Student Use of Scaffolding Software: Relationships with Motivation and Conceptual Understanding

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Abstract This study was designed to theoretically articulate and empirically assess the role of computer scaffolds. In this project, several examples of educational software were developed to scaffold the learning of students performing high level cognitive activities. The software used in this study, Artemis, focused on scaffolding the learning of students as they performed information seeking activities. As 5th grade students traveled through a project-based science unit on photosynthesis, researchers used a pre-post design to test for both student motivation and student conceptual understanding of photosynthesis. To measure both variables, a motivation survey and three methods of concept map analysis were used. The student use of the scaffolding features was determined using a database that tracked students’ movement between scaffolding tools. The gain scores of each dependent variable was then correlated to the students’ feature use (time and hits) embedded in the Artemis Interface. This provided the researchers with significant relationships between the scaffolding features represented in the software and student motivation and conceptual understanding of photosynthesis. There was a total of three significant correlations in comparing the scaffolding use by hits (clicked on) with the dependent variables and only one significant correlation when comparing the scaffold use in time. The first significant correlation \( r = .499, p < .05 \) was between the saving/viewing features hits and the students’ task value. This correlation supports the assumption that there is a positive relationship between the student use of the saving/viewing features and the students’ perception of how interesting, how important, and how useful the task is. The second significant correlation \( r = 0.553, p < 0.01 \) was between the searching features hits and the students’ self-efficacy for learning and performance. This correlation supports the assumption that there is a positive relationship between the student use of the searching features and the students’ perception of their ability to accomplish a task as well as their confidence in their skills to perform that task. The third significant correlation \( r = 0.519, p < 0.05 \) was between the collaborative features hits and the students’ essay performance scores. This correlation supports the assumption that there is a positive relationship between the student use of the collaborative features and the students’ ability to perform high cognitive tasks. Finally, the last significant correlation \( r = 0.576, p < 0.01 \) was between the maintenance features time and the qualitative analysis of the concept maps. This correlation supports the assumption that there is a positive relationship between the student use of the maintenance features and student conceptual understanding of photosynthesis.

Keywords Scaffold · Conceptual understanding · Technology · Concept maps

Because the pace of technology is exponentially rising, facilitating a knowledge explosion, many standards are...
supporting the notion that “good” knowledge is not always independent of the learner (NRC 1996; NETS 2005; NBPTS 2003). According to the National Science Education Standards, teachers should emphasize students’ interests, needs, experiences, inquiry, collaboration and understanding in their classrooms (NRC 1996). The National Educational Technology Standards (NETS) indicate, “The most effective learning environments meld traditional and new approaches to facilitate learning of relevant content while addressing individual needs” (NETS 2005, p. 2). Therefore, the concept of learning goes beyond the traditional knowledge of the past. Instead, the standards focus more on developing the teacher and student’s ability to construct new knowledge from their own inquiry, collaboration and experiences.

To fulfill such standards, many educators examine curriculum and instruction that merge pedagogical content knowledge (Bransford et al. 1999) and technology tools to achieve student learning at high cognitive levels. According to NETS Standards 3–6 (2005), it is critical for teachers to understand the concept of technology integration, which involves using technology as a purposeful tool that empowers students to acquire and construct new knowledge, not merely developing skills (Jones et al. 1999).

For technology integration to occur, educational researchers, software developers and K-12 teachers work together to create technology tools and software that have a strong foundation in research-based learning theory. Theoretically, if software developers create educational technology grounded in learning theory, the use of such tools should increase the probability that student learning occurs. This is especially true when teachers integrate technology in problem or project-based models of instruction. To accomplish student learning beyond the knowledge level, it is critical that student use of technology goes beyond sequencing tutorials and the presentation of information. Instead, teachers and educational researchers are looking at using a Project-Based Science (PBS) model to implement both technology and student inquiry into the classroom (Blumenfeld et al. 1991; Krajcik et al. 1994, 1998a, b; Marx et al. 1997).

In the PBS model, students use technology tools to assist them as they conduct investigations to answer meaningful questions. Technology tools designed to assist science investigation may include productivity software, modeling software, and the Internet. The PBS model, like constructivism, not only provides the students with opportunities to practice scientific inquiry and group investigation; it also allows the teacher and students to focus on the process of scientific investigation, not just the accuracy of the product (Freiberg and Driscoll 2000). In addition to cognitive development, the emphasis of process-oriented instructional models is to focus on student dispositions as well.

In addition to the PBS model, software developers, educational researchers, and K-12 teachers are also working collaboratively to develop ways to merge educational and technology standards by creating and implementing scaffolding software that will support student investigations in a PBS learning environment. The purpose of scaffolding software is to assist students while learning a task. Consistent with the emphasis on the need for social interaction in constructivism, scaffolding software supports the learning process by creating a student-software interaction that acts as a crutch, empowering students to reach a cognitive level they could not reach on their own (Bruner 1986). For example, the software developers may create scaffolding features in the software that support vocabulary, modeling, problem solving and organizational skills. For a scaffolding interaction to occur, the feature must tap into the student’s “zone of proximal development” (ZPD).

According to Vygotsky, ZPD is “the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (cited in Bruner 1986, p. 73). The scaffolds represented in the software are not the scaffolding features. They are the interactions seen between each feature and a particular student. For example, a scaffolding feature designed to help students organize information may only benefit students with poor organizational skills. Just because the feature is labeled a “scaffolding feature” does not mean it will scaffold the learning for all students. The interaction between the software and the student is dependent on both the student’s abilities and the purpose of the features represented in the software.

The Artemis Interface

Artemis is a scaffold-rich, internet based software program developed by the Highly Interactive Computing in Education (HiCE) research group at the University of Michigan (http://www.hice.org/) and was most recently published by GoKnow (http://artemis.goknow.com/artemis/index.adp). The software is a graphic interface that connects students to a library of websites that were evaluated by librarians for both accuracy and readability of content. A graphic of this interaction was provided in the research proposed by Abbas (2001) (see Fig. 1).

Artemis provides a digital library for students to search and sort science information related to project-based investigations. Various learner-centered design components were built into the program. According to Wallace et al. (1998), Artemis was designed to address learners’ needs as they engage in information seeking strategies. See
Wallace et al. for a complete description of the Artemis interface. Figure 2 illustrates of the main page of Artemis.

The interface itself is set in frames which helps the students’ movement between tools. Students are able to develop and organize folders, related to their driving questions, as they perform information-seeking activities. Once related information is acquired, students can save the web site in a driving question folder or share the information with their peers. Students are able to view the shared sites and driving questions by using the buttons at the top of the interface. The right side of the interface informs the student which databases are being searched and at what reading level. The teacher has the ability to control the databases and reading level of the web sites available to the students or they can allow the students to control it.

As students search for information, using either the word search or the word net, the interface provides the students with several word alternatives and provides them with an opportunity to use a dictionary and thesaurus. Students can always revisit past searches and use problem-solving techniques to improve the quality of their searches.

If students double click on the driving question folder, they are given the opportunity to write notes about either the content or the progress of their searches. The driving question folder also enables the students to manage the content of their searches, share and receive information with their peers, and also conduct searches inside the folder.

The process of “web site sharing” provides students with the site shared, a link to the site, the login name and location of the person who shared the site, the date in which the site was shared, and a student’s description or evaluation of the website. This feature is a representation of one of the collaborative features that support peer and teacher collaboration. The teacher can control the students’ ability to send or receive information with students in their class, school, in other schools using the software. If the teacher wishes, the students can control this information as well.

The ability to share driving questions provides students with the driving question, the login name and location of the person who shared the question, and the date in which the question was shared. The sharing features have the potential to support high-level scaffolding between peers and between teacher and students (Abbas 2001; Lumpe and Butler 2002). Finally, every link represented in the interface will allow the creation of a new browser window. This not only helps students move between tools, it also decreases the “cognitive load” of using one browser.

Even though several versions of Artemis exist, the scaffolding features in Artemis still address the needs found in the study by Wallace et al. (1998). The scaffold functions proposed by Abbas (2001) can be grouped into five categories:

Fig. 1 Model of Artemis engagement

Fig. 2 The Artemis interface
1. Search Features—conducting web searches, viewing abstracts of websites, and visiting actual websites.
2. Saving & Viewing Features—students can save and retrieve search results.
3. Maintenance Features—allows students to maintain the results of their searches by editing and deleting information.
4. Organizational Features—persistent workspaces and personal space that is stored on a server.
5. Collaborative Features—students can share information with others in their class, school, or in the entire Artemis system.

Purpose

The goal of this study was to provide insight on how students use the scaffolding features embedded in the Artemis interface and the extent to which student use of features are related to student conceptual understanding and motivation. The following research questions guided the study:

Research Question #1: How do fifth grade science students use the scaffolding features in Artemis? Research Question #2: Is there a relationship between feature use and student conceptual understanding and motivation?

Methods

Context

A rural elementary school in the Midwestern part of the United States was used in this study. Due to its proximity to the local university, its population is quite diverse, including students from 30 countries. International and American college students' children, university professors' children, and farm community students create a rich intercultural environment for learning. With a district poverty level at 50%, the school implements a technology infrastructure using state and federal resources. A total of 27 5th grade science students participated in this study.

Before the project began, the researchers trained the students on several topics. First, students were trained on how to create and use concept maps to organize science concept understandings, which lasted 5 days and consisted of a presentation on concept maps and 4 days of activities in which students developed concept maps on various topics. Second, over a period of 4 days, students were introduced to the scaffolding features in Artemis and practiced using the features to perform information-seeking activities. All trainings were done in the computer lab of the school.

The teacher then initiated a project-based science (PBS) (Blumenfeld et al. 1991; Krajcik et al. 1994, 1998a, b; Marx et al. 1997) unit on photosynthesis. The unit consisted of several classroom activities related to photosynthesis, building a foundation of prior knowledge needed to perform constructivist activities. During the project, students used the features found in Artemis and the resources found in the Middle Years Digital Library to answer inquiry-driving questions. The total time frame for the unit was 3 weeks. At the end of the unit, students were required to develop a scientific experiment and a persuasive essay. The goal of the experiment was to prove that photosynthesis was needed to sustain life on earth and the essay was constructed to defend their position. The teacher evaluated the experiment and essay using a scoring rubric. The rubric was teacher generated and focused on the expectations described above.

Before and after the unit, students were asked to build a concept map on photosynthesis. Because the focus of this study was more on conceptual understanding than the mastery of knowledge, the researchers provided the students with the concepts of an expert map and asked the students to connect the concepts using a proposition that explains their relationship and an arrow that explains the direction of the relationship. After the maps were completed, the researchers collected the maps for analysis and administered the motivation survey.

Data Sources

Database

As students used Artemis, the features they used were documented in a database. Because students login to Artemis, researchers had access to data informing them on what scaffolding features students used, for how long, and the content of their dialogue with each other.

Motivation Survey

This survey is part of a larger questionnaire called The Motivated Strategies for Learning Questionnaire (MSLQ). It was developed by a team of researchers (Pinrich et al. 1991) from the National Center for Research to Improve Postsecondary Teaching and Learning (NCRIPTAL). The questionnaire is composed of twenty-six items that are rated on a 7-point Likert scale from “not at all true to me” to “very true to me”. The development of this instrument has been ongoing since 1982. In the study, thirty-seven classrooms were sampled, spanning fourteen subject domains and 380 students.

The instrument is composed of five different components. First, the instrument is composed of questions that
measure the student’s perception of the reason he or she is engaging in the learning task (alpha = 0.74). Second, questions are present that measure the degree to which the student perceives him or herself to be participating in the task for extrinsic reasons (alpha = 0.62). Third, questions are present that measure the student’s perception of how important, how useful, and how interesting the task is (alpha = 0.90). Fourth, questions are present that measure the student’s beliefs that his or her efforts to learn will result in positive outcomes (alpha = 0.68). Finally, questions are present that measure the student’s expectation to perform the task well and to be self-efficient (alpha = 0.93).

Concept Maps

The concept maps focused on the concepts of photosynthesis. For the purpose of triangulation, the researchers chose to implement three different analyses for this study. First, the researchers used a quantitative measurement developed from the work of Goldsmith et al. (1991). In this measurement, the researchers compared the student generated concept maps to an expert map. There are three components considered in the comparison. The first component is to determine whether or not the concepts are connected to one another in the same way. This is called the type A measure. The second component focuses on the agreement of the linking proposition used to define the relationship between the two pairs. This is called the type B measure. The third component focuses on what degree the directionality of relations match. This is called the F measure. The values of the data are in percentages. So, if the student map were identical to the expert map, the student map would receive a score of 1.00 or 100%.

The qualitative analysis originated from a study done by McClure and Bell (1990). In this study, McClure and Bell proposed a qualitative protocol that focuses on the relationships between concepts. This type of protocol allows for conceptual flexibility. The idea is that if a student’s map is structurally different and is composed of different propositions than an expert map, the student may still possess great understanding of the overall concept. Both may be an accurate depiction of the overall concept, but the maps may look very different.

Finally, because the concept map on photosynthesis is somewhat hierarchical, the researchers used another analysis that focuses on both quantitative and qualitative analysis. It is a procedure proposed by Novak and Gowin (1984). In the scoring scheme, 1 point is given for each correct relationship (concept-concept linkage); 5 points for each valid level of hierarchy; ten points for each valid and significant cross-link; and 1 point for each example. By not comparing the student maps with expert maps, it provides the students with the freedom to develop their own understandings. However, the assessment also concentrates on the conceptual understanding of the overall concept.

Because the qualitative and hierarchical analyses are somewhat subjective, the researchers decided to perform an inter-rater reliability analysis. The inter-rater reliability for the maps was calculated using the data from three different raters. All three raters possessed graduate degrees in the life sciences and had previously taught the concept of photosynthesis to secondary and college level students. The researchers provided training to the raters, which consisted of a presentation of the analysis procedure and several maps that had already been analyzed by the researchers. Following the presentation, the three raters worked on analyzing several sample maps until everyone was comfortable with the techniques. Because the training was in a small group setting, there was great discussion and debate about the techniques, which created a clear consensus on both procedures. Overall, the rating reliabilities ranged from 0.891 to 0.991 for the qualitative analysis and 0.608 to 0.948 for the hierarchical analysis.

Since the correlations indicated that the analysis procedures for the qualitative and hierarchical analysis were reliable, the researchers moved forward with the analysis on the remaining maps. Therefore, there was one score for each variable related to the concept map analysis (quantitative, qualitative, hierarchical).

Analysis

By using the database information, the researchers were able to use the scaffolding categories described by Abbas (2001) (Table 1) to classify and collapse the scaffolding instances, or Action IDs, into their various groups. The scaffolding instances are the results of student use of the scaffolding features.

The researchers were then able to sort the data by scaffolding category, which enabled them to tabulate the number of hits and amount of time a student used each scaffolding category. The number of hits represents the number of times students clicked on a particular feature. In the case of scaffolding categories, it represents the number of times students clicked on the scaffolding features in a particular category. For example, if a student performed a search, used the dictionary and then viewed an actual website, the student would have performed 3 hits in the searching features category. The amount of time represents the time frame in seconds that students used the scaffolding features in each category. For example, if a student viewed the shared cool sites for 60 s and viewed the shared driving question folders for 30 s, the student would have spent 90 s using the collaborative features category. This information allowed the researchers to use descriptive
statistics to show how the students used the scaffolding features in Artemis.

The researchers used the information from the database and correlated (Pearson’s r) each student’s scaffolding feature use with their scores on conceptual understanding, motivation, and two performance scores at the end of the project. In the motivation survey, all of the questions pertaining to specific areas of motivation were added together to produce five scores of motivation for each student: Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, and Self Efficacy for Learning and Performance.

The researchers then correlated each motivation score with the two previous scores describing the time and hits that each student spent using each one of the scaffolding categories. From these correlations, the researchers looked for evidence to determine if there was a relationship between scaffolding feature use and student motivation.

Finally, the last step was to repeat the previous correlation procedure with the three measures (quantitative, qualitative and hierarchy) collected on the student concept maps and the two performance scores at the end of the unit. Again, each one of these scores was correlated with both the scaffolding category hits and time to see if there was a relationship between scaffolding feature use and conceptual understanding of photosynthesis.

### Results

Research Question #1: How do fifth grade science students use the scaffolding features in Artemis?

In relation to hits, the students used the searching features more than any other (Table 2). In general, the students averaged 54 hits on the searching features, 21 hits on the collaborative features, 15 hits on the organizational features, 10 hits on the saving/viewing features and 1 hit on the maintenance features.

In relation to time, the students used the searching features more than any other (Table 3). In general, the students averaged 3.69 h on the searching features, 2.22 h on the collaborative features, 1.30 h on the organizational features, 0.37 h on the saving/viewing features and 0.02 h on the maintenance features. It should be noted that the standard deviation indicates a large variance of use for the searching, maintenance, and collaborative features.

Overall, when combining hits and time, the students used the collaborative features 25% of the time, the maintenance features 1% of the time, the organizational features 16% of the time, the saving/viewing features 7% of the time and the searching features 51% of the time. The percentage values for student use can be seen in Fig. 3.

Research Question #2: Is there a relationship between feature use and student conceptual understanding and motivation?

There were a total of three significant correlations in comparing the scaffolding use by hits (clicked on) with the dependent variables. Again, in addition to the dependent variables for conceptual understanding and motivation, the researchers also correlated the scaffold feature use with the experiment and essay student performance scores.

The first significant correlation was between the hits on the saving and viewing features and the student scores for task value \( r = 0.499, p < 0.05 \). The second significant correlation was between the hits on the searching features and the student scores for self-efficacy for learning and performance \( r = 0.553, p < 0.01 \). Finally, the third significant correlation was between the hits on the collaborative features and the student performance scores on the essay \( r = 0.519, p < 0.01 \).

There was only one significant correlation when comparing the scaffold use in time with the dependent variables. This correlation was between the use of the maintenance features and the student scores on the quantitative analysis \( r = 0.576, p < 0.01 \).

### Discussion

The database allowed the researchers to examine two indicators of student use when performing the analysis, hits
and time. For both hits and time, the scaffolding features used most were the searching features. Because these features reflect the features found in most search engines (e.g., Yahoo, Google), it should be no surprise that the students would use them often. They are comfortable with performing keyword searches.

Collaborative features were the next prevalent feature used by the students. Past studies on Artemis (e.g., Lumpe and Butler (2002) demonstrated little student use of the collaborative features. However, it is hypothesized that the collaborative features have the potential to be powerful scaffolding tools (Lumpe and Butler, 2002; Abbas 2001). The collaborative features of Artemis were emphasized during the training with the students and with the classroom teacher. By the students using the collaborative features almost 30% of the time and evidence of a strong relationship between the collaborative feature hits and the student essay performance scores, it is hypothesized that the students were able to access teacher and peer scaffolding in a virtual environment. Therefore, the theoretical

<table>
<thead>
<tr>
<th>Table 2 Scaffold category hits</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hits on collaborative features</td>
<td>4.00</td>
<td>70.00</td>
<td>20.5652</td>
<td>14.83799</td>
</tr>
<tr>
<td>Hits on maintenance features</td>
<td>0.00</td>
<td>14.00</td>
<td>1.4348</td>
<td>3.18842</td>
</tr>
<tr>
<td>Hits on organizational features</td>
<td>5.00</td>
<td>45.00</td>
<td>15.1739</td>
<td>10.93224</td>
</tr>
<tr>
<td>Hits on saving and viewing features</td>
<td>2.00</td>
<td>22.00</td>
<td>9.8261</td>
<td>5.14916</td>
</tr>
<tr>
<td>Hits on searching features</td>
<td>17.00</td>
<td>90.00</td>
<td>54.4783</td>
<td>19.80099</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3 Scaffold category time</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time on Collaborative Features</td>
<td>386.00</td>
<td>107,917.00</td>
<td>7,981.6957</td>
<td>22,257.36649</td>
</tr>
<tr>
<td>Time on Maintenance Features</td>
<td>0.00</td>
<td>917.00</td>
<td>77.0870</td>
<td>217.82518</td>
</tr>
<tr>
<td>Time on Organizational Features</td>
<td>346.00</td>
<td>49,324.00</td>
<td>4,689.9565</td>
<td>10,656.48533</td>
</tr>
<tr>
<td>Time on Saving and Viewing Features</td>
<td>0.00</td>
<td>14,005.00</td>
<td>1,330.0000</td>
<td>2,952.74396</td>
</tr>
<tr>
<td>Time on Searching Features</td>
<td>915.00</td>
<td>81,637.00</td>
<td>13,281.9130</td>
<td>19,087.40399</td>
</tr>
</tbody>
</table>

Fig. 3 Student use of scaffolding features
“scaffolding power” of this feature is magnified because it enables students to have access to human scaffolding as they conduct searches to meaningful questions.

The organizational features were the next utilized features with 15% of the hits and 17% of the time spent using these features. This finding indicates that some of the students used much of the file manager system found in the Artemis interface. This tool may have given some students an organization over information that they would not have had on their own. Finally, the students used the saving/viewing features and the maintenance features rarely. The researchers believe that both of these features together would require the student to think critically about the searches. In combination with each other, the features would allow a student to look at past searches and use problem solving skills to learn from past failures and successes. Therefore, without more training and practice, the researchers believe that students that used these features were the minority of students who already possess these skills. In this sense, the features will function as a good search tool, not a scaffold.

There were a total of four (3 hits and 1 time) significant correlations between feature use and student conceptual understanding and motivation. Each feature use, by category, was correlated to the five indicators for student motivation, the three independent measures for conceptual understanding and the two performance scores at the end of the unit. Again, feature use was divided into use by hits (clicked on) and the time of use in seconds.

The first significant correlation ($r = 0.499$, $p < 0.05$) was between the saving/viewing features hits and the students’ task value. This correlation supports the assumption that there is a positive relationship between the student use of the saving/viewing features and the students’ perception of how interesting, how important, and how useful the task is. Theoretically, high task value should lead to more involvement in one’s learning. The second significant correlation ($r = 0.553$, $p < 0.01$) was between the searching features hits and the students’ self-efficacy for learning and performance. This correlation supports the assumption that there is a positive relationship between the student use of the searching features and the students’ perception of their ability to accomplish a task as well as their confidence in their skills to perform that task. The third significant correlation ($r = 0.519$, $p < 0.05$) was between the collaborative features hits and the students’ essay performance scores. This correlation supports the assumption that there is a positive relationship between the student use of the collaborative features and the students’ ability to perform high cognitive tasks. In the essay, the students were to persuade the reader on the reasons why photosynthesis is needed to sustain life on earth, explain how plants are an essential part of food chains and food webs and explain how more plants could play a role in helping to alleviate the global warming problem. In addition, the students were to include at least four vocabulary words from the photosynthesis unit and include at least one example from a website of their choice that would support their argument. Finally, the last significant correlation ($r = 0.576$, $p < 0.01$) was between the maintenance features time and the qualitative analysis of the concept maps. This correlation supports the assumption that there is a positive relationship between the student use of the maintenance features and student conceptual understanding of photosynthesis.

In research question one, the student use of the scaffolding features in Artemis was very diverse. In general, some scaffolding categories were used more than others and there seemed to be a large deviation between scores for both hits and time. This implies that some students used the scaffolding features often, while others used them rarely. By observing the students using the software and considering the wide deviation between scores, it is recommended that the use of scaffolding software in educational settings should be voluntary. The software should be available to those who would like to use it and should function as a supplement or tool to perform high-level cognitive activities.

The results from research question two imply that there is a direct relationship between some of the features in the software and student conceptual understanding and motivation. However, without a comparison group, it cannot be determined if the positive relationship is due to the influence of the software or if students with higher conceptual understanding and motivation tend to use particular software features. Nevertheless, from the results of question one and two, classroom teachers should focus on the individual needs of students when encouraging student use of scaffolding software or conducting scaffolding software training. More specifically, before implementing scaffolding software in the classroom, a classroom teacher may want to conduct needs assessments to determine the specific needs or skills that should be developed in his or her students. With this information, a teacher may be able to provide more effective training on the use of scaffolding software.

As a search tool, it may not be Artemis that will influence student learning, but how Artemis is used. Students with lower cognitive abilities and search skills should benefit from the scaffolding features in Artemis, especially having access to a digital library with reliable resources. However, as a student grows cognitively, these scaffolds should fade over time. The student cannot rely on the scaffolding interaction provided by the teacher or software. Instead, the student’s ability to perform the tasks the software was made to supplement should be the final goal.
The concentration on how scaffolding software can meet the needs of individual students is the best way to implement the software in educational settings. In reality, Artemis may scaffold the learning of some students, but may hinder others. As Aleven et al. (2003) noted, in spite of positive evidence that interactive learning environments impact student learning, students may or may not know how to use embedded scaffolds.

Future research on scaffolding software will need to provide empirical evidence that scaffolding software can and will scaffold student learning. To accomplish this goal, it will be essential to look at student learning in both the cognitive and affective domains. Since the concept of scaffolding is nothing new, especially in special education, the research will also need to focus more on how the software can scaffold the learning of students at different levels of cognitive ability, skills, and dispositions. Again, because true scaffolding should fade over time, a cause and effect relationship will not be found with scaffolding software and student learning unless researchers target student populations that do not possess the cognitive and affective abilities to perform the tasks on their own.

In software design, it is recommended that software developers incorporate scaffolding features that support human interaction and scaffolding in virtual environments. This interaction should not only include the ability to share questions and websites, but it should also include the ability to share teacher and student generated products (artifacts). In developing critical thinking skills, the software should support a level of interaction that provides the students and the teacher with the opportunity to communicate, evaluate and synthesize information. They should also be able to share products they have developed and information and products from others in the learning community. Such a design has the potential to scaffold the learning of everyone involved. The ability to perform such tasks is interdisciplinary and not particular to science. Scaffolding features that would support this type of interaction would support the development of skills related to the evaluation, defense and communication of information. Such skills, which support the concept of a reflective teacher or student, are a visible strand in educational standards at every level.

For continual research and practice of scaffolding software, it is recommended that research should not only look at how scaffolding software can help students succeed in high cognitive tasks, but also that research and curriculum should focus on how to help students develop the critical thinking skills that the software was developed to supplement. It is not enough to just look at how the software can help students perform a task. Instead, the research, software, and curriculum should focus on developing the student’s ability to organize information, assess the reliability of information, etc. This will take a continual effort between software developers, educational researchers and teachers. The overall goal is not only to help students perform a task they can’t, but to provide them with the skills and abilities to perform that task without the help of a software feature or a more capable other.

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