AC 2008-590: USING CYBER-INFRASTRUCTURE ENHANCED PRODUCT DISSECTION TO INTRODUCE ENGINEERING TO MIDDLE SCHOOL STUDENTS

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Abstract

This study examines the influence of engineering dissection activities on middle school students' interest in science and engineering careers. Attracting students to engineering is a matter of growing concern considering that engineering related jobs are currently being created at five times the national average¹. This trend coupled with relatively low college admissions rates into engineering programs points toward the need to develop greater student interest in engineering and engineering related fields at much younger ages. Studies suggest that students introduced to the potential and promise of science and engineering during middle school have a much greater inclination to pursue science related careers in later years^{2,3}. In the study presented here, an inquiry based, interactive "WebQuest" was developed for 6th grades students which focused on product dissection, with a goal of helping students develop an interest in Engineering, Archaeology, History, and Anthropology. Product dissection has long been recognized as a powerful teaching tool that utilizes disassembly, analysis and assembly of an artifact or process in order to reach desired educational objectives and outcomes. Most recently these outcomes have been placed within a framework for engineering dissection activities which high lights the ability of dissection to (1) expose students to engineering concepts and vocabulary; (2) inspire students through engagement in a self-discovery learning environment; (3) foster inquiry into engineering principles and theory; and (4) encourage exploration of generation, redesign, and design processes⁴. Changes in student interest in engineering as a result of participating in the "WebQuest" were measured through a pre/post design which utilized the Science and Engineering (S/E) Career Interest Survey (CIS); a validated engineering career interest survey designed for middle school students⁵. Findings indicate that through participation in the "WebQuest" students became more interested in possible careers in engineering. This project was undertaken as part of an NSF Cyber Infrastructure Teams grant to explore new techniques for enhancing engineering education through cyber-supported product dissection that includes nine universities and 34 faculty members.

Section 1: Introduction

Product dissection has been used in a variety of ways to successfully engage engineering students in their learning. Intellectual and physical activities such as dissection help to anchor knowledge and practice of engineering in the minds of students^{6,7} and has been successfully used to help students identify relationships between engineering fundamentals and hardware design^{8,9}. Product dissection provides "hands-on" activities to couple engineering principles with significant visual feedback^{10,11,12}, and such "learning by doing" activities encourage the development of curiosity, proficiency and manual dexterity, three desirable traits of an engineer¹³. Dissection also gives students early exposure to functional products and processes, and introducing such experiences early in the students' academic careers has been shown to increase motivation and retention¹⁴.

While many benefits to product dissection have been identified, there exist several challenges: (1) start-up and maintenance costs, (2) space for disassembly and storage, (3) preparation of educational materials and activities, and (4) access to more complex products such as copiers, refrigerators or automobiles. In response a partnership of nine universities with 32 faculty has assembled to establish a National Engineering Dissection Cyber-Collaboratory that builds on the CIBER-U project¹⁵ and is supported by the National Science Foundation's CI-TEAM program. The goals of this CI-Team implementation project include:

1. Deploying a cyber-collaboratory to support physical and virtual dissection of engineered products and systems;
2. Creating and disseminating educational materials nationally, including development and implementation of collaborative design exercises across the participating universities;
3. Assessing the educational impact and CI competency of the 12,000 participating engineering and CS/IST students including user adoption of the cyber-collaboratory; and
4. Engaging under-represented groups and K-12 to promote a diverse CI-savvy workforce.

While product dissection exercises have demonstrated success at the undergraduate engineering education level, the question arises about the potential for K-12 education. Attracting students to engineering is a matter of growing concern considering that engineering related jobs are currently being created at five times the national average¹. This trend coupled with relatively low college admissions rates into engineering programs points toward the need to develop greater student interest in engineering and engineering related fields at much younger ages. Studies suggest that students introduced to the potential and promise of science and engineering during middle school have a much greater inclination to pursue science related careers in later years^{2,3}.

Super¹⁶ has identified that career interests are learned characteristics. Research suggests that different sources of information may influence a students' choice to pursue science^{17,18}. Koszalka³, found that higher levels of science career interest resulted from information richness of high sociableness and high webnicity. High sociableness occurs when people are actively and socially involved in sharing information with others in the learning environment. Webnicity is a measure of a resource's interconnectedness of information to other supporting information³. This work strongly suggests that there is a benefit to educational activities that combine sociable activity with information exploration from internet resources. A carefully crafted learning module combining engaging interactivity of product dissection with internet search of materials like that of the product dissection cyber-collaboratory can prove beneficial in developing students' awareness and interest in engineering careers.

A WebQuest is an inquiry-oriented online tool for learning. This means it is a classroom-based lesson in which most or all of the information that students explore and evaluate comes from the World Wide Web. The WebQuest concept was developed by Bernie Dodge in 1995, with input from Tom March, during a class in which he was teaching pre-service teachers. WebQuests are tools, not educational theories, so they can be used in virtually any classroom with appropriate computer access²⁰. It is important to note that WebQuests are not the best way to teach factual recall, simple procedures, or definitions²⁰. A WebQuest allows students to work in groups and solve a problem as a team while gathering most or all of their information from the Internet. WebQuests are designed to use learners' time well, to focus on using information rather than on

looking for it, and to support learners' thinking at the levels of analysis, synthesis, and evaluation.

Probably the most important thing to remember when creating or using a WebQuest is to ensure that it fits into the curriculum being taught. Don't let the technology tail wag the curricular dog²¹.

In order to engage students in higher level cognition, WebQuests use scaffolding or prompting which has been shown to facilitate more advanced thinking²². In other words, when you break a task into chunks and students perform specific sub-tasks, the students use the WebQuest to step through a thinking process that a more expert learner would use. By doing part of the work for the students, we allow them to go beyond what they would be able to do alone. Over time, we hope, they internalize the structures we provide until they can work autonomously²³. A WebQuest provides all the information needed which in turn eliminates wasted time spent searching for answers and more time is spent synthesizing and working collaboratively.

Good WebQuests embody the critical attributes of a successful cooperative learning environment and include the following²⁴:

- *Positive interdependence*: Learners perceive that they cannot succeed without each other.
- *Promotive interaction*: (preferably face-to-face): Students help teach and applaud each other as they wrestle with authentic work.
- *Individual and group accountability*: The group is held accountable for completing the task, and each individual is held accountable for his or her part in the process.
- *Interpersonal and small group skills*: Most children (and many adults) need to be taught how to work together.
- *Group processing*: Conversation about how to improve the group's effectiveness is deliberately built into the process.

WebQuests use a central question that honestly needs answering. When students are asked to understand, hypothesize, or problem-solve an issue that confronts the real world, they face an authentic task²². A WebQuest involves having the students read different Web pages or having them read the same Web pages from differing perspectives which promotes positive interdependence. If the 21st century goal is to prepare students for a real world collaborative work environment that includes the use of various assisting technologies then a WebQuest is a tool that can be used to achieve that goal.

A WebQuest embraces the constructivist's approach to teaching by allowing the teacher to serve as a coach while working with individuals or small groups. If the teacher has created a well thought out WebQuest or chosen one planned by someone else, they will experience first hand a real life learning experience. Cooperative learning strategies are then applied to necessitate each student's input. By running several WebQuest groups in the same class, students will also see that different solutions were chosen by each team because of the quality of the group members' research and argumentation skills. As students complete more WebQuests they will become increasingly aware that their individual work has a direct impact of the intelligence of their group's final product²².

While middle school students are exposed to various fields of science, the relationship to engineering is not as prevalent. It is important then to place engineering in the context of fields and careers that students can more readily grasp from other educational anchors. In middle school, students have taken or are taking courses in math, science, social studies and history. There can be a tremendous benefit by integrating engineering in context with relation to these fields.

The following section of this paper (Section 2) describes the creation and use of an educational WebQuest for middle school students that utilizes product dissection activities and internet exploration of the engineering dissection cyber-collaboratory to enhance students' awareness and competency in engineering. "Digging up the Past and Putting it Back Together" is the title of the WebQuest and a detailed description is provided along with educational objectives and outcomes. Section 3 describes the methodology for studying the influence of the WebQuest on students' interest in science and engineering careers including a description of the participants, procedure and measures. Section 4 presents the results which are followed by implications, conclusions and suggestions for future work.

Section 2: WebQuest – Digging up the Past and Putting It Back Together

"Digging Up the Past and Putting It Back Together"

(www.dragon.k12.pa.us/facstaff/MS/west_t/www/dig.htm) is an interdisciplinary unit that addresses Science and Technology, Geography, History, and Career Education and Work standards. By completing this WebQuest the middle school students will:

- develop an interest in Engineering, History, Archaeology, and Anthropology
- learn to work with a team to achieve their goals
- understand that decision making is better served through various perspectives
- appreciate their local community and state

One of the goals of this WebQuest was to have the students develop their critical thinking skills while working in groups of four. They did this by formulating their own ideas, synthesizing the information, and debating with teammates. Below is a list of relevant Pennsylvania state standards addressed in this WebQuest.

Science and Technology Standards

3.8.7.C	Identify the pros and cons of applying technological and scientific solutions to address problems and the effect upon society.

Geography Standards

7.1.6.A	Describe geographic tools and their uses.
7.1.6.B	Describe and locate places and regions.

History Standards

8.1.6.A	Understand chronological thinking and distinguish between past, present and future time.
8.2.6.A	Identify and explain the political and cultural contributions of individuals

- and groups to Pennsylvania history from Beginnings to 1824.
- 8.2.6.B Identify and explain primary documents, material artifacts and historic sites important in Pennsylvania history from Beginnings to 1824.
- 8.3.6.B Identify and explain primary documents, material artifacts and historic sites important in United States history from Beginnings to 1824.
- 8.3.6.C Explain how continuity and change has influenced United States history from Beginnings to 1824.
- 8.4.6.A Identify and explain how individuals and groups made significant political and cultural contributions to world history.
- 8.4.6.B Identify and explain important documents, material artifacts and historic sites in world history.

Career Education and Work Standards

- 13.1.8.G Create an individualized career plan including, such as, but not limited to career goals and individual interests and abilities.
- 13.3.8.B Analyze the role of each participant's contribution in a team setting.

An excellent WebQuest needs a creative introduction to set the stage for the student's learning (see Figure 1 below). The setting for this project is the year 3008 and ancient artifacts have been discovered beneath an old robot engineering factory. The students must assume the role of one of the following four professions: Mechanical Engineer, Archaeologist, Historian, or Anthropologist. Their quest is to dig up the artifacts, determine what they are, dissect them, and compare and contrast their artifacts to similar artifacts found in an online repository. The students will present their findings along with both state and local history and culture, as well as the differences and similarities between all four professions.

Figure 1

The first stage of the WebQuest is for the students to select their roles and begin the process of becoming an expert in their chosen fields. The students are given guided worksheets and a group of websites to assist in the acquisition of background knowledge. The Mechanical Engineering websites included videos, activities, and a site that allowed the students to ask an engineer a question. Figure 2 shows the students using the provided websites and worksheet. This is an

extremely important stage of the WebQuest as this serves as the basis for the presentation which follows and gives the students a feeling of self-worth when talking in their groups regarding their profession. For example, when it is time to start the dissection process, the Mechanical Engineer in each group leads not only the dissection but also the related conversation. After the students have gained the information needed to become so called experts it is time to move to the group process.

Figure 2

The first part of the group process is to use a GPS unit and unearth each team's artifact. After hiding each team's artifact the instructor marks a waypoint which the students will use to help discover their artifact. Figure 3 shows a team using the GPS. Figure 4 shows the students digging for their treasure. Figure 5 shows the discovery of a stapler.

Figure 3

Figure 4

Figure 5

The next phase is an engineers dream, the dissection of the stapler artifact. Each group is given a laptop, small screwdriver, guided worksheet, digital camera, ruler, and their stapler. The process starts with the students accessing a video, from the online repository, that demonstrates how to take the stapler apart as Figure 6 demonstrates. After the video, (http://www.dragon.k12.pa.us/facstaff/MS/west_t/www/TotA1.m4v), the Mechanical Engineer starts the dissection, as seen in Figure 7, while the others take notes and pictures. The students label, sketch, and measure each piece of the stapler. After the students have finished their notes, they watch the video to assist them in putting back together the staplers. The students take turns doing all aspects of the dissection but the Mechanical Engineer is the lead.

Figure 6

Figure 7

In this step the students compare and contrast their stapler to another stapler using a laptop, guided worksheet, and both staplers. Again the students access the repository and watch a video of stapler #2 being dissected (http://www.dragon.k12.pa.us/facstaff/MS/west_t/www/PaperProA1.m4v). Here is where the real critical thinking happens and the students help each other as they work collaboratively to achieve their goal as in Figure 8. Some groups test the staplers to see how many sheets they can staple and how hard it was to staple them. At this point even though each member of the team is an expert in their respective fields, engineering becomes their minor as they continue on their quest. Keep in mind that it is the year 3008 and people do not use staplers anymore nor do they know what they were used for. The students answer anthropological questions like: Who used them? What are they used for? Where were they used? Discussions start to include: How can it be better? What features might be helpful? This part of the WebQuest is the real life learning that students need to be successful in the 21st century as well as interest them in a career choice of engineering.

Figure 8

The final phase of the WebQuest has the students preparing for the presentations. This is where the students present:

- background information about the history of the local community
- cultural background of the state
- artifact comparison and contrast
- similarities and differences between Mechanical Engineers, Archaeologists, Historians, and Anthropologists

The unit ends with a visit from a mechanical engineering professor from a local university who

discusses the engineering careers and places engineering in context with archeology, anthropology and history. The WebQuest includes a teacher section that provides a script for the lesson for other teachers to use in their classrooms.

Section 3: Methodology

Participants

Children from six sections of a sixth grade combined social studies/technology class participated in this study. There were 18 to 25 students in each section of the class and 116 students participated overall. The demographics of the children in this sample reflect the demographics of the middle school which they attend which is mostly white and middle class. The school and community are located within a largely rural setting in the Northeastern United States with approximately 400 students attending the middle school.

Within the sample there were 63 girls and 53 boys and the average chronological age of the group was 11-12 years. Ten children were receiving special education services, and 3 children were learning English as a Second Language. Table 1 presents the sample characteristics for the children participating in the study.

Table 1 Participant Characteristics

Gender	63 girls, 53 boys
Chronological Age	11-12 years
Children with Disabilities	10
English Language Learners	3

Procedure and Measures

The study collected data on students' interest in science and engineering careers using a one group pretest/posttest repeated-measures design with an educational intervention. Before the intervention began, the researchers collected informed consent letters from the parents of the students and also collected letters of assent from the students themselves.

The study is designed to check on changes in students' interest in science and engineering careers at the mid point of the project (after students have completed the WebQuest) and again at the completion of the entire project (after the students have developed and presented their findings). The overall goal of the study was to determine whether or not participation in the activities described above would increase student interest in science and engineering careers.

Pretesting: Before students started working on the WebQuest, they were given the science and engineering (S/E) career interest survey (CIS)⁵. This test was used to measure baseline interest in science and engineering careers. This instrument consists of 56 questions and was developed to measure the overall science and engineering interest of middle school students. There are four sections within the CIS. In Part I students select preferred occupational activities from a set of constrained choices. In Part II they are asked to select from various occupations. Part III and Part IV provide an internal validation scale⁵. The test-retest reliability coefficients for the CIS for one week and eight months are .96 (n=57) and .78 (n=1937)⁵. The KR-21 estimate which measures internal consistency reliability was calculated as .92. With respect to validity, in previous testing the CIS was shown to correlate (.75) with the scientific subscale of the Kuder General Interest Survey (Kuder GIS) and additional content validity was established by a thorough review of a group of professional educators, engineers, and scientists⁵. The CIS was administered through a web-based format which took students approximately 20 minutes to complete.

Intervention: The intervention in this study was the WebQuest described above. Students worked with the GPS units, staple dissection, and other activities as described above over a three week period which marked the mid-point of the project. Students then prepared presentations describing what they had learned from the Webquest and delivered them to their class.

Mid-point-testing: At the mid-point of the WebQuest, but before developing their final presentations, all participants again completed the CIS.

Post-testing: After students made their concluding presentations and an engineering professor from a local university made a presentation to their classes focusing on the WebQuest and links between engineering and the careers which they had examined, the CIS was administered for a final time.

The primary null hypothesis in this study assumed there would be no important or statistically reliable difference between mid-point and final scores on the CIS and pretest scores. The Statistical difference was judged using a paired-samples *t* test and statistical reliability was set at .05.

During the studies development the researchers considered several challenges to the validity of this repeated measures design such as possible maturation effects, intervening events, and regression toward the mean. With respect to the first two issues the relatively short time frame for the intervention tempered concerns related to maturation or disruption. The lack of comparison group also raised concerns with the researchers; however, this design was ultimately selected over other possibilities because of human subject issues (such as the inappropriateness limiting any student's access to the required social studies curriculum) and ease of data collection. Other challenges to validity are discussed in the results sections below.

Section 4: Results and Implications

Mid-Point Results

As described above, a paired sample t test was conducted at the mid-point of the project to evaluate whether or not participation in the WebQuest increased students' interest in science and engineering related careers. There were 73 complete sets of paired data that were used in the analysis (missing data disqualified a number of surveys). The results indicated that the mean CIS score after participation in the WebQuest ($M=21.8$, $SD = 7.9$) was higher than the mean CIS score prior to engaging in the dissection related WebQuest ($M=20.0$, $SD = 8.6$) but the difference was not statistically significant, $t(72) = -.124$, $p = .22$. The mean difference was 1.8 points between the two administrations of the CIS, and as shown in Figure 9 below, there was considerable overlap in the distributions for pre and post scores.

Figure 9

While not statistically significant, the upward change of 1.8 points on the CIS from pretest to the mid-point of the project, may indicate that students are beginning to show increased interest in science and engineering careers.

End-Point Results

A final administration of the CIS at the conclusion of the project showed even greater changes with respect to interest in science and engineering careers. This analysis focused on the differences between student scores on the final administration of the CIS and the initial administration (pretest). There were 74 complete sets of paired data that were used in this final analysis. These results were quite different from those reported above. The mean CIS score after participation in the WebQuest ($M=22.3$, $SD = 9.7$) was higher than the mean CIS score at the mid-point. In fact the overall difference between the initial and final scores on the CIS is statistically significant, $t(73) = -.257$, $p = .012$. The mean difference was 2.3 points between the first and final administrations of the CIS. A significant finding means that the change in interest on the CIS is not likely due to chance and allows us to infer that the increase in scores was caused by Web-Quest intervention. However, with a large enough sample, even small differences can result in significant results. For this reason we also calculate the effect size (in this case Cohen's d), which is a measure of the magnitude of the intervention's effect. In this

case the effect size was .25 which indicates the average student's interest in engineering and science careers after the Web-Quest is equivalent to the interest of students at the 60% percentile prior to the intervention. Figure 10 below shows the movement of CIS scores to larger values between the pre-test and the final administration of the CIS. The percent of non-overlap in the two distributions is 18%.

Figure 10

Given these significant differences and the moderate effect size, the researchers became curious about the potential influence of gender on the results. In order to determine the influence of gender, separate paired sample *t* tests were run for boys and girls. This additional analysis, which focused on pre-test and final CSI scores only, shows that the WebQuest may have been more effective in increasing boys' interest in science and engineering careers than girls. Results for the 30 complete sets of paired data for boys indicated that the final mean CIS score ($\bar{M}=27.7$, $\bar{SD} = 9.0$) was much higher than their initial score ($\bar{M}=24.8$, $\bar{SD} = 7.9$). This is a statistically significant difference $t(29) = -3.58$, $p = .001$ with an effect size of .34. For girls (44 sets of paired data), the situation was much different with lower scores both at the beginning ($\bar{M}=18.52$, $\bar{SD} = 8.0$) and at the end of the WebQuest ($\bar{M}=18.63$, $\bar{SD} = 8.3$). This difference in the girls scores was not statistically significant. Thus, the significant finding for the full group (boys and girls together) reported above, is largely attributable to robust increases in boys interest in science and engineering careers and relatively stable and lower interest for the girls. Table 11 below reports mean pre-test and final CIS scores for boys and girls.

Figure 11

Despite the greater positive influence of the WebQuest on boys, all of the students made comments about the activity which were positive and indicative of improved dispositions toward science and engineering careers. This conclusion is bolstered from the qualitative responses of students to two open ended questions focused on potential changes in their career interests that have come as a result of participating in the WebQuest. The following examples are representative of the kinds of comments students made after finishing the WebQuest, but prior to the final presentations and help to illustrate the impact of the project on students' career aspirations. The spelling has been corrected for ease of interpretation:

- Mechanical engineering may be something to look into.
- WebQuest has influenced my thinking towards a career of an engineer by letting me understand what a mechanical engineer does.
- Yes, the WebQuest has influenced my idea of a future career, in that I could be a mechanical engineer that takes things apart and puts them together in a better way.
- I like how the mechanical engineer takes stuff apart and makes it better.
- Engineering is really fun and might be right for me. Engineering was fun and I wanted to be one because I like taking apart things and putting them back together
- It helped me because now I know how to be mechanical engineer.
- It made me think I might like a job like a historian or a mechanical engineer.
- The WebQuest has influenced me by showing me what mechanical engineers do.
- It helped me learn things that I didn't know about and a certain thing or two that might be interesting when I grow up and I am in college.
- I like this WebQuest because it has helped me decide what I want to be.
- It opened more things that I liked like in different science jobs so it makes me think about what I want to do more.
- The WebQuest has influenced my thinking for possible future careers because it made me act like the job...and it also made me think about the job more than I would have if I hadn't done the WebQuest.
- In the section where we picked which job we might be interested in the future, I picked a scientist.
- It helped me think about what I want to be when I am done with my school.

These kinds of comments illustrate the high level of student engagement in the WebQuest activity and its usefulness in raising awareness of possible careers in science and engineering fields. Many students like the idea of being able to make a product better, and several others mentioned their new interest in engineering as a possible career. More broadly, these comments also illustrates the effectiveness of these types of activities in helping students develop a better sense of their overall career aspirations.

Explanations for the relatively small change in CIS scores at the mid-point , in light of the student comments listed above include the possibility that the instrument itself may not be sensitive enough to pick up small but important changes in student career interests in the short term. The significant positive change in attitude toward science and engineering careers observed at the end of experience, support that contention that inquiry based science activities, such as the WebQuest designed for this project, are cumulative and that prolonged exposure to such activities are necessary to see large scale changes in attitude. Differences in the influence of the WebQuest activity on boys and girls raises additional questions about why this difference may exist and the kinds of educational experiences necessary to stimulate increased interest in science and engineering related careers. Again, one possible explanation is that girls may need even greater and more prolonged exposure than boys to these types of activities in order for them to have an impact.

It is also clear that the CIS itself needs to be updated. Developed in the early 1980s, many of the job descriptors included in items on the CIS are out of date and led to some confusion on the part of the 6th graders as they completed the surveys. Updating the CIS and reconfirming its reliability and validity should be a priority for future studies in this area.

Conclusions

This paper presented a student-centered, cooperative learning activity for middle school students, a WebQuest, that places engineering in context with other fields such as archaeology, anthropology and history. Through role-playing, students engaged in multiple activities including product dissection and reverse engineering as they examined technology and its influence on cultures. Students were directed to utilize the cyberinfrastructure to seek out information that supported their activities and constructed relationships between technology and these fields. Qualitative results based on students' comments and observations of the instructor suggest that this activity has helped the students better understand these fields as possible career options. Statistical analysis of survey data from the midpoint of the did not indicate a strong change in students' career choices, however, at the end of the experience there was a significant increase in students interest in science and engineering careers. This increase was particularly true for boys, whereas girls, interest remained lower and relatively stable over the course of the WebQuest.

Overall, the data suggests that activities such as this WebQuest have the potential to increase middle school student interest in science and engineering careers, but when used in isolation may only have a limited impact on deeply held beliefs about issues such as future career choice, especially for girls. Embedding more activities like these into the middle school curriculum could have a greater influence on students' career interests. Opportunities for future work

abound to study the cumulative effect of repeated exposure to different fields placing science and engineering in context. One thing is for certain; the students certainly enjoyed participating and learned a lot about the material satisfying the state standards.

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