of Educational Multimedia and Hypermedia, 8*(1), 241-269.

Fitzgerald, G. E., Wilson B., & Semrau, L. (1997). An interactive multimedia program to enhance teacher problem-solving skills based on cognitive flexibility theory: Design and outcomes. *Journal of Educational Multimedia and Hypermedia, 6*(1), 47-76.

Harvey, D. M., Godshalk, V. M., & Milheim, W. D. (2001). Using cognitive flexibility hypertext to develop sexual harassment cases. *Computers in the Schools, 18*(1), 213-219.

Iiyoshi, T., & Hannafin, M. J. (1998, April). *Cognitive tools for open-ended learning environments: Theoretical and implementation perspectives.* Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA.

Jacobson, M. J. & Archodidou (2000). The design of hypermedia tools for learning: Fostering conceptual change and transfer of complex scientific knowledge. *The Journal of the Learning Sciences, 9*(2), 145-199.

Jacobson, M. J., Maouri, C., Mishra, P., & Kolar, C. (1996). Learning with hypertext learning environments: Theory, design, and research. *Journal of Educational Multimedia and Hypermedia, 5*(3/4), 239-281.

Jacobson, M. J., & Spiro, R. J. (1995). Hypertext learning environments, cognitive flexibility, and the transfer of complex knowledge: An empirical investigation. *Journal of Educational Computing Research, 12*(4), 301-333.

Kraus, L. A., Reed, W. M., & Fitzgerald, G. E. (2001). The effects of learning style and hypermedia prior experience on behavioral disorders knowledge and time on task: A case-based hypermedia environment. *Computers in Human Behavior, 17*(1), 125-140.

Land & Zembal-Saul (2003). Scaffolding reflection and articulation of scientific explanations in a data-rich, project-based learning environment: An investigation of progress portfolio. *Educational Technology Research & Development*, *51*(4), 65-84.

Li. T., & Jonassen, D. (1996). The effect of lesson structures on prediction and inference. *Proceedings of Selected Research and Development Presentations at the 1996 National Convention of the Association for Educational Communications and Technology*, Indianapolis, IN, *18*, 423-429.

Miller & Spellmeyer (2003). *The New Humanities Reader.* Boston: Houghton Miller.

Miyake, N., & Norman, D. A. (1979). To ask a question, one must know enough to know what is not known. *Journal of Verbal Learning and Verbal Behavior, 18*(3), 357-364.

New York City Department of Education, Division of Assessment and Accountability. (n.d.) 2002-2003 annual school report. Retrieved July 10, 2004 from http://www.nycenet.edu/daa/SchoolReports/03asr/102413.pdf.

Niederhauser, D. S., Reynolds, R. E., Salmen, D. J., & Skolmoski, P. (2000). The influence of cognitive load on learning from hypertext. *Journal of Educational Computing Research, 23*(3), 237-255.

Oliver, K., & Hannafin, M. J. (2000). Student management of web-based hypermedia resources during open-ended problem solving. *The Journal of Educational Research, 94*(2), 75-92.

Reed, W. M., & Palumbo, D. B. (1992). The effect of BASIC instruction on problem solving skills over an extended period of time. *Journal of Educational Computing Research, 8*(3), 311-325.

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *The Journal of the Learning Sciences, 13(3)*, 273-304.

Sherin, B., Reiser, B. J., & Edelson, D. (2004). Scaffolding analysis: Extending the scaffolding metaphor to learning artifacts. *The Journal of the Learning Sciences, 13(3),* 387-421.

Spiro, R. J., Coulson, R. L., Feltovich, P. J., & Anderson, D. K. (1988). *Cognitive flexibility theory: Advanced knowledge acquisition in ill-structured domains* (Tech. Rep. No. 441). Champaign, IL: University of Illinois at Urbana-Champaign.

Spiro, R. J., Feltovich, P. J., Jacobson, M. J., & Coulson, R. L. (1991). Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knowledge acquisition in ill-structured domains. *Education Technology, 31*(5), 24-33.

Warwick, P., Stephenson, P., & Webster, J. (2003). Developing pupils' written expression of procedural understanding through the use of writing frames in science: Findings from a case study approach. *International Journal of Science Education, 25*(2), 173-192.

Wolf, S. E., & Brush, T. (2000, October 25 - 28, 2000). Using the big six information skills as a metacognitive scaffold to solve information based problems. *Proceedings of Selected Research and Development Papers Presented at the National Convention of the Association for Educational Communications and Technology,* Denver, CO, 471-481.

Zydney, J. M. (2003). [The effect of scaffolding in a multimedia program on students defining complex problems]. Unpublished raw data.

Zydney, J. M (2005). Eighth-grade students defining complex problems: The effectiveness of scaffolding in a multimedia program. *Journal of Educational Multimedia and Hypermedia, 14*(1), 61-90.

Author's Note

Janet Mannheimer Zydney, Department of Administration, Leadership, and Technology, New York University.

Janet Mannheimer Zydney is now at the Department of Special Education and Rehabilitation Counseling, University of Kentucky.

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Correspondence concerning this conference paper can be addressed to jzydney@uky.edu.