AC 2010-2027: EVALUATING THE MOTIVATIONAL AND LEARNING POTENTIAL OF AN INSTRUCTIONAL PRACTICE FOR USE WITH FIRST YEAR ENGINEERING STUDENTS

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Evaluating the Motivational and Learning Potential of an Instructional Practice for use with First Year Engineering Students

Abstract

An experiment was conducted within a first-year engineering laboratory to provide empirical evidence to support the pedagogical viability of Disassemble/Analyze/Assemble (DAA) activities, such as Reverse Engineering and Product Dissection, in engineering education. The outcome of the laboratory indicated that the knowledge learned as a result of engaging in DAA activities can be transferred to design tasks. Following an activity that required students to take apart a one-time use camera and analyze its components to discover how it works, 43% of the students were able to describe an approach for modifying the camera that involved the adaptation of a current mechanism. In addition, the results of the post-laboratory survey indicate that the DAA activity elicited high levels of motivation.

Introduction

The insightful findings from Seymour and Hewitt[1] about the causes for discontentment among persisters and switchers in science, engineering and math (SEM) disciplines have provided a starting point for addressing issues related to persistence in engineering. Criticisms of pedagogical effectiveness, assessment, and curricular structure accounted for 36.1% of all switching decisions. Students strongly believed that faculty did not like to teach, did not value teaching as a professional activity, and valued their research above teaching. Some of the specific attributes of poor instruction, as identified by students in the Seymour and Hewitt study, were ill prepared and dull presentations, predominant use of one-way lectures, lack of discussion, assessments focused on rote memory, faculty reading directly from textbooks, and no indicated application or implication of material. There is an undeniable need to identify and implement pedagogical practices that motivate students as well as facilitate learning. This is particularly relevant in first-year courses where introductory material is taught and students are most likely to switch due to discontentment. This study responds to the aforementioned charge by experimentally investigating the pedagogical viability of Disassemble/Analyze/Assemble (DAA) activities such as Reverse Engineering and Product Dissection.

Disassemble/Analyze/Assemble (DAA) Activities

Ogot and Kremer[2] introduced the term "Disassemble/Analyze/Assemble (DAA) activities. Based on a prominent industry practice, these discovery based activities involve the systematic disassembly of an artifact, the subsequent analysis and possible reassembly of its components for the purpose of understanding the physical, technological and developmental principles of the artifact. DAA activities have been successfully utilized in engineering learning environments, and their value as pedagogical tools is primarily supported by reviews from professors and students[3, 4, 5, 6, 7, 8]. Enhanced understanding of engineering artifacts, exposure to the vocabulary of engineering systems, awareness of design processes, interest in learning about engineering in the future and improved ability to make connections between theoretical concepts and real-world hardware, are some of the learning outcomes attributed to DAA activities[8, 9, 3, 10, 6, 11, 4, 5, 2, 12, 7]. In addition, DAA activities are also accredited with adding a "hands-on" active learning component to many engineering courses. Many of the professors involved with the incorporation of DAA activities in engineering courses have linked the pedagogical success of these activities to their ability to capitalize on students' inquisitiveness, which in turn enhances learning. Professor Harry Hess from the College of New Jersey describes Reverse Engineering as "the instructor's fire keg that lights the imaginations of the engineering students"[5].

Assessing the Pedagogical Value of DAA Activities

The systematic analysis of the pedagogical benefits of DAA activities is a relatively recent phenomenon. The current DAA literature presents highly descriptive accounts of its use and affordances in engineering curriculum; claims primarily supported by instructor observations and course evaluations. Most of the research methods that have been employed thus far are not capable of providing the evidence needed to evaluate the unique allowances of DAA activities with respect to motivation or learning. An experimental approach is needed where students engaged in DAA activities can be compared to a control group engaged in other traditional activities. This experimental approach can provide answers to questions such as:

1. How do DAA activities affect motivation?
2. What types of knowledge can students gain from engaging in DAA activities?
3. How does the knowledge gained from engaging in DAA activities support subsequent performance on other engineering materials?

Part of the current need for this work stems from the trouble undergraduate institutions are having recruiting and retaining engineering majors[13]. Seymour & Hewitt[1] found that many students leave the discipline because of poor instruction. This suggests that new instructional practices are needed that motivate students in addition to giving them skills that will help them adapt to the ever-changing field. The ability to adapt one's prior knowledge to solve new problems is known as transfer. A major goal of formal education is to prepare students to transfer their knowledge since the context of learning usually differs from the context of application[14]. One approach to answering some of the aforementioned questions about the pedagogical value of DAA activities involves measuring the transfer of learning from DAA activities to new engineering activities and the motivation elicited from the DAA activities.

Study Overview

Morphological Analysis, a method for clarifying the requirements of an artifact's design, and then using the requirements to generate design ideas, was recently introduced into the curriculum of a first-year engineering course. One of the primary steps involved in Morphological Analysis is function identification / decomposition, and DAA activities have been identified as a useful tool for accomplishing this process[15, 16, 17]. With this new addition to the curriculum, an opportunity to have first-year engineering students engage in DAA activities was created, and a study was designed and conducted in an attempt to capture and measure the motivation elicited from the activity and the transfer of the learning that occurred.

The study was conducted as part of the laboratory activity affiliated with the Morphological Analysis topic. Following a lecture on Morphological Analysis and a related home-work assignment which provided students with three opportunities to practice the Morphological Analysis process with varying degrees of scaffolding, students participated in the Morphological Decomposition laboratory. A total of 290 students completed the lab. The students were distributed among 11 lab sections consisting of 28-32 students each. Based on the self-reported data collected in the post lab survey, the gender and ethnic distributions of students are illustrated in Figure 1

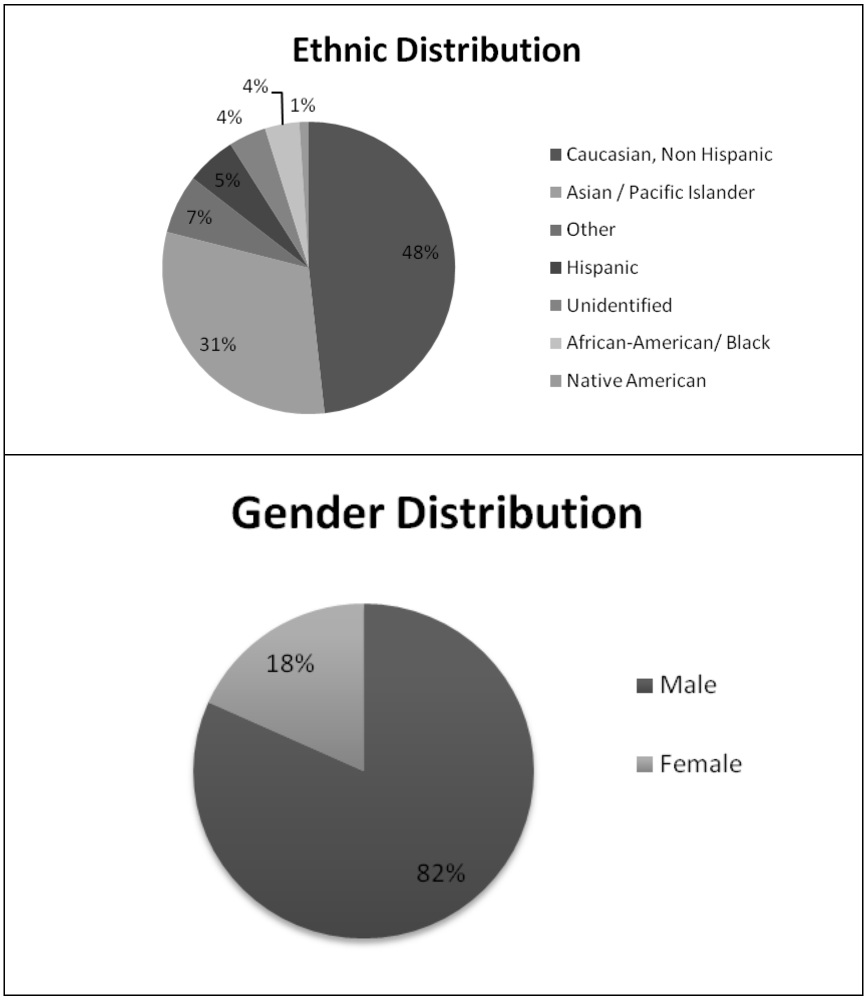

Figure 1 - Demographics of study participants

The lab was 110 minutes long and consisted of 5 tasks designed to help students develop tools for generating design concepts and a post-lab survey used to gather students' background data and their perceptions of the activity. Students worked on 3 tasks individually and 2 tasks in teams of mainly 4 students .The lab tasks were sequenced in two ways; 6 sections used the first sequence (S1) and 5 sections used the second sequence (S2) (View Table 1 - Study Design). The first task was the same in both sequences and it served as a pre-test. Students were asked to generate ideas for a new toothbrush device. This task was used to determine whether students use Morphological Analysis / Morphological Charts when generating design ideas. The second task was either the guided Morphological Analysis (GMA) task, as was the case in S2, or the Artifact Disassembly (DAA) task, as was the case in S1. The GMA task was designed to guide students through the Morphological Analysis process for a camera, particularly the development of a

Morphological Chart and using the chart to generate new design ideas for a camera. The DAA task was designed to provide students with an opportunity to disassemble a Fujifilm QuickSnap Outdoor1000 one-time use camera, and analyze the components to determine how it works. The third task was the same in both sequences and it served as a first post-test. Students were asked to map the functions of the Fujifilm QuickSnap Outdoor1000 one-time use camera to the components used to accomplish the function. This task was used to test whether students will be able to apply / adapt the knowledge gained from completing the previous task to help them identify essential sub-functions, and associate components to a particular functionality. The fourth task was either the GMA task, as was the case in S1, or the DAA task, as was the case in S2. The fifth task was the same in both sequences and it served as a second post-test. Students were asked to generate variant designs of the disassembled camera that at minimum will have variable shutter speeds. Following the completion of all 5 tasks, students completed a post lab survey. The post lab survey required students to respond to questions about their background and perception of both instructional tasks. Using seven-point likert scales, as shown in Table 2, students were asked to rate both the DAA and GMA tasks on: 1) perceived sense of learning, 2.) enjoyment derived from engaging in the activity, and 3.) helpfulness in preparing them to respond to the variant design question given in task 5. The three aforementioned elements were used to measure the motivation elicited from each instructional task. Individual student responses to the pre-test and post-test tasks and post-lab survey, as well as team responses to the GMA and DAA tasks were the main sources of data for the study.

Table 1- Study Design

Duration of Task (min)	**Task #**	**Situation 1 (S1)**	**Situation 2 (S2)**	**Task type**
10	1	Pre-test	Pre-test	Individual
30	2	Artifact Disassembly (DAA)	Guided Morphological Analysis (GMA)	Team
10	3	Post-test 1 (P1)	Post-test 1 (P1)	Individual
30	4	Guided Morphological Analysis (GMA)	Artifact Disassembly (DAA)	Team
15	5	Post-test 2 (P2)	Post-test 2 (P2)	Individual
05	Post-Lab Survey			Individual

Table 2- Motivation Measures

Sense of Learning from Task:		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Nothing						A Lot
Enjoyment of Task:		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Strongly Disliked						Strongly Liked
Perception of Task Helpfulness:		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Not Helpful						Very Helpful

Results

Motivation

The disassembly task was expected to be more motivating than the morphological analysis task because it involved disassembly rather than simply following a set of step-by-step instructions. This expectation was met on all three measures of motivation as shown in Figure 2 : a) task-enjoyment, $t(283) = 9.627$, $p < .001$; b) sense of learning, $t(283) = 4.109$, $p < .001$; and c) perception of its helpfulness, $t(284) = 4.377$, $p < .001$.

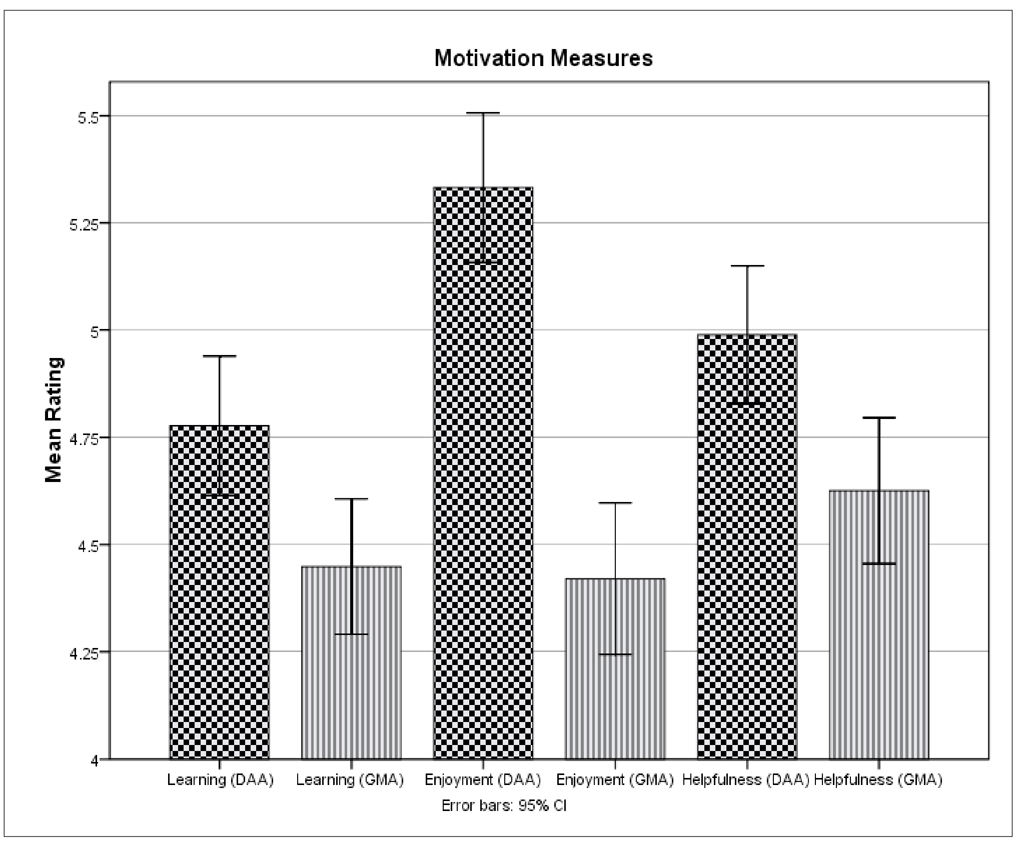

Figure 2 - Comparing the Motivation Measures for GMA and DAA activities

Results from the motivation measures were further supported by the unprompted additional comments students' provided on the post lab survey. Of the seventy-one students that provided additional comments, seventy-six percent referred to satisfaction, enjoyment or learning derived from engaging in the lab tasks. A representation of these comments is shown in Table 3

Table 3 - Sample Student Comments from Post lab Survey

Student Comments
"This lab was interesting and taught how important disassembling is to understanding and gaining knowledge as to how something works."
"My favorite part of this lab was the disassembling the camera and I think that I learned the most in this part of the lab."
"This was my favorite 126 lab."
"More destruction in the future"
"I thought this was the most interesting and intellectually stimulating lab yet. I am glad I came."
"It was quite fun to take the camera apart. I feel I learned more of how it works by doing so."
"This was a great learning experience"
"I liked hands on experience a lot. Learned a lot from it."
"I liked the variant design a lot. Also disassembly was cool because sometimes it is hard to apply what we learn in class to the real world"

Learning

As expected, no differences between conditions were found at pretest on students' use of Morphological Charts for generating and documenting design ideas, χ^2 (1, N = 286) = .433, p = .511. Despite encountering the material in lecture and for homework, less than 10% of the students spontaneously used a Morphological Chart on the design task (Frequencies: 7 of 156 for DAA First (*DAA First refers to situation 1 (S1) where the DAA task precedes the GMA task*) and 8 out of 129 for GMA First (*GMA First refers to situation 2 (S2) where the GMA task precedes the DAA task*).

For the 2nd lab task, participants in DAA First disassembled a camera to identify how it worked while those in GMA First constructed morphological charts with the help of computer prompts. It was expected that these activities would produce different types of knowledge; specificity of components for students that disassembled the camera and broad design possibilities for students that created Morphological Charts. The first posttest (task 3), where participants were to map camera functions to the components that could accomplish them, was meant to test this hypothesis. Using a random sample of 44 participants (4 from each lab section) for coding, DAA First generated significantly more camera components that were part of the Fujifilm QuickSnap Outdoor 1000 camera (Mean ± SD = 5.96 ± 1.71) than GMA First (3.10 ± 1.86), $t(42) = 5.31$, $p < .001$. As expected, the results were reversed for components that were not part of the disassembled camera (Means = .04 ± .204 and 1.90 ± 1.21 for DAA First and GMA First respectively), t (19.9) $_{\text{equal variances not assumed}}$ = -6.79, $p < .001$. This result may be due to participants in GMA First transferring in the use of Morphological Charts, which they used significantly more than participants in DAA First, χ^2 (1, N = 290) = 24.920, $p < .001$.

After participants switched to the other task (e.g., from DAA to GMA), a second posttest was given to see to what degree participants could adapt what they had learned to solve a novel problem. The novel problem asked participants to design a one-time-use camera with variable shutter speeds. To successfully solve this problem, participants had to have learned that a spring controlled the shutter of the camera they had disassembled earlier in the lab. To adapt this mechanism to make a shutter of variable speeds, they would need to be able to adjust the tension of the spring. Some participants suggested doing this by switchable springs of various tensions while others recommended adding a dial to tighten or loosen the spring like on a watch. Regardless of condition, participants showed relatively high rates of spontaneous adaptive transfer on this problem with 46.2% (73 of 158) adapting the spring mechanism for DAA First and 40.8% (53 of 130) doing so for GMA First. Comparing the overall rate of spontaneous adaptive transfer on this problem to the spontaneous use of Morphological Charts on the pretest (5.89%) the redesign task in the final posttest (4.2%), or even the first posttest (30%), significantly more students transferred this knowledge than their knowledge of Morphological Charts. This comparison is illustrated in Figure 3. Wilcoxon Signed-Ranks test Z = -10.21, $p <$ .001.

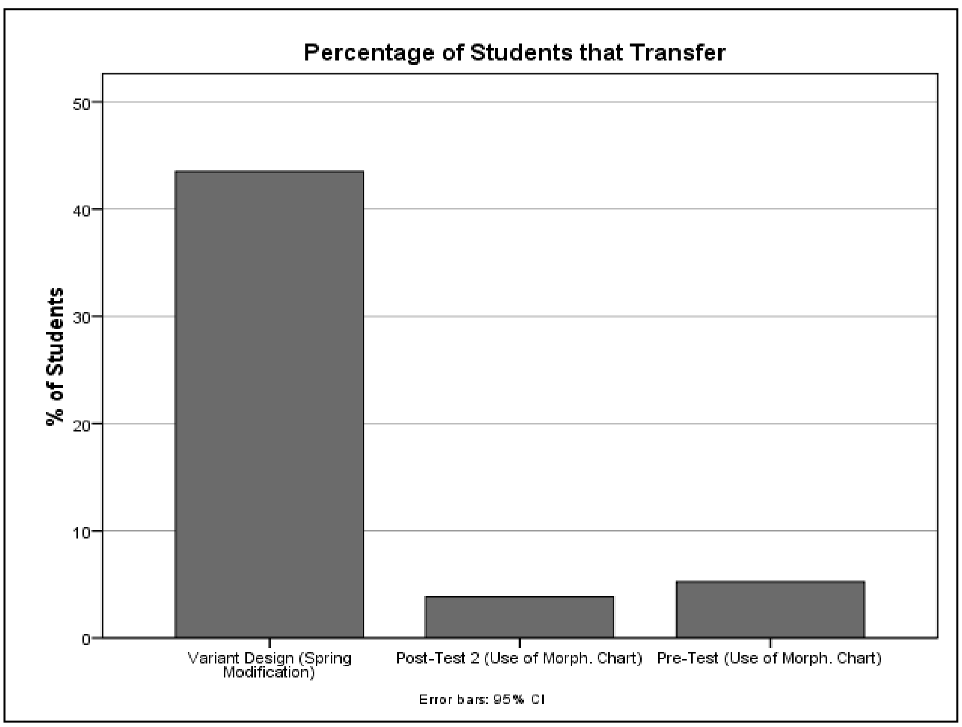

Figure 3 - Comparing the overall rate of spontaneous adaptive transfer

Discussion

The study was designed to compare a Disassemble/Analyze/Assemble (DAA) activity and a Guided Morphological Analysis (GMA) activity on measures of motivation and transfer. It was hypothesized that more students would demonstrate the transfer of knowledge from the DAA activity than the GMA activity and higher levels of motivation would be elicited from the DAA activity. The GMA task was used to guide students through the morphological analysis process, a standard part of engineering curricula that involves decomposing a design into sub-functions, and mapping the sub-functions to their potential means and or components (for accomplishing those sub-functions) in a table (morphological chart). The populated morphological chart then served as a tool for generating and capturing multiple design possibilities. In this study, GMA was used as the control or comparison activity. The DAA activity was also used to facilitate design decisions. It involved physically deconstructing and analyzing the components of an object to gain insight into how the object works, and then applying this knowledge to generate new design possibilities. The DAA and GMA activities in this study both involved cameras.

Compared to the GMA activity, participants rated the DAA activity significantly higher on all three measures of motivation—enjoyment, sense of learning, and task helpfulness—regardless of the order in which they experienced the activities. The open-ended comments of some students suggests that the inclusion of the DAA activity made the lab one of the best engineering experiences in the course. To avoid the concern that the GMA activity was merely a "straw man," it is worth noting that participants' ratings of motivation for this activity were all positive, on average (4.4, 4.5, and 4.6 on a 7 point scale for enjoyment, learning, and helpfulness, respectively). These findings support the views of others involved with the incorporation of DAA activities in engineering curriculum[11, 4, 5, 10, 12, 2, 6, 8, 7]. This study adds to the previous work by providing two important components. First, the measure of motivation specifically targeted the DAA experience as opposed to a global measure of course satisfaction (for a course that includes a DAA component). Second, the comparison to a control activity that involved more traditional instruction allows examination of the relative benefits of DAA compared to more traditional treatment and helps block the possibility of extra student motivation being due to instructor or Hawthorne effects.

It is important that instruction is not only motivating but also promotes learning. An encouraging finding regarding learning was the degree to which students showed high frequencies of transfer of knowledge from the DAA activity. Forty-three percent of them correctly indicated that they would need to adapt the spring system in the single-use camera to add the new function of variable shutter speed. This frequency of transfer was significantly higher than that observed for the morphological chart. Only 4.2% of participants transferred the use of the morphological chart on the final posttest despite working with morphological charts in the lab and learning about them in lecture and homework in the prior week. This finding raises an interesting possibility for future work. The DAA activity was associated with more specific knowledge of the components of a one-time use camera whereas the GMA activity was associated with more general knowledge, as revealed by the first posttest. Students in the DAA First group who recalled the spring mechanism on the first posttest were much more likely to successfully adapt that mechanism for the final posttest than those who did not. This raises the possibility that learning general engineering design principles and becoming a better design engineer may require the specific knowledge of component and mechanism that DAA experiences seem well-suited to offer. Future work will investigate this possibility and focus on what features of DAA activity are most critical to motivation and transfer of learning.

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