AC 2009-2425: SCAFFOLDING TECHNIQUES FOR IMPROVING ENGINEERING STUDENTS' WRITING SKILLS

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Scaffolding Techniques for Improving Engineering Students' Writing Skills

Abstract

Writing is related to critical thinking and good writing skills help students improve their academic performance. Engineering students as well as engineering courses have some unique needs and issues when it comes to writing, and require better approaches to improve students' writing skills. Scaffolding is one such approach to teach writing skills as it builds students' writing skills gradually from simple to complex tasks, and helps students become better writers. This paper describes the successful use of scaffolding techniques to improve students' writing skills in three engineering courses. The scaffolding techniques involved modeling the concepts and expected behavior by the instructor, conducting in-class activities to help students learn the concepts, assigning homework activities that build on the previous steps, and providing clarifications and support resources to help students in the learning process. The scaffolding techniques allowed students to go from simple to complex aspects of writing, such as citations, academic integrity, literature review, grammar, format, and the writing process, and develop the necessary writing skills and confidence in their abilities. The paper includes results from implementing scaffolding techniques in the three courses, and a discussion on how the techniques can be integrated by other faculty in their courses without spending too much time and effort or sacrificing course content.

Introduction

Good writing skills are more important than ever, especially in this age of technology[4,6]. A survey of 120 major corporations conducted by the College Board's[3] National Commission on Writing revealed that nearly two-thirds of salaried employees of those corporations held positions that required good writing skills. According to Richard Sterling, executive director of the National Writing Project, the results of the 2007 Survey of Teaching Writing conducted by the National Writing Project[12] indicate that the public recognizes the importance of good writing skills more than ever and that learning to write well is as important as learning to read. Sterling exhorts that "The word is out: writing must be an integral part of the curriculum."

Engineering faculty members recognize the importance of good writing skills but often have the difficult task of promoting effective writing practices among their students. Faculty members cannot always assume that their students would have learned the basic writing techniques in high school or in core competency courses in college. Even if students were exposed to basic writing techniques in their pre-engineering courses, they usually forget those techniques if they do not have sufficient opportunities to refresh and practice them regularly. Faculty members also need supplementary resources to help students refresh their basic knowledge of grammar, style and organization, and techniques to integrate writing assignments effectively into engineering courses. Wheeler and McDonald[17] state that "engineering faculty members have a common "discomfort with their ability to assign, and especially evaluate prose" as many engineering faculty members may feel that it is the responsibility of the English department to teach students writing. Another legitimate concern of faculty members is the time required for developing,

assigning and evaluating writing assignments. Engineering students also have some unique needs and issues when it comes to effective writing. Many engineering student may view writing as a "flat representation of facts than as an effort at real communication."[17] Engineering students, while pursuing their degrees, may not recognize that effective writing is an important aspect of professional communication within the engineering community. However, after beginning their employment many of them recognize the vital importance of effective writing for communicating discipline-specific information within their professional community.

Scaffolding is an effective approach for teaching writing skills to engineering students as it builds their writing skills incrementally and helps them communicate effectively. Scaffolding techniques also help engineering faculty integrate manageable writing assignments in their courses and provide timely feedback to students. This paper describes the successful use of scaffolding techniques in improving engineering students' writing skills.

Scaffolding Techniques

Scaffolding is a term that engineers can readily understand as scaffolds are temporary, physical structures used in tall construction sites to allow workers to reach their work places as well as complete their work around the structures easily. Instructional scaffolding is a pedagogical technique that helps students receive incremental support in learning activities that may be too difficult to complete initially on their own. As physical scaffolds are not needed after a building has been constructed, instructional scaffolds should also be removed after students have developed the necessary skills. Instructional scaffolding is not a new technique, and it has been in use for a long time, especially in K-12 and special education environments[2]. Scaffolding is a problem-based learning technique, which is often used to teach students to solve ill-structured problems in a cooperative learning manner[8].

According to McKenzie[11], instructional scaffolding involves eight characteristics:
1. Provides clear directions to students on what they should do and reduces their confusion.
2. Clarifies the purpose of what students are asked do and why it is important.
3. Provides structure and keeps students on task so that they do not wander off from the task.
4. Clarifies expectations by providing quality examples of work as references.
5. Directs students to available resources which they can choose to use in their tasks.
6. Reduces uncertainty, surprise, and frustration so that students maximize their learning.
7. Delivers efficiency in the learning process by helping students to focus on their work.
8. Creates momentum in the learning process by allowing new ideas and experiences to flow.

From the mentioned characteristics of scaffolding, it is easy to infer that instructional scaffolding involves developing instructional plans that build on students' existing knowledge to result in a deeper understanding of new information. The instructional plans must be implemented and the participating students must be supported during the learning process for the scaffolding to benefit students[10]. The types of instructional and support plans that have to be developed and implemented will depend on the types of students, nature of skills to be gained, and the background knowledge of students. Scaffolding has been used as an effective technique for improving students' writing skills in K-12 courses[15], ESL classes[5], and higher education settings[9].

Scaffolding instructional plans generally involve the following steps[10]:
1. Modeling the task and the desired behavior so that students see how the instructor completes the task.
2. Offering explanations that can range from detailed explanations at the initial stages on how the instructor accomplished the task to simple clarifications at the later stages.
3. Inviting students to participate in the task through activities that can range from inviting a student to explain on the board what he or she had learned to inviting groups of students to do the same task.
4. Verifying students' work and clarifying their understanding as this feedback is critical to reinforce what students have learned as well as resolve any difficulties they may have.
5. Inviting students to contribute ideas about the topic, which can guide instructor's discussion based on their ideas and lead students to a deeper understanding of the topic.

The five steps clearly illustrate the constructivist approach of the scaffolding technique and its cooperative learning strategy. The technique requires active involvement of the instructor as well as the students, and it calls for a detailed instructional plan and support system for students. Due to the problem-based learning nature of the scaffolding technique, it is most suited for teaching difficult concepts to engineering students as they are usually receptive to solving problems. Therefore, scaffolding is an effective technique for teaching engineering students good writing skills.

Scaffolding to Improve Engineering Students' Writing Skills

In the past, the author of this paper had integrated writing assignments in engineering courses by assigning a term paper or project report that was due at the end of the semester. This approach did not always improve students' writing skills as students did not have the opportunity to receive timely feedback, refine their work, and learn from this process. As a result, students' confidence in their writing abilities did not improve. To overcome the limitations of this approach, the author decided to experiment with scaffolding techniques in three of his courses in the Department of Industrial and Systems Engineering at Northern Illinois University.

The first step in applying scaffolding techniques is to analyze students' background knowledge and skills on the chosen topic so that appropriate instructional scaffolds can be developed to build on the background knowledge and skills. A thorough analysis of students' writing assignments revealed that the students were competent in their technical abilities but were deficient in a number of aspects with respect to their writing in engineering courses:
1. Paragraphs did not have any topic sentences, did not flow logically from one paragraph to the next in each section, and were too long to read and comprehend.
2. Sentences stated independent facts but did not flow logically from one sentence to the next within a paragraph and did not come across as professional communication to the community.
3. In-text citations and list of references were inconsistent in style, and were often incomplete.
4. Information taken from other sources were not paraphrased and cited properly.
5. Literature reviews were just plain summaries and did not synthesize past literature to indicate gaps in the reviewed topic or the need for proposed engineering idea, design or technique.
6. Students' papers and reports were replete with common grammatical errors.
7. The papers and reports were formatted inconsistently.

To help students overcome the mentioned deficiencies and develop confidence in their writing abilities, the author developed and implemented an instructional scaffolding plan in three courses in Industrial and Systems Engineering. The scaffolds included "modeling" by the instructor, support resources, in-class activities, and homework assignments. The scaffolding activities in the instructional plan were implemented in the courses in the order explained below to allow students to develop confidence from completing simpler activities of smaller duration successfully before attempting complex activities of longer duration.

Citations: A simple analysis of issues related to students' inability to cite sources properly revealed that allowing students the flexibility of following the citation style of any refereed engineering journal was the basic problem. This is similar to asking a beginning driver to learn driving by observing another driver and this is not necessarily the best way to learn to drive! The journals that some students selected to follow did not have all the possible citation situations students needed for their work, and so they made up those needed citation situations to the best of their abilities. Most importantly, students did not know or understand basic citation styles, and as a result, did not pay much attention to the details of the citations they had prepared. The instructor was also unable to check particular citation styles of various journals used by different students in the course, correct their work properly, and give them feedback.

To overcome the mentioned problems related to citations, the author implemented the following scaffolds in his courses:
- Prepared a handout on basic citation styles, presented a brief lecture on the topic in class and modeled the proper use of citations in course materials.
- Required all students in the course to follow the basic APA citation style as this allowed the use of APA citation generators available online to create citations easily. Use of the same citation style also allowed the instructor to correct students' work and provide feedback easily.
- Conducted a short in-class activity that required students to identify mistakes in a number of citations in-text citations and references.
- Assigned a small homework activity for students to create citations for a number of citation situations such as journal articles, books, websites, product manuals, etc.
- Provided students with additional support resources, such as self-test exercises and resource websites.

Academic Integrity: Even though in every engineering course, the course instructor discusses academic dishonesty and plagiarism policies, students do not fully comprehend the issues. As lecturing students on academic dishonesty and citing course policies on plagiarism have not had a serious impact on students' ability to avoid plagiarism concerns, the author implemented the following scaffolds in his courses to promote academic integrity:
- Developed and published with his colleagues an online tutorial on academic integrity at http://www.niu.edu/ai and required students to view the tutorial, learn the issues, take a series of quizzes, and print and submit a certificate of completion.
- Discussed issues related to academic integrity in class and clarified students' questions.
- Modeled in class how to paraphrase or use verbatim information taken from external sources.
- Conducted an in-class exercise that required students to paraphrase an engineering source.

- Required students to submit electronically a two-page technical paper, and ran the papers through SafeAssign[13], a feature available through Blackboard web course management system to identify matches between students' work and published sources.
- Provided students detailed feedback on their two-page papers and also made available additional web resources on paraphrasing, citations, and use of direct quotes.

Literature Review: Literature review is one of the aspects of writing that engineering students have a difficult time comprehending and the literature reviews they prepare are plain summaries of past literature that they find only through web search engines and not through engineering journal databases licensed by the university library. The reviews neither include a critical analysis of the literature they find nor identify gaps or voids in the existing literature. Students also do not know how to organize the reviews in a logical and coherent manner. There are also a number of software such as EndNote and OneNote commercially available for conducting literature reviews, and there are free social bookmarking tools, such as del.icio.us[7] and Scholar[14] available on the web. However, a majority of engineering students do not know or use these electronic resources. To help students understand the literature review process and prepare better reviews, the author implemented the following scaffolds in his courses:

- Developed a brief handout on the literature review process and discussed it in class.
- Modeled in class the process of finding literature quickly on a particular topic using engineering databases compared to sorting through thousands of links found on the web.
- Provided a sample analysis of literature collected for a research topic in engineering to illustrate how the review could be organized and presented.
- Required students to create an account on a social bookmarking tool such as del.icio.us or Scholar, and use it for literature review purposes.
- Required students to prepare a Venn diagram or concept map to focus their literature search and present the analysis of the literature in the form of a table as shown in Figure 1.
- Required students to organize the literature review using the literature review table as a guide.

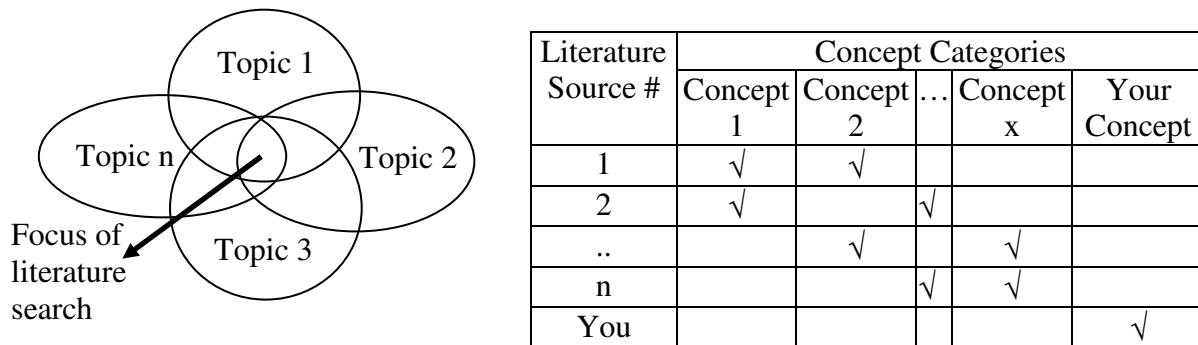| Literature Source #	Concept Categories				
	Concept 1	Concept 2	...	Concept x	Your Concept
1	√	√			
2	√		√		
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Figure 1. Literature review diagram (left) and literature analysis table (right)

Grammatical Mistakes: Engineering students generally tend to focus on technical facts in their writing and not pay much attention to grammar. Their writing is often replete with common grammatical errors, such as subject-verb disagreements, run-on sentences, dangling participles, and fragmented sentences. Engineering courses also have a considerable number of international students for whom English is a second language, and these students find it much difficult even to

recognize grammatical errors in their writing. It is also impractical for engineering faculty to spend their class time to review English grammar and help students avoid common grammatical mistakes in their writing. However, the author strongly felt that the students in his courses needed help in recognizing and preventing common grammatical mistakes. Therefore, he implemented the following scaffolds to help students in his courses:

- Reviewed in class the common grammatical mistakes and provided students with a list of common grammatical mistakes and steps on avoiding them.
- Required students to go through an online tutorial on effective writing practices published by the author and his colleagues at http://www.niu.edu/writingtutorial and test themselves on common grammatical mistakes.
- Modeled in class the proper use of grammar, and explained writing situations where one could easily make grammatical mistakes.
- Conducted in-class activities to help students recognize common grammatical mistakes in sample paragraphs.
- Provided students detailed feedback on grammatical mistakes in their writing assignments and required them to correct those mistakes in successive versions of their work.

Format: Formatting a paper or report is one of the easiest aspects of writing, and a well-formatted work is visually pleasing and easy to read. However, engineering students usually pay more attention to technical details than the aesthetic aspects of writing. It is common to find engineering students' papers or reports with section titles that are inconsistent in style and font size, unnecessary blank spaces at the end of pages, inconsistently formatted paragraphs, and lists that are not parallel in construction. Therefore, to help students in his courses understand these issues, the author implemented the following scaffolds in his courses:

- Explained in class the importance of visual appeal and consistency in formatting.
- Illustrated in class examples of consistently and inconsistently formatted work.
- Modeled consistency in formatting in his course materials and assignments.
- Provided students with a checklist consisting of twenty-five items to check for in their papers or reports before submitting them.

The Writing Process: Writing is not an easy task for anyone and it is even more difficult when one does not have a plan or a sense of direction on what to write and how to navigate the process effectively. Even though engineering students know how to plan and conduct a research experiment, they do not apply the same approach to the writing process. The author conducted a brief survey of students in his courses about their writing process and realized that a majority of them did not have a process to follow and did not know how to navigate the writing task easily. Many of them had not even heard of outlining or topic sentences and did not know about transitioning smoothly from one idea to the next in their work. Most importantly, many engineering students thought of writing assignments as a documentation of facts and not as professional communication critical for functioning effectively in their field. As these are difficult concepts for students to comprehend and apply, the author implemented these last in his courses through the following scaffolds:

- Prepared a small handout on outlining, creating topic sentences, applying transitions and organizing information into visually appealing paragraphs, and distributed it to students.
- Modeled in class the process of outlining, creating topic sentences, etc., and illustrated them with engineering examples.

- Conducted in-class activities on creating outlines and topic sentences.
- Required students to prepare and submit outlines and topic sentences of their technical papers or project reports before working on the drafts.
- Provided students with additional resources on the writing process available on the web.
- Provided students with detailed feedback on their writing assignments on issues related to paragraph structure, transitions, flow, etc.

After covering issues related to the basic writing process, the author addressed the unique writing needs of engineering students and courses through several scaffolding activities. The unique writing needs pertain to communicating technical concepts effectively to technical as well as non-technical audiences. The author strongly believes that the most important prerequisite for effective writing is critical reading of well-written papers or book chapters on engineering topics. Engineering students usually read a book chapter or article to find example problems similar to those covered during a lecture but not read it to comprehend how well those book chapters or articles are written and how effectively the technical information is presented in them. Therefore, the author selected one or two well-written journal articles on a topic covered in each course or particular chapters in the textbook and required students to read them thoroughly. Then during one of the following classes, the author required students to discuss in small groups in class and identify various aspects of effective writing in those articles or book chapters. This was certainly eye-opening to engineering students as they were not accustomed to reading critically, and this reading activity helped them to compare their own writing with those well-written journal articles and book chapters.

Another scaffolding activity the author employed to reinforce the importance of effective communication in engineering courses was to require students to write a two-page paper on a technical topic for a non-technical audience. The author required his students to share their papers with non-engineering students, friends or family members and find out if they were able to comprehend what was being conveyed in their papers. Many students found this activity very difficult and some of them were surprised to find out that the non-engineering audience could not comprehend what their papers were trying to convey. This activity clearly demonstrated to students the need for writing effectively in the engineering profession.

Results

The scaffolding techniques discussed in the previous section were implemented in three different engineering courses taught by the author over a period of three semesters. The results of the implementation clearly showed improvements in students' work and their feedback. The gradual approach to implementing scaffolds from easy to difficult concepts was successful and it helped students to gain confidence in their writing skills and increase their awareness of issues related to writing.

The scaffolding activities on citations resulted in immediate improvement in students' ability to cite sources properly and follow a consistent citation style. Students also learned to use citation generators on the web to create citations easily instead of trying to figure out the unique citation styles of different journals. If students had any minor citation mistakes, it was easy for the author to identify them quickly and provide feedback.

Students commented that the in-class exercises and web resources on paraphrasing, and the use of SafeAssign to check their writing increased their awareness of paraphrasing and plagiarism concerns. Table 1 shows a sample of percent "match" of students' text with other sources before and after using SafeAssign to check their work in one engineering course taught by the author. It should be clarified here that SafeAssign will also match the text within quotes and citations, and SafeAssign's match of a piece of text with an external source does not automatically mean that the text was plagiarized or included without proper citation. This explains the greater than 0% percent matches in both before and after columns in Table 1.

Table 1. Sample of Percent Match of Students' Text to External Sources

Student	% Match Before Using SafeAssign	% Match After Using SafeAssign
1	29%	24%
2	31%	4%
3	19%	11%
4	12%	1%
5	19%	0%
6	11%	2%
7	30%	11%
8	16%	1%
9	29%	11%
10	30%	14%

A majority of students in the author's courses commented that they had no prior exposure to the formal process of conducting literature reviews before taking the author's courses. The students overwhelmingly commented that the information shared by the author, his modeling of the literature review process in class, and the simple activities they were asked to complete before writing their literature reviews were very helpful to them to learn about conducting literature reviews properly and easily. Students especially found the Venn diagram and the literature review analysis table very useful. They also appreciated the opportunity to learn about electronic tools and resources, such as engineering databases available through the library and social bookmarking tools such as del.icio.us and Scholar to conduct literature searches quickly and easily.

The scaffolding activities had mixed results on reducing students' grammatical mistakes. When students were given feedback on grammatical mistakes in their draft work, they were able to correct those mistakes and submit better final versions. However, they committed the same grammatical mistakes again in other assignments. This shows that students are unable to carry over the feedback they receive for one assignment to another writing assignment, and are unable to recognize the grammatical mistakes on their own. This helped the author recognize that

scaffolding activities on grammar would have to continue for a while, and the need for additional activities and resources to help students reduce their grammatical mistakes.

Students' ability to format and organize consistently their papers and reports improved considerably as a result of the scaffolding activities. The check-lists and the feedback on draft work helped students to improve their ability to recognize formatting inconsistencies in tables and figures with technical data. Students also commented how their papers and reports for other courses had improved as a result of the check-lists they had used in the author's courses and the feedback they had received.

The implementation of scaffolding techniques for improving the writing process resulted in significant improvements in students' writing abilities. The results were significant because the scaffolds for the writing process were implemented last to allow students to gain confidence from the previous steps and apply their increased awareness of writing techniques in the writing process. Students were able to develop outlines for their writing assignments quickly instead of spending days on writing and refining just the introductory paragraphs and not having a sense of direction on how to proceed with their assignments. At first, students had some difficulty in drafting topic sentences but once they became comfortable with the process, they were able to draft meaningful topic sentences and expand them into coherent paragraphs. Similarly, they had some difficulty in transitioning from one idea to the next smoothly in their writing, but the author understands that this will improve over time with more practice and feedback.

The "critical reading" and "writing for a non-engineering audience" assignments were the most eye-opening scaffolding activities from engineering students' perspective. Many students in the author's courses had not ever read before a technical article or a book chapter critically to identify effective writing aspects, and similarly, they had not written a paper on a technical topic for a non-engineering audience before. These activities helped students realize the importance of effective communication within the engineering profession.

Conclusions

The scaffolding techniques implemented in the three engineering courses in the Department of Industrial and Systems Engineering at Northern Illinois University have resulted in significant improvements in students' writing skills. Students are able to complete their writing assignments much more easily and quickly as a result of the scaffolding activities. Students commented to the author that their writing assignments for other courses had also improved as a result of the writing techniques they had learned in the author's courses. Students' attention to details as a result of the scaffolded writing activities is beginning to spill over into their non-writing assignments such as oral presentations, and this is a positive outcome. Even though the author had to spend some time and effort initially to develop and implement the scaffolds, he spends less time and effort now for grading writing assignments and providing feedback, and he is also less frustrated with students' writing!

Even though it is easy to recognize the benefits of implementing scaffolding techniques to improve students' writing skills in engineering courses, faculty members may be concerned about the time needed for integrating scaffolding activities in their courses and wonder if it

would require them to sacrifice some course content. These are legitimate concerns and require some discussion. First, it is important to recognize that writing is related to critical thinking and good writing skills help students improve their academic performance[1]. Therefore, faculty members should allocate some time in their courses for writing activities, and be prepared to spend time to develop writing assignments, evaluate students' work and provide feedback. Second, the author of this paper did not develop and implement in one semester all the mentioned scaffolding techniques in three courses. The author developed the materials and resources needed for the scaffolds over a period of three semesters and implemented them gradually in three engineering courses without sacrificing any course content. He also engaged students in learning activities outside the classroom as not all learning has to take place inside the classroom. Third, a majority of students who benefited from the scaffolding techniques were enrolled in all three courses taught by the author in successive semesters. This enabled these students to benefit from the incremental implementation of scaffolding techniques in those three courses. If more engineering faculty members implement scaffolding techniques to improve students' writing skills in their courses, it will reduce individual faculty member's time and effort, and it will also make it much easier to remove the scaffolds later.

Finally, and most importantly, the process of implementing scaffolding techniques to improve students' writing skills was also helpful to the author of this paper to improve his own writing skills as well as recognize the fact that he should deliberately model the skills and behavior he expects from his students.

Acknowledgments

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