6-2019

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Publisher Citation

Erdil, N. O. (2019, June), Motivating Students for Learning using Scaffolding and a Variety of Assignments and Activities Paper presented at 2019 ASEE Annual Conference & Exposition , Tampa, Florida. https://peer.asee.org/33121

Motivating Students for Learning using Scaffolding and a Variety of Assignments and Activities

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Abstract

This paper discusses the impacts of various course assignments and activities that were used to increase student motivation and learning. The courses selected for the study are Quality Analysis and Design of Experiments courses, which are offered as required courses in the industrial engineering graduate program at the University of New Haven. The assignments and activities include term project, term paper, homework, in-class exercises, quizzes, exams, library training and factory visit. In an earlier pilot study in the Quality Analysis course, scaffolding -an instructional strategy that enables students to build on prior experience and knowledge as they work towards mastering higher level skills- was employed using these activities and assignments, and the impact on student motivation and learning was analyzed. The results supported the hypothesis that scaffolding is effective in motivating and engaging students in learning. In the following semesters, the same scaffolding structure was used in a Design of Experiments course in addition to the Quality Analysis course, and data in the form of responses from student feedback surveys, student work and course grades were collected and analyzed. The focus of the analysis was on the following items: What type of activities and assignments do students value the most? Which activities and assignments enhance motivation for learning and contribute to learning?, and Does scaffolding have positive impacts on student outcomes? The sample size was 68, which was generated from three courses offered in fall 2016 and fall 2017. The results reviewed as a whole and individually provided insights on student preferences, engagement and learning particularly from the perspectives of the two courses, Quality Analysis and Design of Experiments, which have substantial practical applications within the Industrial Engineering discipline.

Introduction

Scaffolding is an instructional strategy that is based on L. Vygotsky's Zone of Proximal Development (ZPD). The range between the ability level of a person achieved by individual efforts versus under adult guidance or in collaboration with more capable peers denotes ZPD [1]. With scaffolding, the materials that the learner has to absorb are broken down into smaller components so that the amount of cognitive efforts that the learner has to make at a given time is reduced. Instructional scaffolding can be accomplished in multiple ways [2]. A large assignment can be broken down into several smaller assignments; a concept, principle or procedure can be introduced multiple times with increasing difficulty at each time; or a single assignment can be structured in a way that provides guidelines to the learner on how and/or in which sequence to tackle the assignment tasks. Another approach in breaking down the materials is using the level of learning based on learning outcomes, and give different types of assignments that lead to more complex assignments at each step. This type of scaffolding is known as critical thinking scaffolding, which is the approach used in this study. The aim was to help students with acquiring information and knowledge through various activities and assignments and connecting this material for use in a more complex assignment to gain higher level of learning skills. Literature supports scaffolding as an effective instructional strategy. In order to accomplish the desired results when scaffolding using any of the approaches listed above, it is important to

consider the factors that effect student motivation and learning. The factors that were considered in this study were based on the MUSIC model developed by Brett D. Jones. In this model, empowerment, usefulness, success, interest and caring are the main components that are considered critical to student motivation. The MUSIC model furthermore proposes that increased student motivation leads to increased student learning [3].

In an earlier study, the focus was on developing scaffolding with course assignments with the goal of helping students to acquire higher level of learning skills, namely apply, analyze, evaluate and create in Bloom's taxonomy, by the end of the course [4]. As the scaffolding structure was refined in each course offering, increasing emphasis was placed on the five factors that were listed earlier. The type of activities and assignments students value the most, activities and assignments enhance motivation for learning and contribute to learning in general, and the impact of scaffolding on student outcomes were studied using data from student feedback surveys, quality of student work and course grades.

Background

The two courses included in this study are "Quality Analysis" (QA) and "Design of Experiments" (DOE). Both are required courses in the Industrial Engineering master's program at the University of New Haven. The main topics covered in the QA course are principles of quality control systems, control charts for variables and attributes, process capability analysis, measurement system analysis, and acceptance sampling plans whereas the DOE course introduces students to fundamental concepts in planning, designing and conducting experiments and covers various designs such as factorial design, response surface methodology, nested and split-plot designs.

The course assignments and activities have the same structure and format in both courses, and include homework, quizzes, term paper, term project, in class exercises and discussions, two exams (midterm and final), library training and factory visit. A brief description of each course component is shown in Table 1.

Implementation

The overarching goal in using scaffolding in both of these courses is to help students in achieving higher level of course objectives. The scaffolding strategy is built on the library training, factory visit, term paper and term project assignments. The remaining course activities and assignments are not explicitly included in the scaffolding structure but are used as supporting materials throughout the courses. The details of the scaffolding structure, its implementation and the assessment of its impact have been the focus of a prior paper [4]. The implementation of scaffolding was limited to one course at the time, QA; it has since been used in another course to examine its effectiveness independent of course topic, and furthermore the data collected from all implementations allowed impact analysis of different assignments and activities both from students' perspective and from the results of direct assessment of student work.

Student feedback was collected using a survey which was administered at the end of the last class session of the semester. The timing of the survey administration is important as the survey includes questions about the impact of term project presentation on student motivation and learning. In this last session, the students present their projects to the class. A 7-minute question

and answer period is held after each presentation and the students are expected to carry out discussions about the project presented. Therefore, the survey is conducted after the presentation period is completed.

Table 1 Course Assignments/Activities

Assignment /Activity	Description
Homework	Homework assignments are individual assignments and include case studies, quantitative problems and/or conceptual short answer questions. Students are allowed to work on the questions together; however, an individual report from each student is required. Students usually have a week to complete and hand-in the homework assignment.
Quizzes	The quizzes are brief 5-10 minute unannounced tests or in-class exercises or short take-home assignments in various forms targeting students to learn a key concept through self-study.
Term Paper	The term paper assignment is a literature review study focusing on applications of the course topic in an industry setting. The students are asked to do a literature review to find peer-reviewed articles that presents a practical application example of QA or DOE. They first summarize then analyze and interpret the article within the context of their course. Their work is evaluated on the following criteria and the quality of their writing: Problem Statement-all study questions are listed and discussed?; Methodology-explained clearly and concisely?; Finding/Results-presented completely?; and Synthesis-connection between theory and real world practice provided?.
Term Project	The term project assignment is conducted in teams. It involves selection of a problem and then using the methods and tools covered in class solving the problem and presenting the results. In DOE, conducting a physical experiment as part of project work is required.
Midterm/ Final Exam	Exams are closed book and given in-class. The students are allowed to bring a reference sheet, one page for the midterm exam and two pages for the final exam. The reference sheets can contain only formulas, and must be hand-written and prepared by the student.
In class exercises	Both courses are run in a computer lab and a typical class session consists of lecture and exercises solved by hand and by computer.
In class discussions	These are short discussion periods on any course topic steered by student questions, instructor guidance, and/or in class exercises.
Library Training	This is an in-class training provided by a library staff. The training tailored for the courses in this study includes a class presentation with an interactive hands-on search practice. The term paper assignment is used as a guide to conduct the search practice.
Factory Visit	This is a tour of a manufacturing company. The aim is to select a plant in which the students can observe QA or DOE methods in practice.

There were 39 survey questions. 5 questions were designed to collect demographical data and another 6 targeted to gather student perception about the course content and the instructor. The remaining questions were a combination of multiple choice or rank order using a five point Likert scale, and the data collected from these questions were used in the impact analysis of the different types of course assignments and activities to student learning and motivation from the student perspective. In addition to indirect assessment performed using student survey data, the direct assessment approach was employed using overall student course grades.

Assessment and Findings

The focus of the analysis was on identifying the items students find of value in terms of enhancing their learning; items that enhance their motivation for learning; items that contribute to their learning, and the impact of scaffolding on making connections and on student outcomes. The sample size was 68, which was generated from three courses offered in fall 2016 and fall 2017. The results on assignments and activities reviewed as a whole and individually provided insights on student preferences, engagement and learning particularly from the perspectives of the two courses, Quality Analysis and Design of Experiments, which have substantial practical applications within the Industrial Engineering discipline.

Course Assignments/Activities & Student Perception About Their Impact on Learning

Students were asked to select the course components that they think *enhanced their learning* in the context of the course. Figure 1 shows the responses from the three course offerings, and the magnitude of the average response next to the category names. The results show that students place high value on typical course assignments such as homework, project and paper; medium value on in class discussions and exercises; but rank exams and quizzes relatively lower. Although homework, course project and course paper assignments are often listed as examples of summative assessment items, these assignments are structured in the QA and DOE courses as formative assessment tools. Taking this customization into account, the data suggest students benefit more from formative assessment compared to summative assessment in terms of enhanced learning.

Figure 1, furthermore, shows medium to high rating for the non-traditional course component, factory visit, which is encouraging. The role of factory visit in the scaffolding structure is explained further in the following text. Finally, a low rating is observed for another non-traditional course component, specifically library training. However, this result is not unexpected, hence not discouraging. Because, the library training activity was included in these courses for a particular reason which was to provide students resources to use in other course assignments, thus, students most likely did not consider the library within the array of items they complete to learn the course material.

Course Assignments/Activities & Their Impact on Enhancing Student Motivation for Learning

Since the survey was initially designed to seek student feedback on the scaffolding strategy, the survey included detailed questions about the course components which were part of the scaffolding structure. The students were asked to rate how useful they found the term paper, the term project and the factory visit with respect to *enhancing their motivation for learning* in the course. The rating was on a five-point Likert scale (with 5=strongly agree, and 1=strongly disagree). Figure 2 shows average student responses by item and the course in which it was

deployed.

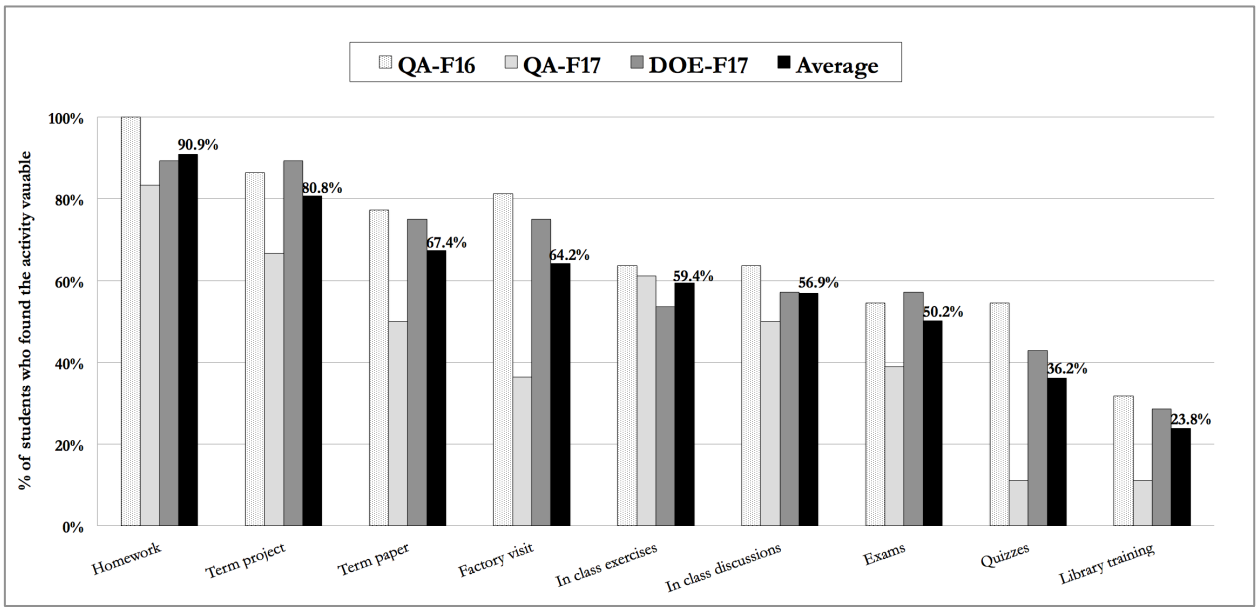

Figure 1 Items students value the most in terms of their perceived contribution to learning

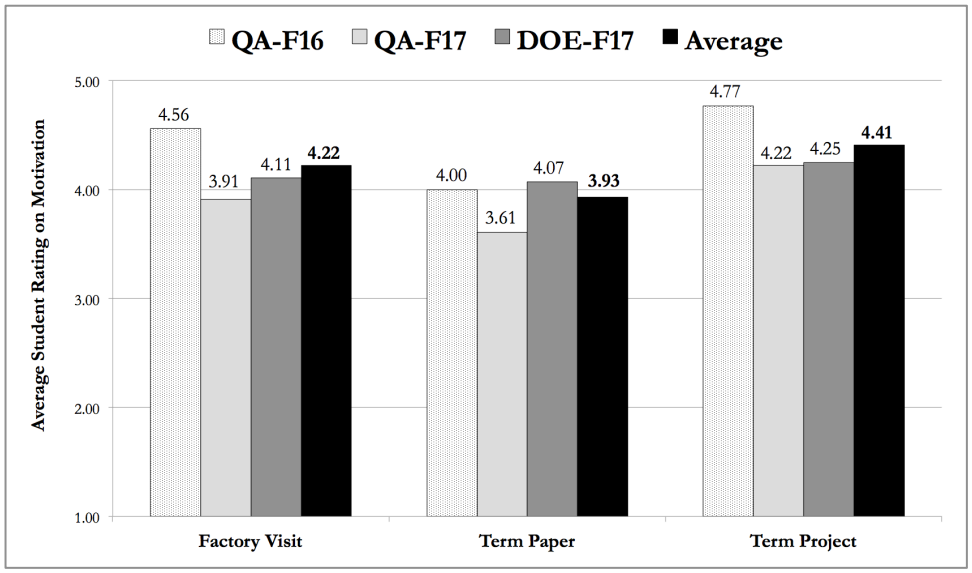

Figure 2 Average Student Ratings of Items - enhance motivation for learning

When the results on factory visit are examined on a course basis, there are a few indications that can be observed. Among the three offerings, QA-F16 received the highest rating, and QA-F17 the lowest. The company that the class visited during fall 2016 heavily uses statistical quality control methods in monitoring its production, and the students were able to observe these applications when they toured the production floor. The following year, in fall 2017, both QA and DOE classes, took a tour of a different manufacturing company together. This company, although using considerable quality management methods, could provide students only limited

access to the production floor, and during the tour, our guide presented more information on the areas in which they use experimental design methods frequently. Moreover, the data showed that QA-F17 had the highest number of students employed followed by DOE-F17 and QA-F16. This ranking inversely matches with the average student rating on the value placed on factory visit. Student ratings combined with these additional background information supports the importance of "usefulness", one of the factors considered critical to student motivation in the MUSIC model. The purpose of coursework and its relevance to the students' field of study are main contributors to students' understanding of why the content is useful. The students in fall2017 courses were less enthusiastic about the factory visit's contribution to their learning most likely due to not being able to see a high relevance of what they observed at the factory in their course work or they already had the exposure to work environment.

The term paper assignment, rated moderately high on enhancing motivation for learning (3.93), received the lowest rating among the three course items examined. This assignment requires a lot of reading which students seem to find tedious. Although, as we will see in the next section that the students think the term paper assignment contributes to their learning, they do not find it to be a strong motivator for learning due to the amount of work involved.

Finally, the term project assignment received the highest ratings in overall, and on a course basis on enhancing motivation for learning. This result is attributable to the assignment structure and content as the assignment is designed for usefulness and empowerment; factors that increase student motivation and learning. While the factory visit is fun and engaging, students are in the observer role. The term project assignment provides students a platform to apply what they learn in class and requires students to select a topic that has real-life applications (usefulness), and is open ended (allows empowerment). Figure 3 shows a summary of student feedback on ratings of items in relation to their relevance to the course material. As seen in the figure all course items received high ratings for relevance.

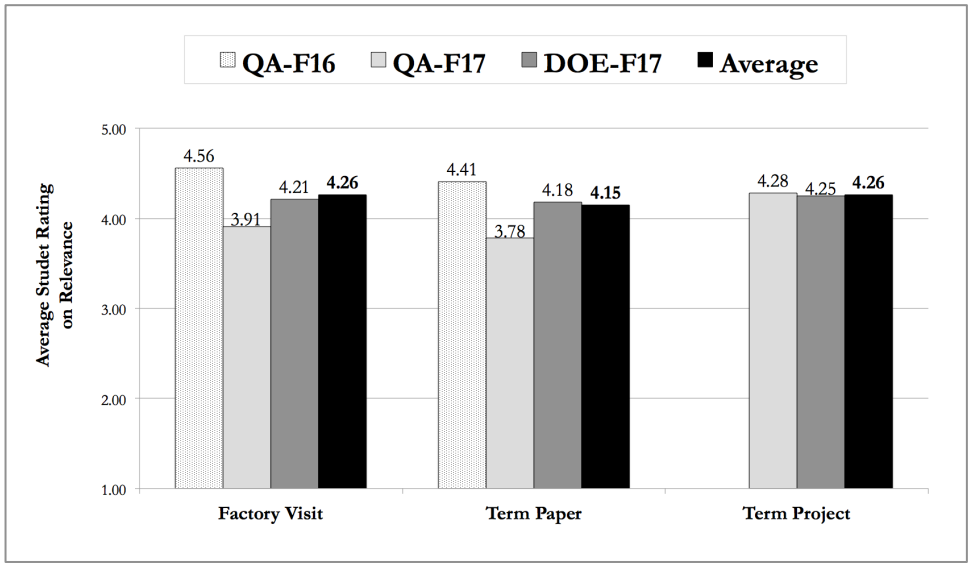

Figure 3 Average Student Rating of Items - Relevance of Course Material

Course Assignments/Activities & Their Contribution to Student Learning

Students were also asked to rate the term project, factory visit and term paper on their contribution of learning in the context of the course. Table 2 shows the average student ratings on contribution together with the student ratings on enhancing motivation that were discussed above. Overall, the students found that all three items increased their motivation of learning and contributed their learning.

Table 2 Average Student Ratings of Items - Enhancing Motivation vs. Contribution to Learning

Component ➔	**Factory Visit**		**Term Paper**		**Term Project**	
Course⬇	Enhanced Motivation	Contributed To Learning	Enhanced Motivation	Contributed To Learning	Enhanced Motivation	Contributed To Learning
QA-F16	4.56	4.50	4.00	4.32	4.77	4.32
QA-F17	3.91	4.17	3.61	3.72	4.22	4.17
DOE-F17	4.11	4.21	4.07	4.29	4.25	4.32
Average	***4.22***	***4.28***	***3.93***	***4.15***	***4.41***	***4.26***

The data indicates even though the term paper assignment was not ranked very high for impacting motivation, it is valued more in terms of contributing to learning. This assignment requires students to research applications of materials covered in the course, and write a report using two example case studies. While increased motivation for learning leads to increased student learning, the former is not a requirement for the latter, which is supported by the ratings on the term paper component.

The Impact of Scaffolding

The primary focus of this study was on examining different course items and their impact on motivation and learning, nevertheless, the data collected provided materials to perform a follow-up study on the pilot implementation of scaffolding done in fall 2016. The results from all three implementations individually and on average are shown in Figure 4. The purpose of scaffolding in this study was to help students acquire higher level of learning skills by giving them different types of assignments that lead to more complex assignment at each step. Figure 4 shows the connections between these different assignments, and the percentages shown on the connectors reveal the proportion of students in class that were able to use the findings and learning from the former assignment in the subsequent assignments. For example, 78.2% of students on average indicated that they started considering possible term project topics while working on the term paper assignment, and 76.1% indicated that they explored possible term paper topics based on what they learned during the factory tour. As seen from the data, scaffolding produced high ratings for almost all connections in all three courses and overall. The lower rating on the path from the "library training" to the "term project" assignment is not a concern as the main path of assignment sequence was library training, factory visit, term paper, and finally the term project.

Further Assessment and Discussions

In addition to student feedback survey, student performance in the form of course grades was compared to previous years' results to assess impact of scaffolding and improved learning. The columns with the DOE data in Table 3 show the course with scaffolding (fall 2017) and without

scaffolding (spring 2017) offerings. Similarly, QA-F17 and QA-F16 show with scaffolding and QA-F15 is without scaffolding offerings. To determine whether a statistically significant difference exist between these offerings a 2-sample t test was performed. All samples satisfied the normality assumption. Since all samples failed equal variance test the 2-sample t test with separate variance was run.

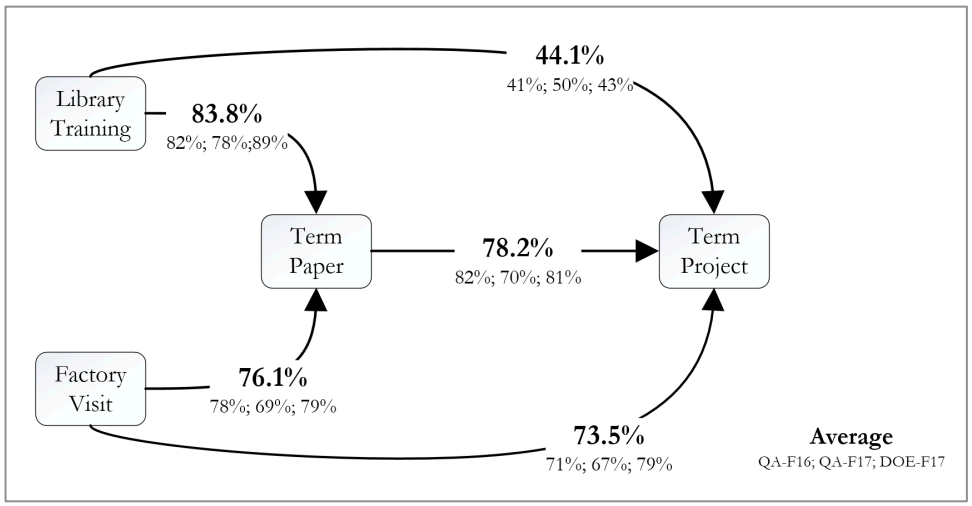

Figure 4 Students Rating of Items - Making Connections

Table 3 Pre and Post Student Performance Comparison

Item	DOE-F17 (S)	DOE-S17 (NS)	QA-F17 (S)	QA-F16 (S)	QA-F15 (NS)
Course Grade – Average (max. 100)	71.00	66.21	88.39	76.90	71.03
Course Grade – Median	69.94	62.79	88.92	79.39	71.10
Course Grade - Standard Deviation	9.37	19.00	8.59	12.86	22.03
Course Grade - Minimum	53.75	33.31	74.00	49.49	20.62
Sample Size (N)	28	30	18	22	22

The comparison between QA-F16 vs. QA-F15 showed no statistical difference between the average course grades (p-value=0.144), however, a statistically significant reduction in variance was detected (p-value=0.009). In the next offering of the QA course, a statistically significant difference in the average student grade and a slight reduction in variance (p-value=0.001 and p-value=0.048 respectively) were observed between fall 2017 and fall 2016 data suggesting that the refined scaffolding strategy along with the emphasis on factors influencing student motivation and learning have generated positive impacts on student learning.

The DOE course comparison generated results similar to those observed in the transition from the QA course with no scaffolding to QA with scaffolding. While there was no statistically significant difference in the average course grade (p-value=0.113), a statistically significant difference in variance was observed (p-value=0.0).
Furthermore, a significant improvement is observed in the lowest performing student outcomes in every subsequent offering of the courses indicating that the strategy employed is effective in

improving student motivation and increasing student learning in the courses studied. The increase in minimum score combined with the reduction in variance, furthermore, denotes that scaffolding strategy may produce greatest gains for weakest students.

Conclusion and Future Work

This paper presents the findings of a study that involved two major courses in the Industrial Engineering practice: Quality Analysis and Design of Experiments. A scaffolding strategy was employed in both courses along with an explicit emphasis on factors that effect student motivation and learning. The scaffolding structure included library training, factory visit, term paper and term project assignments. Furthermore, other type of coursework, homework, exams, in class exercises, etc. were also used to assist students with their learning and to assess the level of learning occurred in class. Both, the student feedback and the student performance in the form of overall course grade provided positive evidence on the effectiveness of the course items used in these courses. Providing students resources that will help them achieve better outcomes in their work, for example offering in-class library training prior to assigning them a literature review work, generates significant impacts on the quality of their work, and their learning. In efforts to design a course that considers all the factors discussed above, it is important to understand student background and expectations. The future work for this study includes a detailed analysis on the course items that were ranked high for impacting learning, but are not covered in depth in this study. These are homework, in-class exercises and in-class discussions.

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