# Scaffolding Wiki-Based, Ill-Structured Problem Solving in an Online Environment

## *Andamios Cognitivos Basados en Wiki, Solución de Problemas Mal Estructurados en un Ambiente Online*

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**Abstract**

To scaffold students' wiki-based, ill-structured problem solving in an online environment, the author designed conceptual, metacognitive, procedural, and strategic scaffolds. Using mixed methods research, this study explored the effectiveness of the scaffolds and the use of wikis in the ill-structured problem solving process. Data were collected from multiple sources, including surveys, virtual observations, project-related documents and postings in Blackboard, e-mails, and group wiki pages. The findings of this study suggest that soft scaffolding is necessary, especially for conceptual guidance, to effectively support students' ill-structured problem solving. The hard, metacognitive scaffolds provided in the course not only supported student groups' planning, monitoring, and evaluation in their ill-structured problem solving processes, but also helped the instructor provide tailored conceptual, metacognitive, and strategic scaffolding. The participants in this study reported that they depended on synchronous communication tools, rather than wikis, to discuss the project issues and make group decisions. The results of this study indicate that although wikis are effective for collaborative writing and editing, they are not very effective as a communication tool in the ill-structured problem solving process. The implications for future scaffolding design and implementation are discussed.

**Keywords:** Scaffolding, scaffolds, conceptual, metacognitive, procedural, strateic, ill-structured problems, ill-structured problem solving, wikis

**Resumen**

Para enseñar a los alumnos a resolver problemas mal estructurado en un ambiente online, el autor ha diseñado andamios conceptuales, meta cognitivos, de procedimiento y estratégicos. Utilizando métodos de investigación mixtos, este estudio exploró la efectividad de los andamios cognitivos y el uso de wikis en el proceso de solución de problemas mal estructurados. Los datos fueron obtenidos de múltiples fuentes, incluyendo encuestas, observaciones virtuales, documentos relacionados con los proyectos y publicaciones de mural, correos electrónicos y páginas wiki. Los resultados de este estudio sugieren que un andamio cognitivo flexible es necesario, especialmente para la orientación conceptual, para apoyar eficazmente a los alumnos a solucionar problemas mal estructurados. Los andamios cognitivos rígidos proporcionados en el curso, no sólo apoyaron la planificación de grupos de alumnos, seguimiento y evaluación del proceso de solución de sus problemas mal estructurados, sino que también ayudaron al profesor a proporcionar conceptos a la medida y el andamiaje cognitivo estratégico. En cuanto al uso de wikis en el proceso de resolución de problemas, los resultados de este estudio indican que aunque los wikis son eficaces en la edición y escritura conjunta, no son muy eficaces como herramienta de comunicación en el proceso de resolución de problemas mal estructurados. Los participantes en este estudio informaron que dependían de herramientas de comunicación sincrónica para discutir los temas del proyecto y tomar decisiones en grupo. Las implicancias para el diseño futuro del andamio cognitivo y la aplicación son discutidas.

**Palabras clave:** andamiaje cognitivo, andamios cognitivos, conceptos, meta cognitivos, procedimiento, estratégicos, problemas mal estructurados, solución de problemas mal estructurados, wikis

## Introduction

Educators and researchers have increasingly emphasized the importance of developing students' ability to solve ill-structured problems (e.g., Cognition and Technology Group at Vanderbilt, 1990, 1993;

Jonassen, 1999; Reigeluth, 1999). Like most problems one encounters in everyday life, ill-structured problems are complex, ill-defined, and open-ended. They have many alternative solutions and multiple solution paths, and the actions needed to solve them are not readily apparent (Chi & Glaser, 1985; Ge & Land, 2004; Jonassen, 1997; Sinnott, 1989; Voss & Post, 1988). Thus, ill-structured problems are much more difficult to solve than well-structured problems (Jonassen, 1997; Koschman et al., 1996) and demand higher cognitive and metacognitive abilities (Ge & Land, 2004). Novices tend to interpret complex problems in simplified ways, overlooking critical factors, demonstrating difficulty identifying relevant information, and often failing to consider alternative solutions or ideas (Powell & Willemain, 2007; Voss & Post, 1988).

More and more educators and researchers emphasize the need to provide external support or scaffolding to facilitate students' cognitive and metacognitive processes during ill-structured problem solving. Although a variety of scaffolds have been developed and implemented, there is a lack of research on the design and implementation of scaffolds for supporting the whole process of ill-structured problem solving in online learning environments, especially wiki-based collaborative problem solving. This paper focuses on four different types of scaffolds designed and implemented to support online graduate students' wiki-based collaborative learning and ill-structured problem solving processes.

**Scaffolding**

Scaffolding refers to support provided by a teacher, an expert, a more capable peer, or other resource that enables an individual to perform tasks that he or she cannot perform independently (Vygotsky, 1978; Wood et al., 1976). C. M. Reigeluth clarifies the concept of scaffolding by distinguishing it from support for learning. Defining scaffolding as support for performing, he argues that if there is no performance that it supports, then it is not scaffolding (personal communication, July 13, 2010). Scaffolds can take various forms, including question prompts, expert modeling, expert advice, learner guides, resources, and tools. Hannafin et al. (1999) identify four types of scaffolding: conceptual, metacognitive, procedural, and strategic. First, *conceptual scaffolding* guides learners regarding what to consider and helps them reason through complex problems. It is provided when the problem is defined. Second, *metacognitive scaffolding* provides guidance on how to think during learning. It supports planning, monitoring, and evaluation. Third, *procedural scaffolding* emphasizes how to utilize resources and tools. Finally, *strategic scaffolding* provides guidance on how to approach learning tasks or problems. Its emphasis is on alternative approaches. Further, Saye and Brush (2002) distinguish between hard scaffolds and soft scaffolds. *Hard scaffolds* refer to "static supports that can be anticipated and planned in advance based on typical student difficulties with a task" (p. 81). In contrast, *soft scaffolds* provide dynamic and spontaneous support based on learner responses.

**Scaffolding Ill-Structured Problem Solving Processes**

Researchers have developed a variety of scaffolds and scaffolding frameworks to support ill-structured problem solving. Cho and Jonassen (2002) examined the effects of online argumentation scaffolds on problem solving, especially ill-structured problem solving, among undergraduate students in an introductory economics course. They found that the use of the argumentation scaffold resulted in significantly more problem solving actions, increasing the generation of coherent arguments. Similarly, Oh and Jonassen (2007) found that constraint-based discussion scaffolds can facilitate online argumentation when solving ill-structured diagnosis-solution problems. Ge and Land (2003) investigated the effects of question prompts in scaffolding students' problem solving processes in an ill-structured task. They found that students working with question prompts performed better than the other groups in problem representation, making justifications, monitoring, and evaluation.

Ge and Land (2004) presented a conceptual framework for scaffolding ill-structured problem solving processes using question prompts and peer interactions. They first identified major processes for ill-structured problem solving: (a) problem representation, (b) generating and selecting solutions, (c) making justifications, and (d) monitoring and evaluation. Then, they analyzed each of the problem solving processes with regard to its cognitive and metacognitive requirements and provided types of question prompts and peer interactions for supporting different processes of ill-structured problem solving. Based on various scaffolding models, Belland and his colleagues (2008) presented guidelines for developing computer-based scaffolds to help middle school students create evidence-based arguments.

Although there is no question about the importance of scaffolding in ill-structured problem solving, current research indicates that not all scaffolds have a positive effect on problem solving. For example, Ge and Land (2003) found that peer interactions did not have significant effects on ill-structured problem solving

and suggested that peer interactions must be guided with various strategies, including question prompts, in order to maximize benefits, since learners may interact with each other at a very basic level without appropriate guidance. Further, many studies show that learners often misuse, ignore, or give up using the scaffolds provided (Davis & Linn, 2000; Land & Zembal-Saul, 2003; Ge, Chen, & Davis, 2005), suggesting that not all learners benefit from the same scaffolds. There is a need for additional research on the effectiveness of different types of scaffolds in supporting ill-structure problem solving.

**Wikis in Teaching and Learning**

A wiki, one of the Web 2.0 tools, is a website that allows anyone with a web browser and Internet access to easily create and edit web pages from any location. Its inherent simplicity and flexibility enable nontechnical users to easily access the site, fostering participation through its democratic use (EDUCAUSE Learning Initiative, 2005). Also, due to their openness, wikis are generally in a constant state of flux, and their content is fluid (Lamb, 2004; Wheeler, Yeomans & Wheeler, 2008). Unlike blogs, wikis are organized by content or topics of interests rather than chronology and are developed by multiple contributors instead of a single writer (Engstrom & Jewett, 2005; Ferris & Wilder, 2006). Thus, wikis are often used for collaborative content creation or knowledge building as well as knowledge management and sharing (Cress & Kimmerle, 2008; Engstrom & Jewett, 2005), even though they can also be used for personal purposes.

The use of wikis is increasing in education, especially in e-learning. Like other Web 2.0 tools, wikis have the potential to contribute to more learner-centered and collaborative learning environments where students create and share knowledge, rather than passively receive information from teachers. Specifically, they "enable students to collaboratively generate, mix, edit and synthesize subject-specific knowledge within a shared and openly accessible digital space" (Wheeler, Yeomans & Wheeler, 2008, p. 989). Although collaborative writing is perhaps the most common application of wikis (Ferris & Wilder, 2006; Lamb, 2004), they can also support a wide variety of online learning activities that might be impossible in a typical classroom environment. Wikis are commonly used for brainstorming, knowledge construction, project planning, problem solving, resource sharing, case libraries, assignment submission, presentations, and community building. Since wikis can incorporate multimedia objects, such as pictures and videos, they can also be used as a tool to create e-portfolios, digital stories, or other multimedia presentations (EDUCAUSE Learning Initiative, 2005; Engstrom & Jewett, 2005; Ferris & Wilder, 2006; Lamb, 2004; Parker & Chao, 2007).

Despite the possible benefits of wikis, the use of wikis in education is not always effective as few teachers are using them to their full potential. Elgort, Smith and Toland (2008) pointed out that wikis are often perceived and used as a type of asynchronous communication tool similar to that of threaded discussion boards in a course management system such as Blackboard. They argued that "the nature of interaction in wikis is fundamentally different from that of threaded discussions" and that the comparison between wikis and threaded discussion boards is not justifiable. An and Williams (2010) also noted, "educators often do the same thing with a new tool much like early distance education instructors who simply moved their course content to the Web without adapting the course and teaching methods to the new environment." Further, they argued that innovation in teaching methods is required in order to realize the potential benefits of new technologies. Early implementation efforts suggest that wikis work most effectively when teachers give more autonomy to students in the collaborative or constructive process. The potential of wikis to foster collaborative learning can be undermined if teachers impose a lot of control over the process (Lamb, 2004; Richardson, 2010).

A number of researchers have investigated how students use and perceive wikis for collaborative authoring and group learning (e.g., Bonk et al., 2009; Deters, Cuthrell & Stapleton, 2010; Elgort, Smith & Toland, 2008; O'Shea et al., 2006; Wheeler, Yeomans & Wheeler, 2008). In most studies, students used wikis to collaboratively write summaries of assigned readings, project reports, or a glossary of key concepts. However, the researcher could not find any research studies that examined the use of wikis in the ill-structured problem solving context.

**Purpose and Research Questions**

The purposes of this study were (1) to investigate the effectiveness of different types of scaffolds in supporting students' ill-structured problem solving in an online environment and (2) to explore the use of wikis in the ill-structured problem solving process. This study was guided by the following research questions:

1. How do students perceive the effectiveness of different types of scaffolds (conceptual, metacognitive, procedural, and strategic scaffolds) when collaboratively solving an ill-structured problem using wikis?
2. What scaffolding strategies work and do not work well in the ill-structured problem solving process?
3. How do online students use wikis in the ill-structured problem solving process?

## Methods

Using mixed methods research (Creswell, 2009), the researcher explored the effectiveness of different types of scaffolds in supporting students' wiki-based collaborative problem solving in an online graduate-level course.

### Setting and Participants

Teaching with Emerging Technologies was a three-credit-hour graduate course offered online by the Instructional Technology program at a public university located in Texas. The course was offered for seven weeks from January through March 2010. As its title indicates, the course explored innovative ways of utilizing Web 2.0 technologies to facilitate teaching and learning, especially learner-centered instruction. Topics included blogs, wikis, podcasts, social bookmarking, multimedia sharing, and digital game-based learning. Blackboard was used as the course management system.

The course assignments included a group project, on which this study focused. The group project required the students to collaboratively solve an ill-structured, instructional design problem that involved developing wiki-based online guidelines for a selected target audience (e.g., K-12 teachers, university faculty, etc.) on the use of a specific Web 2.0 tool (e.g., blogs, wikis, podcasts, etc.) in support of learner-centered instruction. It was emphasized that the wiki pages should be developed as cohesive work that shows evidence of collaboration.

Participants were 16 students enrolled in the graduate course. Sixty-nine percent were female and 43.75% were between the ages of 20 and 25. About forty-four percent were Master's students in Instructional Technology, and 62.5% were full-time students. Thirty-seven and a half percent indicated that they had never taken an online course before. The participants' background information is summarized in Table 1.

Table 1. *Participant Demographic Information (%, N=16)*

| Sex | | Age | | Major | | Full-time/Part-time | |
|---|---|---|---|---|---|---|---|
| Female | 69 | 20-25 | 43.75 | Instructional Technology | 43.75 | Full time | 62.50 |
| Male | 31 | 26-30 | 0.00 | Education | 12.50 | Part time | 37.50 |
| | | 31-35 | 6.25 | Adult Education | 6.25 | | |
| | | 36-40 | 25.00 | Teacher Certification | 37.50 | | |
| | | 41-45 | 12.50 | Interdisciplinary Studies | 6.25 | | |
| | | 46-50 | 6.25 | | | | |
| | | 51-55 | 6.25 | | | | |

### Scaffolding Design

Using Hannafin et al.'s (1999) scaffolding classification, conceptual, metacognitive, procedural, and strategic scaffolds were designed and provided to facilitate the students' problem solving process. The scaffolds were further categorized into hard and soft scaffolds (Saye & Brush, 2002).

Table 2. *Scaffolding Design*

| Scaffold type | Scaffolds |
|---|---|
| Conceptual | • Project Specification<br>• Resources and Tips<br>• Feedback on social bookmarking activity<br>• Feedback on drafts |
| Metacognitive | • Project Plan<br>• Progress Reports |
| Procedural | • YouTube videos & related articles<br>• Step-by-step instructions |
| Strategic | • Feedback on Project Plans<br>• Feedback on Progress Reports<br>• Resources and Tips |

*Conceptual.* The researcher developed and provided a four-page Project Specification that explained the project requirements, processes, deliverables, due dates, and evaluation criteria. Conceptual scaffolds (e.g., suggested structure, required components, and evaluation criteria) were embedded in the Project Specification. Conceptual scaffolding was also provided through the "Resources and Tips" page in Blackboard where the instructor posted various resources, suggestions, and tips. In addition, a social bookmarking activity was designed to provide conceptual scaffolding. The activity required the students to conduct a literature review and to annotate, tag, and save a minimum of 20 bookmarks related to their selected topic using Delicious, one of the most popular social bookmarking services. The instructor reviewed individual students' Delicious pages and provided feedback on their bookmarks. Furthermore, the instructor also provided each group with tailored feedback on their drafts.

*Metacognitive.* Two required document templates were developed by the researcher and used to support student groups' planning, monitoring, and evaluation in their ill-structured problem solving processes: the Project Plan and Progress Reports. In the Project Plan, which was designed to facilitate the groups' initial planning process, students were required to include their team name and wiki URL, project scope, tasks and activities to be completed, timeline, and team communication and collaboration strategies. The Progress Reports were designed to help the student groups monitor their collaborative problem solving processes, assess what they had done, and make critical group decisions accordingly. Their Progress Reports, which students submitted twice during the problem solving process, included their project title, team name, date, overall project status, project risks and issues, evaluation and lessons learned, and next steps and timeline. The instructor provided feedback on the groups' Project Plans and Progress Reports.

*Procedural.* To help the students learn how to use tools required for the group project, including a wiki and a social bookmarking site, the instructor provided YouTube videos (Wikis in Plain English: http://www.youtube.com/watch?v=-dnL00TdmLY; Social Bookmarking in Plain English: http://www.youtube.com/watch?v=HeBmvDpVbWc) and related articles. She also provided step-by-step instructions for using tools to those who needed additional help.

*Strategic.* Strategic scaffolds were provided mainly through instructor suggestions, tips, and feedback on the groups' Project Plans and Progress Reports. Some of the strategic scaffolds were also provided on the Resources and Tips page in Blackboard.

## Data Collection and Analysis

Using mixed methods research (Creswell, 2009), the researcher collected both qualitative and quantitative data in Spring 2010. Data were collected for seven weeks from January through mid-March from multiple sources, including surveys, virtual observations, project-related documents and postings in Blackboard, e-mails, and group wiki pages.

*Participant observation and document review*: The researcher was the instructor for the course. As a participant observer, the researcher conducted virtual observations of the four groups of students, mostly reading their asynchronous discussions in Blackboard, Project Plans, Progress Reports, emails, and group wikis.

*Surveys:* Participants completed three surveys. The first survey, implemented during the first week, provided background information on the participants, including sex, age range, major, job, technology skills, experience with online courses, and interest areas. The second survey was administered in Week 5 after the participants submitted their second Progress Reports. It focused on the effectiveness of different scaffolds provided in the course and included both Likert-style and open-ended questions. All participants completed the first and second surveys. The final survey was conducted in Week 7 after the project completion. Fifteen out of 16 participants completed the final survey.

Quantitative data from surveys were analyzed by using descriptive statistics. Qualitative data were analyzed by using the constant comparative method (Glaser & Strauss, 1967; Strauss & Corbin, 1990). All qualitative data were carefully examined, coded, and constantly compared to other data.

## Results

The four groups of students in this study had different target audiences for their guidelines (e.g., K-12 teachers, military instructors, and university instructors) and focused on different Web 2.0 tools (e.g., wikis, podcasts, and social bookmarking). Each group consisted of three to five students. Different groups used different communication tools and approached the problem differently.

*Research Questions 1 & 2: The effectiveness of different types of scaffolds*

*Conceptual scaffolding*

The researcher embedded some cognitive scaffolds in the four-page Project Specification. By explicating items to include in the final guidelines and evaluation criteria, the researcher intended to help the students understand the problem and identify appropriate learning needs. However, the hard scaffolds were insufficient for the novice instructional designers. The students seemed overwhelmed by the complexity and ambiguity of the problem. Several students commented that they were new to that kind of ill-structured problem. As one student stated:

> For the first two weeks, my teammates and I really had no idea what exactly we were supposed to be doing. Looking back, it seems rather obvious what we were supposed to be doing. But at first it appeared quite daunting (David, March 8, 2010).

The student groups' Project Plans revealed that all four groups overlooked one or more critical issues. For example, Teams B and C planned to develop step-by-step technical guides on the use of their chosen Web 2.0 tools. Different groups interpreted the problem differently, and the instructor provided tailored feedback on their Project Plans. She also provided a number of tips on the Resources and Tips page, emphasizing that the focus should be on technology integration strategies that support student-centered learning.

After submitting their Project Plans, the students were asked to annotate, tag, and save a minimum of 20 bookmarks using Delicious and to add a minimum of 10 people to their network. This social bookmarking activity was designed to facilitate the literature review process and resource sharing. It was observed that few students saved bookmarks related to learner-centered pedagogy. The instructor provided some basic resources on student-centered learning on the Resources and Tips page. The majority of students (87.5%) thought that resources provided on the Resources and Tips page were helpful for identifying and understanding key conceptual knowledge required for the group project (with 12.5% being neutral). However, the final wiki-based guidelines developed by the student groups showed that the students depended more on Web resources than on the resources provided by the instructor and other peer-reviewed journal articles. This is consistent with Elgort et al.'s (2008) findings.

A week before the project due date, the instructor reviewed the groups' wiki pages and provided detailed feedback on their drafts. Although all participants agreed (37.5%) or strongly agreed (62.5%) that

instructor feedback on their drafts was helpful, one of the groups was unable to make many improvements based on the instructor feedback and suggestions due to lack of communication and collaboration among group members.

*Metacognitive scaffolding*

*The Project Plan*: Overall, the participants thought that the Project Plan activity was helpful for their project planning. A majority of participants (78.6%) agreed or strongly agreed that writing the Project Plan helped their group make initial project plans effectively. One of those who disagreed stated that it was not effective for her group because she had to write the plan by herself without her group members' input or feedback.

*Progress Reports*: Most participants (86.4%) believed that writing Progress Reports helped their team monitor and evaluate their progress and make necessary changes to improve their problem solving process. Most also agreed or strongly agreed (78.6%) that writing Progress Reports helped their team make important decisions for the group project. Student responses to open-ended questions in the second survey also revealed that writing Progress Reports helped them make progress and avoid procrastination. However, writing the Progress Reports turned out to be ineffective when there was a lack of participation and communication among group members.

> Completing the progress reports gives us time to look and see where we are at and what still needs to be done (Samantha, February 22, 2010).
>
> The progress report was also a way to make sure we were doing something each week. It made us not procrastinate because we had to have some kind of improvement each week to show you (Natalie, February 22, 2010).
>
> The Project Progress Reports were a great way for us to crystallize our thoughts and demonstrate to ourselves that we were making progress. I highly recommend them (David, February 22, 2010).
>
> For our team, writing the project progress report was not helpful because I did two of them by myself without any feedback or advice. I posted them, asked for feedback, did not receive any and emailed them to the instructor (Anna, February 22, 2010).

*Procedural Scaffolding*

As addressed above, the students were required to use wikis and social bookmarking for the group project. In the first survey, they were asked to rate their skill levels in using those Web 2.0 tools. A four-point scale was used: 1 (never use), 2 (novice), 3 (competent), and 4 (proficient). As shown in Table 3, 37.5% reported that they had never used wikis before, and 25% rated themselves as novice. Social bookmarking had never been used by 56.25% of the group.

Table 3. *Perceived skill levels in using Web 2.0 tools*

| | 1 (Never use) | 2 (Novice) | 3 (Competent) | 4 (Proficient) |
|---|---|---|---|---|
| Wikis | 37.5% | 25% | 31.25% | 6.25% |
| Social bookmarking | 56.25% | 25% | 18.75% | 0% |

The instructor provided YouTube videos and related articles as hard scaffolds. She also provided step-by-step instructions to a few students who asked for additional help. Although a considerable number of students were novice users, survey data revealed that most students created and used their wikis and social bookmarking without much difficulty. Most participants reported that the YouTube videos and articles were helpful. Interestingly, however, the second survey data revealed that some students learned how to use the required tools better from peer interactions than from hard scaffolds. About 20% of the participants reported that peer help was more helpful than the YouTube videos and articles.

*Strategic scaffolding*

As mentioned earlier, different groups interpreted the problem differently and developed different problem solving plans and strategies. The instructor provided strategic scaffolds mainly by providing tailored feedback on the groups' Project Plans and Progress Reports. Common strategic suggestions were made regarding literature review, timeline, and group meetings and communication tools. Most participants (93.8%) perceived instructor feedback on their group's Project Plan to be helpful. All students agreed (31.2%) or strongly agreed (68.8%) that instructor feedback on their Progress Reports was helpful. A majority (82.25%) reported that their group made some changes to their initial plans or strategies based on instructor feedback.

The student groups' Progress Reports and wiki pages showed that the student groups were trying to complete the project by dividing work into independent subtasks. The instructor suggested that they collaborate rather than cooperate by working on all components of the project together and constructing a shared understanding (An & Reigeluth, 2008; Dillenbourg et al., 1995). Most students (81.25%) reported that their group made changes to their collaboration strategies based on the instructor suggestions on task division and collaboration.

> We divided things pretty equally; we each took a section on each page, and then checked each other's work. We did not divide up pages. We worked together on each page (Natalie, March 8, 2010).
>
> We collaborated on all sections and subdivided small parts of each (James, March 8, 2010).

*Research Question 3: Using wikis in the ill-structured problem solving process*

The students used the wikispaces for writing their Project Plan and Progress Reports as well as for developing their guidelines. Their overall experience with wikis in this study was positive. Most students (93.3%) felt that wikis are easy to use and also felt comfortable with the open nature of wiki spaces. Surprisingly, all students reported that they were comfortable editing others' sections or pages on a wiki. Only two students (13.3%) reported that they did not like their writing being edited by others. The majority of the participants (93.3%) found that wikis were effective for collaborative writing and collaborative knowledge creation. Eighty percent felt that wikis encourage more equal participation.

Six major benefits of using wikis in the ill-structured problem solving process were identified from the participants' responses to open-ended questions in the third survey: easy access, flexibility and convenience, the ability to edit each other's work, the ability to add multimedia components, revision history, and the ability to see changes immediately without having to send emails.

> We could all edit and add information to each other's work. We could get on at any time to update the wiki (Natalie, March 8, 2010).
>
> We could all edit and work on the same document and see the changes immediately without having to send the changes to our partners via email (Ethan, March 8, 2010).

In terms of the major barriers to the use of wikis in the ill-structured problem solving process, a number of students pointed out that wikis do not allow multiple people to edit the same page at the same time (Engstrom & Jewett, 2005). They also reported that they had problems in formatting their guidelines. This is consistent with the findings from Elgort et al. (2008) and Wheeler et al.'s (2008) studies.

> More than one person at a time could not make changes. This is difficult when we are having a group meeting and all wanting to make changes at the same time (Natalie, March 8, 2010).
>
> Seemed to create extra work when we started formatting the final product (Joshua, March 8, 2010).

The data from both the second and final surveys revealed that wikis were not very effective as a communication tool in the problem solving process. Although most students believed that wikis were effective for collaborative writing and editing, they reported that they still had to use synchronous

communication tools such as Skype, text or phone call to discuss the project issues and make decisions. One of the groups whose team members never met in person due to schedule conflicts used Skype extensively and reported that one of the key factors to their success was the use of Skype.

> …but we still have to communicate via Skype to ensure that we are on the same page. There's still nothing like hearing someone's voice tones and inflections, as far as interpreting meaning. (Emily, February 22, 2010)

> I think it worked as far as posting work and letting your teammates see and editing it. However, I don't really like it as far as communication is concerned. I think email, texting and phone calls are more immediate for communicating. I may be out all day and can't check and respond on the Wiki, but I can answer a text or phone call almost immediately. (Ethan, March 8, 2010)

It was also found from the observation and survey data that the wikis might not be used to their potential when students meet face-to-face frequently. Although it was an online course, one of the student groups, consisting of five Army employees, met face-to-face daily during work hours. The Army group members reported that the use of wikis was not necessary and that they did not use theirs effectively. It was observed that they did not use their wiki much for writing and editing. They tended to post their content on their wiki page only when it was required for instructor review and feedback.

> I believe that Wikispaces is a great group tool. We do not use it effectively since we meet face to face daily, but for a group doing a project long distance, it would be very useful. (Julia, February 22, 2010)

**Discussion and Implications**

The findings of this study are from one graduate-level course. Therefore, they cannot be generalized. However, they provide interesting insights on scaffolding wiki-based collaborative problem solving. The implications for future scaffolding design and implementation are discussed below.

**Resistance to Ill-structured Problems**

While many of the students in this study were novice wiki users, their lack of experience did not hinder their problem solving process. Most found that a wiki was easy to use. This is consistent with Deters et al.'s (2010) findings. Their difficulty in completing the assignment was not due to the new technology, but to their lack of experience in ill-structured problem solving and student-centered learning. The students were unfamiliar with the ill-structured problem solving process and overwhelmed by the complexity and ambiguity of the problem presented to them. It is important to keep in mind that there are still many students who are accustomed to traditional teacher-centered instruction. Online instructors should be prepared for students' initial resistance to ill-structured problems. This study suggests that instructors help students understand the learner-centered pedagogy and the ill-structured problem solving process before engaging them in an open, ill-structured learning environment. Once students understand that the problem is supposed to be "ill-structured" and they are going to get support during the problem solving process, they feel safe and are willing to work on the messy problem.

**Soft vs. Hard Scaffolding**

Many researchers have focused on computer-based hard scaffolds or embedded scaffolds to support students' learning and problem solving. Well-designed hard scaffolds can not only support students' problem solving, but also reduce the amount of soft scaffolding online instructors need to provide in an ill-structured problem solving environment. However, as Saye and Brush (2002) noted, "there are limits to gains that may be achieved through hard scaffolds" (p. 93). Student support needs in the ill-structured problem solving process are so complex and unpredictable that it is difficult to successfully support students' problem solving through hard scaffolds alone. Ill-structured problem solving requires dynamic and situational scaffolding from a skilled teacher.

This study also suggests that soft scaffolding is necessary to effectively support students' ill-structured problem solving. In particular, the findings of this study show that more soft scaffolding is required, especially for conceptual guidance. Despite embedded conceptual scaffolds and additional guidance, some groups had difficulties in finding appropriate resources, synthesizing information from different sources, and developing guidelines. In addition, different groups had different support needs. It is

suggested that an instructor carefully monitor each group and provide tailored soft scaffolding to help students reason through complex, ill-structured problems.

### The Project Plan and Progress Reports

In order to collaboratively solve an ill-structured problem, students should make plans, monitor their problem solving processes, assess what they have done, and revise their plans if necessary. As noted earlier, many students are not familiar with ill-structured problems and not well-prepared to effectively manage cognitive and metacognitive challenges posed by them. In addition, students' problem solving processes are imperceptible, especially in online environments, and it makes it harder for the instructor to provide appropriate support. In an attempt to provide metacognitive and strategic scaffolding, the Project Plan and Progress Reports used in this study were a success. The student groups' Project Plan and Progress Reports made their plans, strategies, progress, reflections, and evaluations visible, and they allowed the instructor to understand what was going on in each group and to provide appropriate guidance. Although they were designed for metacognitive and strategic scaffolding, they also helped the instructor better understand the student groups' conceptual needs. Particularly, the Progress Reports forced the student groups to regularly reflect on and assess their collaborative problem solving process and make progress, avoiding procrastination. It appears that the Project Plan and Progress Reports may not only serve as hard, metacognitive scaffolds, but can also help instructors provide tailored conceptual, metacognitive, and strategic scaffolding in the ill-structured problem solving process. However, they might be unnecessary for individuals with a high level of metacognitive skills who do not need much guidance from the instructor. Also, they are not effective when there is a lack of communication among group members.

### Synchronous Communication for Decision Making

Solving an ill-structured problem in a group involves a lot of discussions and decision making and requires great interdependence with group members. In online environments, collaborative problem solving is more complicated and challenging. An and Reigeluth (2008) suggest that online instructors provide both synchronous and asynchronous communication media to facilitate students' collaborative problem solving in online environments. Synchronous communication can be more effective and efficient for group decision making while asynchronous communication allows students to work at their convenience and to have more time to think about the content.

Similarly, the results of this study indicate that, despite wikis' effectiveness as an online collaboration tool, students need to communicate synchronously when they collaboratively solve an ill-structured problem that requires a lot of discussions and decision making. The students in this study were encouraged to have synchronous meetings using Skype or other synchronous communication tool. Some chose to meet face-to-face, but many students who were not able to do so depended on Skype or phone calls. Those who used Skype reported that synchronous online meetings with team members through Skype enabled them to make major group decisions efficiently and to review and work on their wiki pages together.

In the near future, online learners might be able to use more advanced tools that incorporate the features of wikis and online synchronous communication tools. While synchronous communication is critical in wiki-based collaborative problem solving, it is worthwhile to note that wikis may not be used effectively when students meet face-to-face frequently.

### Suggestions for Future Research

Further studies might examine the effectiveness of different types of scaffolds similar to those used in this study in different settings with different types of ill-structured problems. Second, it might be interesting to compare expert and novice groups to see how they use and perceive the effectiveness of different types of scaffolds differently. Finally, future research could explore the use of wikis in a variety of ill-structured problem solving contexts.

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