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Improvement of Workshop Component of Camp Reach

An Interactive Qualifying Project Report

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by

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Abstract

This project addresses female under-representation in engineering fields. This detriment means that, as the number of jobs in the engineering industries grows, women will not have an equal presence in these fields. Equal female presence in engineering would allow for more diverse engineering practices, increased economic security for women, and reduced need for social welfare. Studies have revealed several reasons for the apparent lack of women in engineering pertaining to childhood development, educational contexts, and gender inclusive opportunities in the industry. In the attempt to correct the problem diverse solutions have been researched and implemented. One such solution is the implementation of summer camps and outreach programs. WPI in its effort to contribute to the solution has developed several summer camps including Camp Reach (CR). CR program provides a variety of activities that strive to affect issues of childhood development and educational contexts. Activities in the camp focus on workshops presenting numerous engineering disciplines. The goal of this Interactive Qualifying Project (IQP) is to improve the workshop component at CR. Through consideration of the above this project presents the Oil Rig workshop that was developed and tested, along with a list of recommendations for future implementation.

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1.0 INTRODUCTION

Women are under-represented in engineering. According to the National Science Foundation, female population comprised 34.7% of the total workforce in 1999.[1] This tells us that for equal representation in 1999 women should have comprised about 34.7% of the engineering workforce. As of 2002 only 9.1% of the total engineering work force was female.[2] Though data for percent of female population employed in 2002 is not available, trends in female employment do not suggest a 25.6% decrease of employed females from 1999 to 2002. Therefore we can see an under-representation issue for women in engineering. This suggests that there exists a set of circumstances that prevent females from entering some engineering fields.

Women are not readily entering science and engineering fields. The National Science Foundation, Division of Science Resources studies reported that the percentages of life scientists, physical scientists, and engineers, who were female, remained stagnant from 1993 to 1999.[3] This indicates that factors contributing to female under-representation in engineering have been present for many years. In 2001 the U.S. Bureau of Labor Statistics projected an increase of 22.2 million jobs from 2000 to 2010. Engineering and Science professions represent 45% of this increase. Despite this projection the number of undergraduate female students enrolled in science and engineering degree programs is decreasing.[4] This suggests that action is needed to solve the under-representation problem.

Scarcity of engineers could result in an economic problem. Our economy depends upon the advancement of technology, and, according to the Stanford Institute for Economic Policy, 50% of the U.S. economy depends upon the creation of new technological and science based products[5]. In addition, Gregory Mankiw's "Principles of Macroeconomics" states that the economy is strongly dependent upon the creation of new products. Thus a decrease in production will result in higher prices and consequent economic decline.[6] However, equal female representation in engineering fields will not only prevent harm to the economy, but may also result in benefits to the engineering industry.

There are many other reasons why female under-representation in technical fields is a problem that must be addressed. Male-dominated fields such as engineering and science tend to pay more than female-dominated fields, and according to Stephanie Blaisdell, while she was a doctorate candidate, are more prestigious, therefore it is important that women be able to enter engineering and science as easily as men do.[7] This would reduce the need for social welfare, since most families that are in poverty are headed by women with inadequate education.[8] Thus women will begin to have increased economic security, a better quality of life, and more career choices. A more diverse workforce will also result once women are more equally represented in engineering, thus allowing for fresh thinking practices in engineering.[9] This will offer new solutions to old problems that currently exist in the industry. With this we can see several important reasons to address the female under-representation problem in engineering.

There is a large volume of research that deals directly with the problem of the under-representation of women in science, mathematics, engineering and technology. Organizations such as Women in Engineering Program Advocates Network (WEPAN), National Science Foundation (NSF), Massachusetts Department of Education (MASS DOE) as well as interested undergraduate students and doctorate candidates have all spent a great deal of time and money conducting research studies individually and collectively. Such research considers factors that contribute to the problem overall, including historical trends of female under-representation, and possible consequences if viable solutions are not found. This research is conducted to find the roots of the female under-representation problem, as well as possible solutions for long and short terms.

Early childhood development, influence of role models, and industry-wide gender-inclusiveness are only some of the areas researchers have targeted. Available knowledge of early childhood development and psychology has been used to determine the difference between girls' and boys' interaction and learning capabilities in order to provide effective ways to engage them in the educational processes. The values of social and psychological beliefs, as well as the influences of mass-media, and attitudes toward childhood role models in boys and girls have also been discussed. Research also shows that female under-representation in engineering is also partially due to industry conditions since the percent of women employed as engineers has remained stagnant since 1999, suggesting that an industry-wide overhaul is needed in the future.[10]

A number of strategies have been used to encourage young women to consider engineering as a viable career option, among them outreach and mentoring programs aimed at elementary and high school students, information sessions, workshops and summer camps. Evidence in literature suggests that intense, hands-on, on-campus initiatives such as summer camps, and after school programs, are successful recruitment strategies in educating and motivating young women to consider pursuing an engineering education.[11] Summer camps for girls have been shown to be excellent methods to introduce engineering to young girls due to their hands-on projects and workshops.[12]

Worcester Polytechnic Institute (WPI) in Worcester, Massachusetts, in its effort to increase the number of girls entering science and technology fields, has developed several camps: Camp Reach, GEMS and GEMS Junior. Camp Reach is a two week residential program that has been running since 1997, created for girls entering the seventh grade. The goal of Camp Reach is to generate interest in engineering and technology and to enhance self-confidence and motivation toward education. Different workshops, offered during the camp, give girls a chance to participate in hands-on activities and help them discover their own interest in engineering. At the end of the program the camp participants are surveyed on two points: level of learning accomplished and level of enjoyment experienced. Workshops with lower ratings have been selected for re-evaluation and possible change.

The goal of this project is to improve the workshop component of Camp Reach. We have accomplished this goal by reviewing the seminal sources in the field with respect to female under-representation in engineering, selecting criteria to judge possible improvements to the workshop component, selecting and developing the improvement to be implemented, and pilot testing the proposed suggestions. Thus we have developed a successful workshop component that supports Camp Reach ideals.

2.0 LITERATURE REVIEW

An exploration of the available literature on the under-representation of women in engineering leads us to an understanding of some of the issues that need addressing in order to help solve the problem. Our literature review has revealed that solutions to this problem should be found and implemented to prevent possible negative and promote some positive effects on the engineering industry and the economy in general. Also a thorough understanding of gender roles in childhood development and the differences between boys and girls and how they learn, enabled us to better understand how to engage female students, and generate curriculum ideas geared toward girls. The bias of educators and parental figures, leading to the belief that engineering is just for boys, must be addressed, as well as the lack of enrollment of girls in science and engineering degree programs. And finally, industry changes should take place to better include women and the ideas they offer to the science and engineering community.

2.1 Childhood Development

Children begin identifying gender specific roles for themselves at a very early age, and this information guides their behavior as they mature. Most children begin to process gender differences around their first birthday.[13] Starting around age three, children instinctively figure out the world by sorting virtually everything they encounter into mental categories. That's why around age three, a child's behavior is likely to become noticeably gender-specific. Girls may become less aggressive and choose "girl" games, such as playing house. Boys may turn rough-and-tumble and become interested in "boy" toys, like trucks, action figures and building blocks.[14] While there have been attempts to introduce building toys for girls, overall there is a deficit which is detrimental, said child psychologist Dr. Auerbach. Parents and toy companies need to understand that construction activities are critical for girls also, said Auerbach, who has evaluated toys for 30 years. "It is a very important experience that builds eye-hand coordination, logic that affects reading and math strategies," she said, "And thinking skills involved help them to work out decision-making processes needed for science."[15]

Scientific debate exists on weather biological differences contribute to gender issues. A new study from the University of Chicago indicates that by 4 ½, not by adolescence, as previously thought, boys tend to be better at spatial reasoning than girls. In the study, boys ages 4 to 7 did better than girls on tasks requiring spatial skills, which are used later to read maps, interpret technical drawings, and solve math problems.[16] However, studies also show that young girls and boys share an overwhelming number of characteristics determined by biological factors, and, until puberty begins, they have similar physical development. Thus coed teams before puberty have as many outstanding girl stars as boy stars - assuming of course, that the two had comparable practice and coaching.[17] Also they have the same capacity to succeed in reading, writing and mathematics. Due to these similarities, we concluded that biological factors do not play a significant role in gender differences.

Gender differences may be partially due to children's daily experiences and mass media exposure. Girls are not as encouraged as boys to engage in spatially oriented activities such as playing with blocks and puzzles.[18] And, according to Clewell and Campbell in their paper "Taking Stock: Where we've been, where we are, where we're going", girls tend to score better on open-ended essay items while boys tend to do better on multiple choice items. Clewell and Campbell pointed out that a variety of studies have shown that girls score better on items dealing with algebra, abstract ideas and "school-based knowledge" while boys score better on items dealing with geometry, visual spatial items and "real-life" problem solving and reasoning.[19] As a result, it may be that gender differences do not result from differences in general or scientific reasoning ability or from teaching practices that favor men; rather, they may reflect in large part, differences in outside-of-school experiences, particularly those that promote visual or spatial reasoning.[20]

According to the Northwest Regional Educational Laboratory, parents' involvement in girls' education has a positive influence on their academic performance, school behavior and motivation.[21] Expectations and experiences from family and community members are more likely to influence girls' decisions about where to go to college, if at all, as well as an appropriate time for marriage and children, if at all.[22] Unfortunately, parents have lower expectations for girls in math and science due in part to the myth that there is a biological basis for sex differences in math.[23] According to Eccles and her colleagues (1983, 1985) as reported in "Taking Stock", motivation to achieve in a given field is jointly determined by a person's expectation of success and the value that he or she places on succeeding.[24] However, girls who perceive greater encouragement from their parents are more likely to find mathematics less difficult, which results in higher levels of achievement.[25] As parents become more informed of the problem, they may begin to encourage their daughters into science and engineering fields in greater numbers.

Toys as well as role models introduced at an early age can affect the future behavior of girls. Dr. Lucia Gilbert, professor of educational psychology and director of women's studies at the University of Texas, Austin, recommends providing social support for female students and hiring female faculty to act as role models for girls. In her research she said "female graduate students who identified female professors as role models viewed themselves as more career oriented, confident, and instrumental than did female students identifying male role models".[26] Today TV shows and entertainment videos are popular education and entertainment methods for children. Both young boys and young girls are subject to the same shows and videos, for example: Blue's Clue, Dora, The Explorer, Play ground Disney, Bob, The Builder, etc. These shows present a variety of male heroes that could channel boys toward science, technology, and construction fields, while in the same shows, there are few female heroines. The few female role models that do exist guide girls toward paths that are not science related such as business, environment, and education. These are some of the reasons for girls drawing further away from science and technology, while boys are drawn closer.

As researchers attempt to solve the problem of female under-representation in engineering, an understanding of how to engage children in the learning process will enable them to generate strategies to engage girls in science and engineering. A good curriculum model may include features such as hand-eye coordination and logic skill improvement, while encouraging girls to play with blocks and puzzles to promote spatial visualization skills.

2.2 Education

There is extensive research on what children are taught, how they are tested, and how they incorporate knowledge into their lives. Research suggests that females prefer non-competitive, cooperative, group settings. Also studies show that group support enriches the learning experience for girls. Though currently statistics indicate that boys tend to do better than girls in science and math in pre-college education, it is suggested that girls' ability and desire to communicate and be part of group experiences could be developed to engender successful engineers.

2.2.1 Learning Styles

Learning settings are important for girls. Females prefer to learn in non-competitive, cooperative, group settings; while males prefer settings emphasizing individual achievement recognized hierarchically.[27] According to Johnson et al. in their meta-analysis of girls' learning styles, cooperation is considerably more effective than interpersonal competition and individualistic efforts in promoting achievement and productivity.[28]

As girls mature and gender select into small groups, they provide support for one another. As caring learners that are emotionally connected to one another, the knowledge girls gain is enriched by the group experience. Carol Gilligan, in her book, *In a Different Voice,* says that women not only define themselves in a context of human relationships, but also judge themselves in terms of their ability to care.[29] Belenky, et al. surmised that women come to know things in ways different from those of men, with women being more apt to be connected knowers who gain knowledge through access to other's experiences.[30] According to Rubin Zick, a psychology textbook author, groups of young female friends are networks, overlapping groups of one-on-one friendships. Girls see their friends as a support base, while boys' friends are allies in mischief.[31] As girls mature and incorporate what they have learned into their lives, their experiences with collaboration allows them to think reflectively about their work and discuss their ideas with both peers and people with more experience. This ability to communicate creates more positive interpersonal relationships and attitudes such as mutual liking, respect for differences, a sense of responsibility and a desire to win the respect of others.[32] If exploited properly, these attributes could be further developed to produce creative and productive future engineers.

2.2.2 Female Science and Mathematics Achievements

Female performance in elementary school science and math courses is an indication of future participation in math and science related majors in college. The National Science Foundation stated, "The number and type of pre-college courses taken in mathematics and science are important indicators of preparation for undergraduate majors and course taking as well as general scientific literacy. They are also two of the major factors positively related to elementary and secondary mathematics and science achievement".[33] In 2002 U.S. Department of Education, National Center for Education Statistics reported "a significant difference between males and females in average scores in grades 8 and 12."[34] In the report, females on average scored lower than males in science and math.[35] Thus lower female performance in science and math negatively contributes to number and type of pre-college math and science courses taken. "Students who take advanced mathematics and science courses including advanced placement courses in high school are more likely than those who do not, to major in science and engineering in college," was also stated in the NSF report.[36] Thus current lower scores of females in mathematics and science negatively affect the number of females entering science and engineering careers.

Since math and science education is usually evaluated through individual tests, probably the lack of women's achievements in such subjects can be attributed to learning styles. As mentioned before, girls prefer to learn in a cooperative environment, while these types of classes suggest a competitive environment. Dr. Charol Shakeshaft, with a doctorate in Educational Administration, specializes in the study of gender and schooling, and evaluates the effects of technology. In her book, "Reforming Science Education to Include Girls", she says that science and mathematics classes have expectations that simply exclude girls, leading to lower participation and achievement.[37]

2.2.3 Alternative Educational Methods

In their paper, Clewell and Campbell reported that one study found that teachers believed boys to be more interested, more confident, and higher achievers in science, mathematics, engineering and technology than girls. Teachers, moreover, did not feel that they had responsibility for causing the gender differences. Therefore the authors recommend educational programs for teachers to keep them informed of the issue of under-representation of women and to provide alternative educational methods to motivate girls toward science and engineering.[38]

An example of an alternative educational method is with the way information is presented to girls. According to Women's College Coalition at Mount Holyoke College in Massachusetts, we must resist providing ready answers to the girls.[39] They suggest that we let girls discover their own solutions rather than rescuing them by providing solutions. Research shows that this kind of "rescuing" undermines girls' confidence in their abilities. They also recommend that we must encourage new, non-traditional thinking and methods of problem solving, and help foster an environment where girls know it's acceptable to get sweaty and dirty in pursuit of a goal. In "Encouraging Women to Train as Engineers", Angela Greive, a math teacher at an all-girls grammar school in Birmingham, England, offers suggestions based on information she gathered during her traveling fellowship, in her book "Encouraging Women to Train as Engineers". Greive lists possible strategies to engage girls in engineering. She suggests introducing engineering career options to kindergarten girls and providing welcoming, safe classroom environments. She also recommends providing social support for female students and hiring female faculty to act as role models for girls.

Alternative educational methods, that motivate girls to participate in disciplines such as math and engineering, are currently focused on learning methods development. Different active learning methods include cooperative learning, case teaching, classroom assessment and writing to learn.[40] These methods are useful because they accommodate girls' learning styles as mentioned before.

Cooperative learning consists of the interaction of a small group of students, while trying to solve a specific problem or completing specific tasks to maximize their learning experience and their group relationships.[41] This technique is useful in small groups because it promotes a non-competitive and collaborative learning environment.

However, placing a group of girls together is not enough for cooperative learning to apply. Every group must be carefully assembled for the learning experience to occur. Each member of the group must rely on the others to be able to accomplish group and individual tasks in order to accomplish a final and integrated goal.

Case teaching is the method that uses cases as a learning tactic. Case strategy involves a group of students in discussion and decision making on a specific topic, which is more like a debate. The teacher provides students with enough information on a particular subject, but not the analysis of the problem. The purpose of this method is to enhance the students' communication skills as well as their problem solving abilities, while they look for a solution that will apply to the given problem. This method has been used for the past fifteen years by the National Center for Case Study Teaching in Science, a program that received the 2004 National Dissemination grant from the National Science Foundation's Division of Undergraduate Education. Also, it was chosen by NSF as a National Science Digital Library (NSDL) collection as an exemplary resource and service organized in support of science education at all levels. National Center for Case Study Teaching in Science stated that the case study method has been "amazingly flexible and functional" for diverse science fields.[42] When using this method of teaching students are free to come up with their own answers or solutions to the existing problem.[43]

Classroom assessment is a method that involves the usage of several evaluation activities that will provide the teachers with information about what the students are learning and how well are they learning it. After using various learning methods, it is necessary for the teachers to know the effectiveness of each technique. Patricia Cross, named "Adult Educator of the Year" by the Coalition of Adult Education Associations, wrote that "Classroom Assessment consists of small-scale assessments conducted *continuously* in college classrooms by discipline-based *teachers* to determine what students *are* learning in *that class*. . . . The primary purpose of Classroom Assessment . . . is to improve learning directly by providing teachers with the kind of feedback they need to inform their instructional decisions." [44]

Writing to learn is a method based on the use of journals, free writing, multiple drafts of papers, under graded writing, and any other kind of strategies that enhances the student's ability to write. This method encourages teachers of different disciplines to integrate several writing assignments into their lectures and presentations to stimulate the learning capabilities of their students.[45] The name "Writing to Learn" by Young, Professor of English and Engineering at Clemson University, comes from a movement called "Writing Across the Curriculum" (WAC).[46] This movement introduced in the early 80's was due to a pedagogical deficit in students' ability to write.[47] As explained before, one of the greater challenges for teachers is to know what and how well the students are learning the subject. However, with this method the instructor has an understanding of the students' perception of the subject. The similarity between "Writing to Learn" and "Class Assessments" is that both methods work as a regulator of information that the students are assimilating. "Writing to Learn" works as an enhancer of the learning ability, where the students learn more of the subject by keeping a record or a journal of their comments and thoughts about the class.

2.2.4 Girls' Perceptions of Math, Science, and Engineering

Girls often have mistaken and negative perceptions of science and engineering professions. According to the authors of "Taking Stock", there has been extensive documentation of the fact that girls perceive the fields of math and science to be the domain of White boys and that they do not see these subjects as useful to either themselves or humanity in general, that they do not see themselves as successful practitioners of math and science, and that they do not enjoy these subjects.[48] Some women stay away from engineering because of negative perceptions deeply ingrained throughout their social development, and the reputation of engineering as an esoteric "stealth profession", which could be one of the main reasons why some women find it so unappealing.[49] Pamela Haag, director of research for AAUW's Education Foundation wrote, "They (girls) express a 'we (girls in general) can, but I (personally) don't want to' philosophy, and the study really pointed this out as a problem." Ms. Haag said that the girls think the world of technology is "a waste of intelligence and that technology-focused people are not ambitious and are not connected to daily problems. "Women are more interested in what they have to get done, and men just want to play around," says a Baltimore student. Another high school student summarized her thoughts on a career in the technology field as: "I try not to have feelings about inanimate objects." And, "I'd rather interact with people.[50] Such comments indicate a negative perception of technology and science, which are the precursors to engineering disciplines, as well as an incorrect perception of the applications and responsibilities that engineers have. These negative factors may result in females avoiding participating in the necessary foundation courses for a career in engineering, steering them into other disciplines.

2.3 Industry Conditions with Female Under-Representation

Women are underrepresented in engineering industries for many reasons, possibly suggesting an industry-wide overhaul is necessary for the next decade, to produce a more gender inclusive career opportunity for women in the engineering fields. According to the U.S. Department of Labor, in 1999, 10.6% of the engineering population was female, and in 2000 and 2002 the percentages declined to 9.9% and 9.5% respectively.[51] The proportion of women has remained relatively stagnant since 1999 and even declined in some occupations in spite of increases in women's overall participation in the labor force. According to the authors of "Taking Stock", lower salaries than men, more family responsibilities, and the inequitable distribution of career rewards are negative factors associated with women's employment in science and engineering occupations.[52]

Increase of female presence in engineering industries may also help prevent a possible economic problem. According to the Stanford Institute for Economic Policy, 50% of the U.S. economy depends upon the creation of new technological and science based products[53]. In addition, Gregory Mankiw's "Principles of Macroeconomics" states that the economy is strongly dependent upon the creation of new products. A decrease in production will bring a decrease in the supply of technological products available for consumption and an increase in prices. An increase of prices lowers long-term corporate investment, which will decrease the efficiency of production, lower Gross Domestic Product and lead to economic decline[54]. Without a sufficient number of engineers we, as a society, may lose our ability to address many of the challenges present in modern civilization: cleaner environment, improved healthcare, workplace and home safety. We may also lose our ability to redesign existing products to provide a wider range of services, such as computer-automated appliances for energy efficiency. Thus, if we cannot produce a wide range of solutions to life's challenges as they arise, we may not be able to provide future generations with sufficient technological resources to continually improve the standard of living.

A diverse workforce composed of men and women from a variety of different backgrounds and cultural experiences, is a more creative workforce capable of challenging old attitudes and practices and bringing fresh thinking and greater innovation to product development.[55] As industries become more gender inclusive by allowing flexible schedules for employees as well as equitable distribution of career rewards, women may increasingly begin to contribute to solving engineering problems with a unique perspective.

2.4 Possible Solutions to Under-representation of Women in Engineering

In order to address the under-representation of women in engineering fields, many possible solutions have been considered. Methods such as new educational strategies and development of special programs utilizing them have been implemented specifically to interest girls in engineering. New strategies introduce career options and role models at an early age and such methods provide ways to interest girls in engineering, show possible career paths and provide encouragement and support for their future careers.

Keeping students and teachers alike informed about the latest research, could generate new ideas to help solve the under-representation problem. Educational programs exist for teachers to keep them informed of the issue of under-representation of women and to provide alternative educational methods to encourage girls toward science and engineering. Camps for students are also an excellent intervention method due to their direct involvement with girls. Such programs are attainable by a wide range of young girls of different ethnic and economic backgrounds. Some programs provide scholarships or are being sponsored by outside sources.

One solution is to develop programs and workshops for girls and teachers with hands-on activities.[56] Adamson et al. in "The Journal of Research in Science Teaching" agrees that implementing K-12 engineering programs is an effective way to interest young girls in engineering[57]. Campbell, who has a doctorate in Mathematics Education and Sanders, who is the Director of the Center of Gender Equity, agree that pre-college programs that combine hands-on activities and the provision of role models through mentoring, internships, and career field trips tend to lead to girls' increased self-confidence and interest in Science, Math, Engineering and Technology.[58]

2.5 Camp Reach

Worcester Polytechnic Institute (WPI) in Worcester, Massachusetts, in its effort to increase the number of girls entering science and technology fields, has developed several camps: Camp Reach, GEMS and GEMS Junior. The two-week Camp Reach program includes hands-on, interactive workshops, a design project for a community organization, field trips, recreational activities, and follow-up programs during the academic year. Camp Reach received the prestigious Women in Engineering Program Award from the national organization WEPAN (Women in Engineering Programs and

Advocates Network) in 2003. This award recognizes Camp Reach as a premier, model program by a group of professionals who work in this field.[59] This success is reflected in the results of a survey given to the girls before and then after the Camp Reach experience. In 2003 girls who participated in Camp Reach found engineering and technology more interesting than prior to their participation to a statistically significant degree. There was also a self-reported increase of understanding by the participants of what engineering is.[60]

The 2003 Annual Report for Camp Reach states that their main focus for program improvement in 2004 will be to enhance some of the workshops and other academic activities. At the end of every camp, the campers are asked to fill out an evaluation form that provides feedback on the level of enjoyment and level of learning for each of the programs and workshops. Based on the results of the evaluations, some workshops were judged as not very engaging or too long, therefore the directors of Camp Reach have decided to assemble a team to focus on the program development of these areas.

3.0 METHODOLOGY

To accomplish our goal of improving the workshop component of Camp Reach we constructed a series of objectives. We reviewed literature to determine what interests the age group of Camp Reach participants. This step provided information on how to capture the attention of the girls for whom our workshop is intended. This is a crucial step for getting the message of engineering education to our participants and ensuring that the proposal of ideas for the workshop component of Camp Reach is sufficiently enjoyable and engaging. We accomplished this objective by first reviewing professional literature on how girls learn, learning techniques in today's classrooms, as well as their perception of engineering. We then used the information gained from our research to formulate several criteria to aid us in selecting a workshop that will best accomplish our goal. Once the guidelines were established we used some brainstorming techniques to generate ideas that were used to develop workshops. After the workshop ideas were further developed we went through a workshop selection process to select our final workshop. A pilot test was conducted after the workshop was fully developed to ensure our workshop met all the criteria. Finally we presented our project to the directors of Camp Reach.

Our research helped us to determine criteria for a workshop. The criteria helped ensure that the message our workshop conveyed was that engineering is a collaborative problem solving process, a "helping profession", and is fun. We accomplished this objective by forming conclusions from our literature review about appropriate topics of research. We felt that the most helpful topics for this objective were: ways of engaging the girls, the context of the workshop component within the camp and the logistics of the proposed ideas.

After establishing the criteria for successful workshops, we did some brainstorming for workshop ideas. We accomplished this objective by conducting a brainstorming session that used many resources to ensure that we generated as many useful and viable ideas as possible. Some of these resources were sixth and seventh grade curriculum guidelines, our own engineering textbooks, as well as library resource material on various engineering subjects.

Once we had an extensive list of workshop ideas, we applied the criteria we developed to the pool of ideas produced by our brainstorming session. We were able to eliminate all but three final workshop ideas. This allowed us to focus more specifically on the most viable and appropriate ideas. In order to decide which workshop idea was best suited for Camp Reach after the initial selection, we developed each to a point where we were able to pilot test them on our own IQP team members. Once that was done we were able to eliminate two ideas for logistical reasons.

Once the workshop idea was selected we developed the workshop completely. Our focus was on determining the best way to conduct the workshop. We explored possible presentation methods, created teaching material for the actual presentation, and generated an evaluation questionnaire.

Once an idea was developed, we gathered feedback on our workshop to determine if we succeeded in creating an enjoyable and educational engineering related experience for our participants. We designed a pilot test that provided the most accurate and useful results. We chose a pilot test group from a list of Camp Reach alumnae from the past two years, so as to have a group that most closely resembled possible Camp Reach participants. We selected a method of collecting feedback from our chosen group of girls, which was in the form of a questionnaire and observation methods. Next we presented this group with our workshop in an appropriate environment - as similar to Camp Reach conditions as possible.

Finally we determined if change to the workshop was needed. This is a crucial step that lets us focus on perfecting our final product. We accomplished this objective by examining the collected responses and suggestions and determined if recommended changes satisfy our original criteria.

Our final deliverable provides an instruction manual for campers as well as instructors so that the Camp Reach instructors can easily facilitate the workshop. The manual includes all instructions needed for teachers and students, workshop objectives, necessary background information, list of needed supplies and where they may be purchased, detailed set up instructions, workshop timeline, and all needed handouts for the campers.

4.0 WORKSHOP SELECTION AND DEVELOPMENT

Once we completed the literature review, we had the knowledge required to create a successful improvement to the workshop component of Camp Reach. Here we closely followed the steps outlined in the methodology and were able to produce a well thought out, educational and fun workshop that fits in with current Camp Reach activities. We began by assembling a complete list of criteria our workshop had to satisfy, and an extensive list possible workshop ideas. After selecting three of the most appropriate workshops we developed each enough to distinguish the best option.

4.1 Criteria

After review of literature and research on the subjects of female under-representation, educational methods, and possible solutions to the under-representation problem in general, we were able to create a list of criteria (Appendix A). The workshop improvement must satisfy the criteria we chose in order to justify our conclusions that the workshop would encourage the girls toward engineering. This list was very extensive and included criteria for learning styles, contexts for our audience, and logistics. Out of this list of 37 criteria, we selected eight criteria that workshops would either pass and be considered for future use or fail and be removed from the list of possible workshops to develop. We made our selections by referring back to our literature review and appraising whether a particular criterion was mentioned as crucial and whether a suggested workshop idea could be modified to fit the criteria in question. In some cases the discussed criterion was in a gray area, in which case it was not regarded as one a final workshop must pass in order to be kept on the list, to allow for flexibility when judging workshop ideas. Finally eight pass or fail criteria were selected out of the original thirty-seven possibilities. These are:

1. Must be hands on
2. Must not require special skills or talent
3. Must have a real life application
4. Must be affordable by Camp Reach budget
5. Must be significantly different from existing activities in Camp Reach
6. Must not duplicate 6^{th} or 7^{th} grade work
7. Must be repeatable
8. Must include age-appropriate information

Must be hands on

According to Vickers, Ching and Dean a workshop that is hands-on will engage the campers mentally physically, and emotionally, which serves to reinforce the learning experience.[61]

Must not require special skills or talent

A specific skill may give one team a significant advantage over another changing the workshop environment from cooperative to competitive. If a special skill or talent, such as computer literacy, is required to participate in the workshop, our main goal of encouraging rather than frustrating the girls may be defeated

Must have a real life application

Girls must see the engineering experience and how it relates to real life. If they can be shown that engineers help people and solve real-life problems they may become more interested in engineering. One of the active learning methods was the cases study. As explained before, this method is based on the application of solutions to real life situations, so if the workshop can relate to something the girls already have some experience with, they may be more interested to continue learning on the subject.

Must be affordable by Camp Reach budget

The workshop must be affordable. A workshop that is too cost prohibitive may be eliminated in the future purely from an economic standpoint, which would not support the goal of this project to improve the workshop component.

A workshop that is too costly may also require funds being taken from other activities decreasing the overall quality of the Camp Reach experience.

Must be significantly different from existing activities in Camp Reach

The workshop must be innovative enough so as to add value to the entire Camp Reach experience. A new activity that is too similar to an existing activity may defeat the purpose of the Camp Reach experience, and bore the girls, therefore deterring them from engineering rather that interest them.

By exposing them to different engineering activities we also provide them with more knowledge on possible career choices and paths.

Must not duplicate 6th or 7th grade work

The workshop must differ enough from the 6th and 7th grade curriculum so as to engage the girls, but at the same time build on the information they already have about math and science. This will ensure the workshop does not give some girls advantages over those who may not have had similar experiences in 6th grade work, and therefore keep the workshop a non-competitive experience.

Must be repeatable

The workshop must be repeatable. The materials must be easy to get and store. The instructions must be complete and easily understood by any future Camp Reach Instructor.

If the experiment is not repeatable in any future year then time and effort spent designing this years experiment would need to be repeated next year.

Must include age-appropriate information

The information offered in the workshop must be complex enough to engage the participants to provide a learning experience. However this information must also be simple enough to build confidence and promote interest in the subject.

4.2 Brainstorming

The quality of the final workshop to be implemented depends largely on the ideas the workshop presents, therefore it is crucial that the pool of ideas from which the final workshop may be selected be as large as possible. To achieve the best results from the limited time we had to spend on brainstorming for workshop ideas it was crucial to have a good technique and a clear set of rules to follow for the brainstorming meeting. Infinite Innovation Ltd, creator and developer of tools on brainstorming, creativity and subliminal messages, suggests that any brainstorming meeting have one person in charge to guide the flow of ideas and to enforce group rules. The rules put forth were:

1. Withhold judgment of ideas. This rule is critical since ideas that may not appear "best" or applicable might later inspire ideas that do fit the necessary criteria to be considered usable. Also judgment of ideas may discourage some participants from voicing all of their ideas, once again limiting the idea pool.

2. Support wild and exaggerated ideas. This rule is important partially for the reason provided above - wild and seemingly unusable ideas may spark creative and new material not thought of before.

3. Quantity, not quality. For the first round of brainstorming participants should focus more on quantity rather than the quality of ideas. Once a large and diverse pool of ideas is created it is easy to tame unusable material.

4. Build upon other ideas. It is important to look at broad topics from several directions to ensure that every area is covered. For our case this was especially important since engineering fields are usually very broad and have many practical applications that could be explored to encourage interest in engineering.

5. Every idea belongs to the team. Finally, it is necessary to remember that every idea spoken out loud belongs to the team and not any particular individual. This rule encourages professional behavior and eliminates any personal attachments to ideas that may not be as applicable or feasible as others.

Following these rules, the conducted brainstorming meeting was productive. The purpose of the session was clearly stated. The purpose was to create a large and diverse pool of ideas from which we would later create and select a workshop to be proposed. Next, the rules of the session were stated and explained. This list was always available for participants to refer to during the session. Then a warm up was conducted to initiate the creative process. This activity was not related to the purpose of the session to help ease the participants one step at a time into the proper state of mind. Then we began the session with ideas that had already been previously generated by the group members prior to the meeting. All ideas were recorded on large pieces of paper and were clearly visible to all participants at all times. Several methods were employed when discussion and idea generation ran slow. A prevention method taken was allowance of a short five minute break every 20 to 25 minutes to practice improvisation methods and to illustrate alternative thinking methods. Also various related literatures, as well as web resources, were provided for reference. These resources included books on various types of engineering applications, several websites dealing with how things work as well as Camp Reach style programs. And, finally, word cards that contained one or two words per card, dealing with technology, science, and engineering. The purpose of this resource was to provide a "random" word selection for the participants, which was suggested by Infinite Innovation Ltd.

4.3 Workshop Selection

When the brainstorming session was completed over a hundred words, topics, and workshop ideas were generated. From this list the participants were asked to generate as many possible usable workshop ideas as they could. The next list of suggested workshops amounted to 48. (Appendix B)

We looked at each of the 48 ideas one by one and compared them to the list of our pass or fail criteria. This was done to limit the list of workshop ideas to a manageable size. Each idea was brought up for discussion against each of the pass or fail criteria and examined for possible ways the workshop suggestion may satisfy a particular criterion. If the idea was not able to satisfy one of the criteria, it was considered not practical and was no longer in the running for the final workshop. Therefore each idea that we eliminated did not meet all of our criteria. Finally three ideas were selected that were able to satisfy the entire list pass or fail criteria.

To distinguish further between the workshop ideas we developed each into a workshop to the highest possible degree, or until it was clear that the workshop was not able to satisfy all the workshop criteria. We developed a Fire Protection (FPE) workshop: this would be a build it and burn it workshop, an Industrial Engineering (IE) workshop: role-playing workshop, where the girls could manage their own company, and an Environmental Engineering based workshop: oil spill re-creation and cleanup.

The FPE idea, as other IQP groups have discovered, began to explore a more dangerous part of engineering.

The IE idea required a lecture that would describe information flow within an organization and how to interview people in order to properly place them in the organizational chart. The IE workshop idea had too much lecture required, was not engaging enough and did not have enough hands-on activity, so it was eliminated.

The Oil Rig/Oil Tanker workshop idea, was not only flexible enough to satisfy all the criteria we put forth, but also adaptable enough for implementation. Unlike the FPE, this idea did not require dangerous activities or a special facility to conduct any experiments. Unlike the IE workshop, the Oil Rig/Oil Tanker offered a very hands-on activity that did not require a lengthy explanation. As the workshop got developed, the focus changed from rigs and tankers to oil spill cleanup. This shift allowed us to explore a wider variety of engineering disciplines (Mechanical, Chemical, and Environmental). Also, we discovered that oil spill cleanup workshops already exist for our targeted age group, but are not often implemented. We were able to combine parts of already existing workshops and use them as guides toward age appropriate materials as well as introduce new parts we designed ourselves to ensure a complete engineering experience.

4.4 Workshop Development

To create the best workshop on the Oil Rig/Oil Tanker theme it was first necessary to discover whether similar workshops already exist and whether they offer suitable for adaptation activities for our purpose. This search resulted in a small number of workshops suggesting that workshops of this type are not common. These workshops were: "How to cleanup up oil spills" developed by Ohio State University[62], "Oilrigs" developed by ACTUA, a Canadian organization providing youth with positive learning experiences[63], "Oil Spill Activity" developed by Watt Watchers, a Texan organization increasing energy use awareness[64], "Slick Sea Spills" developed by the Franklin Institute[65], and "How to clean up an oil spill" developed by Victoria Broje, a Ph.D. student at University of California Santa Barbara[66].

The structure of the discovered existing workshops was consistent. First all the workshops provided an introduction explaining the purpose of the workshop, presenting the objecting, and answering any preliminary questions the participants may have. Then the participants begin the specified experiment following specific steps. And finally, when the experiment is completed, a discussion session is conducted to ensure that the material learned is correct and will be remembered. We chose a similar structure for our workshop since it appeared a standard as well as logical choice.

Since the course of the experiment determined the information in the introductory and concluding parts of the workshop, we decided to construct the experiment first and build the rest of the workshop around it. The existing workshop experiments last no longer than 1 hour and include only one type of activity, such as building of an oil rig, or cleaning up an oil spill, or examining oil effects on animals. However, for our purposes we needed an activity that would fill 3 hours, so we decided to combine various activities and link them logically to create an appropriate workshop.

Thus the workshop experiment was decided to have three parts. The first part would explore the structure of an oil rig, and its design. The second part would explore oil and water interactions. And, finally, the third and last part would combine all the learned material for a chance to apply it and rescue a beach environment from an oil spill.

The first part of the workshop experiment gives the participants a chance to get focused. In this part they are asked to design and build an oil rig to certain flexible specifications. Here they use popsicle sticks and glue guns to create a structure able to support a cup of simulated crude oil above water.

In the next part the participants are introduced to oil and its behavior on water. Here the girls are given oil and water and are asked to write down their observations, predictions of interactions, and impressions of the substance and it behavior. This part allows the girls to get familiar with oil to encourage them in the next part, when they must get very hands on.

The third part allows the girls to combine the previous two. Here the girls are asked to create a beach environment in which an oil spill will occur. They are encouraged to make it as realistic as materials and time allow to have a better understanding of possible large scale effects of a spill. Then they are asked to place the constructed oil rig into the environment and to simulate an oil spill and attempt to clean it up using the techniques they have developed from the previous part.

Following the experiment we decided to have a discussion session. In this session questions were to be asked of the participants on the material learned and conclusions made. This would provide the girls with a way to solidify and define what they have learned, as well as allow for various of their questions to be answered.

From this experiment we were able to construct an introduction which explained the purpose and workings of oil and oilrigs, types of crude oil, and the kinds of engineers that work in fields that deal with crude oil. This introduction also explained the purpose of the experiment and provided the girls with a way to relate to the work they were about to do.

The experiment also gave us a foundation for the conclusion to the workshop. Since many methods used in real life are not repeatable on a small scale such as ours, we felt it was important to present the participants with an illustration of the methods actually used. Therefore the conclusion to the workshop included an explanation and presentation of alternative methods of oil spill clean up.

Finally, a choice had to be made on materials to be used during the experiment. Most of the materials were obviously needed from the workshop design, others were up to us to chose to give to the girls as clean up alternatives. Here we chose to have mechanical and chemical means for clean up. As mechanical means we chose common objects such as string, cloth, and paper towels, and as chemical means we chose powdered and liquid detergents. All materials were chosen for their commonality in everyday life and easy of obtaining them for the experiment.

The oil to be used, however, was a subject to some debate. It was obvious that it would be impossibly difficult to obtain proper amounts of crude oil, so we chose to simulate it. To do so several options were put forth. These were: olive oil, vegetable oil, transmission lube, and used motor oil. Finally used motor oil was selected for its color, which allowed us to see it easily in the water, and for its viscous properties, which closely resemble those of crude oil. Dangerous effect of the oil could be prevented easily if they are instructed to follow certain safety rules such as wearing gloves and goggles. Safety was discussed with Manager of Environment & Occupational Safety at WPI who agreed that precautions of gloves and goggles would be sufficient. The final versions of the student and teacher manuals for the workshop can be found in appendices B and C.

5.0 PILOT TEST AND EVALUATION

A pilot test was essential in providing us with feedback on the quality and success of the designed workshop. It was able to bring up overlooked points, misleading instructions, and areas in need of improvement.

In the invitation letter we simply invited the girls for a pilot test of a possible new workshop for Camp Reach. We decided that we might get a more bias group of girls if we described our environmentally based workshop, so we did not describe our workshop in the invitation letter.

On Saturday, April 24, 2004, our Camp Reach IQP team hosted a pilot test for our completed workshop. Prior to Saturday, we sent out invitation letters, gathered materials and secured an appropriate room for the event. We sent out invitation letters to the 2002 and 2003 Camp Reach alumnae and received 10 responses. On test day, 7 girls showed up to participate in the pilot test. The girls seemed enthusiastic and eager to see what we had planned for them to do during their visit to WPI.

The workshop was scheduled from 12:30 p.m. – 4:30 p.m. We chose a four hour block of time to reduce the pressure a shorter block of time might have produced if we experienced any unforeseen problems. Given our inexperience in presenting workshops to children, we agreed that a four hour block of time would allow us time to present material, have a snack, conclude the workshop, get feedback and then try out our optional activities provided everything progressed smoothly.

Once the girls arrived at the Campus Center, they were brought over to the room we reserved, re-introduced to each other and got reacquainted with each other through "ice-breaker" activities. Each girl reassured us that they knew another girl in our test group, which made the ice breaker activity a little more enjoyable because the girls were already familiar with each other. They began to form groups immediately, and actually had to be rearranged by our team in order to get more even group sizes. We had three 12 year olds – "going on 13", three 14 year olds, and one 13 year old – "going on 14"

The girls in all of the groups worked well with their teammates, allowing each girl to participate in the building process as well as the design process of each part of the workshop. We had hoped to have three groups of three and ended up with two groups of two and one group of three.

The girls received a ten minute introduction on oilrigs and oil tankers, and then a brief explanation of how to begin Part I of the workshop. They sat still, listened carefully and seemed to enjoy the introduction. Once they received their instructions for the workshop activity, they began to discuss the design of their oil rig. They worked quietly together and within 18 minutes the first group was done building. The other two groups were a little farther behind the first group.

Each group successfully produced an oil rig using only a glue gun, a Styrofoam cup, and colored Popsicle sticks. Each design was completely different from the others, but each team found success. The colored Popsicle sticks began to turn the color of the "ocean" water blue, and at least one girl burned her arm with hot glue. The blue water did not seem to change the oil and water properties in any way, but once the oil rigs were under water one oil rig began to fall apart.

At 2pm, the girls began Part II of the workshop. The girls poured about an ounce of used motor oil into an aluminum roasting pan, then they experimented with the oil and water mixture and wrote down their observations on a worksheet. One of the girls expressed that she enjoyed wearing the gloves, and while none of the others expressed their opinion one way or the other, they all continued to wear their gloves. As we all went around to each group to gather feedback and watch them move the oil around the pan with "wind" and "waves" we were able to ask them questions about what they observed. They seemed genuinely interested and engaged in the whole process. After observing the oil and water interactions we asked them to clean up the oil with the materials we provided. The girls spent some time picking up oil with cotton balls, fabric, pipe cleaners, and a host of other materials, each with different properties and responses to the oil and water in the pan. We gave them a little soap to add to their oil and water mixture, and encouraged them to record what they saw. The watched the oil move away from the soap or begin to break up and the girls commented with surprise. Two groups cleaned their pan so well without soap that we had to pour more oil into their pan so they could see what soap does to oil. After Part II, everyone stopped working to take a snack break.

At 2:50 we gave them instructions for Part III. In Part III, the girls arrived back at their work stations and began to add cupfuls of sand to the new pan of water placed on the desk while the girls were eating. Each group made a beach, complete with palm trees, animals and other wildlife made from pipe cleaners. They expressed a lot of sadness when we suggested that they now pull the tape from their oil filled oil rig in their "ocean" and recreate an oil spill. The all expressed concern for each of their creations. One group had a duck they tried to protect, while another group had a person they were concerned about. They were so concerned about the environments they had created, we had to really encourage them to allow the oil to spill from the cup and move to the sand, pipe cleaner trees as well as the colorful feather laden "animal" they had created. Once they got over their loss, they seemed to enjoy trying to clean up the oil. In some cases, they noticed the futility of wiping oil off of feathers and sand and commented on how bad an oil spill is for the environment. One rambunctious learner in the group was wrist deep in oily sand and water with both gloved hands while she expressed her delight. "This is so much fun!" After observing the girls for a few minutes, we concluded that aprons should be provided for the Camp Reach event. For the most part, each girl left as clean as she arrived, but one girl got her long hair into the water and oil on her arms, and one other girl got a little oil on her shirt.

From 3:20 till 3:40, the girls finished up their play and began to complete their observation sheet then sat in a circle for the discussion questions. The sat patiently and each girl did participate in the discussion, but we could tell that we were losing their attention. Once we reviewed the evaluations, we saw that four girls suggested a shorter discussion period.

From 3:40 till 4:00 the girls sat through the power point conclusion and despite the fact that some girls asked questions and they politely sat still and watched the presentation they became increasingly fidgety. After the conclusion, we all went outside to begin the optional activity. The optional activity was done to give the girls an understanding of how big an oil tanker is. We put down 20 foot sections of string and marked a line form the Campus Center almost all the way to the library, which was still only half of a 980 foot oil tanker. They seemed impressed but ready to go home.

A proper evaluation of our workshop was essential to determine its quality and value to Camp Reach, as well as whether the workshop has met its goals and objectives. We needed records and documentation to show information about the participants and the workshop. For such purposes surveys were used as an evaluation method as well as observing and interviewing the campers during a pilot test.[67] As suggested in Camp Reach report of 2003, the surveys were short and anonymous to promote honesty and to provide clear answers to clearly stated questions. Some questions we asked were open-ended in order to generate new ideas and suggestions from the participants, while others were closed-ended to acquire an overall understanding of the girls' experiences. When observing the campers, the observer had good listening and attention skills. They were able to write down what was heard and were able to describe what was going on and the feelings and participation level of the campers.[68] The observer's account was thorough and unbiased.

6.0 EVALUATION RESULTS AND RECOMMENDATIONS

The purpose of this evaluation was to receive a feedback form the pilot test subjects about the development, structure and knowledge used fort the design workshop. Also to determine if it met the criteria expose above. In order to get useful information from our evaluation, the results gather were compared with last years CR evaluations.

From the CR Annual Report for the 2003, the highest point earned by a workshop for level of learning was 3.6 by the Field Trip to Bose Corp. The lowest was 2.4 by The Computer Orientation. Considering the level of enjoyment, the highest point earned was 3.8 by the Robotics Demonstration, and the lowest was 2.5 by the Automotive Engineering.[69] Based on the results of last year's workshops evaluations, we decided that our evaluation results should be higher than the lowest point for both categories. Consequently, we decided that our scores should be higher than the mean value between the lowest and highest ranking reported on the last year CR annual report. For last year CR workshops, the mean values for enjoyment and learning was 3.15, and 3.0 respectively.

In the Table 1 we can see the results of the level of enjoyment of the pilot test. Table 2 shows the results of the level of learning of the entire workshop. The pilot test subject showed an overall enjoyable experience through the different parts of the workshop. The score was a higher (3.57) when compare to the mean value of CR last year evaluation (3.15). With respect to the level of learning, the design workshop also scored higher (3.29) than the mean value of CR last year evaluations (3.0).

Table 1: Enjoyment Inquiry Statements for the Workshop Evaluation	
Enjoyment Inquiry Statements	Mean Average*
I enjoyed this workshop a lot	3.57◊
I was bored during part I	0.00
I was bored during part II	0.14
I was bored during part III	0.00
^This result is comparing it with the minimum score for this category (0). † This is the difference between our workshop score and the 2003 CR Annual Report highest average reported for enjoyment (3.8). *Response was given on a scale were strongly disagree was equal to 0, disagree was 1, neutral was 2, agree was 3 and strongly agree was 4. ◊ This value is higher than the last year mean value for enjoyment (3.15)	

Table 2:Learning Inquiry Statements for the Workshop Evaluation	
Learning Inquiry Statements	Mean Average*
I learned a lot from this workshop.	3.29
I had ample time in the discussion to reflect upon the material I've learned.	3.71
I think the knowledge I've gained today will help me with future school work.	3.0
† This is the difference between our workshop score and the 2003 CR Annual Report highest average reported for learning (3.8) *Response was given on a scale were strongly disagree was equal to 0, disagree was 1, neutral was 2, agree was 3 and strongly agree was 4.	

Table 3 shows the evaluations results on how well did the workshop met the criteria expose by this project. The results demonstrate statistically that the criteria were met in every part of the pilot test. The girls agree that the workshop was very hands-on, like any other experience, none related to any school work, and very engineering oriented.

Table 3: Workshop Evaluation meets criteria

Criteria Inquiry Statements	Mean Average*	Max	Min
This workshop was very hands on.	3.71	4	3
This workshop was more cooperative than competitive.	3.71	4	2
I see real life applications for the knowledge I've gained.	3.14	4	2
I see connections between some engineering disciplines as a result of this workshop.	2.86	4	2
I have gained knowledge that I might use in everyday life.	2.57	3	2
This workshop is similar to activities I have done before in school.	0.29	1	0
I think this is an appropriate addition to activities in Camp Reach that I have already participated in.	3.71	4	2
I utilized my creative thinking and reasoning abilities.	3.14	4	2
I see possible career paths for someone who might be interested in this topic.	2.43	4	1
This workshop has sparked an interest in this subject for me.	2.14	3	1

* Response was given on a scale were strongly disagree was equal to 0, disagree was 1, neutral was 2, agree was 3 and strongly agree was 4.

Table 4 is a supplement of table 3 since explain in more detail other elements of the criteria. Table 4 shows the evaluations for the workshop structure, for example: the worksheets, the presentation, level of difficulty, and instructions. In general, the result was above average. Individual comments were made form the pilot test subject about these categories:

- Overall the workshop was not rated as too long. 57% responded with a "strongly disagree", and 28% "disagree", and only a 14% (one person) responded with a neutral decision.

- 42% of the girls agreed that the discussion was too long. The reason given was because of the many questions that were involve, not enough demonstrations (more pictures, less explanations).
- The introduction was also rated as not having enough interaction with the students; some of them propose to add some questions or discussion to this part.
- 71% agreed on the sufficient amount of material to complete the experiment.
- Both the instructions and descriptions of the different parts of the workshop were clear and easy. 84% responded "strongly agree or agree" to the description been clear, and 100% responded "strongly agree or agree" to instructions been clear.

Table 4: Workshop Structure Evaluation

Workshop Structure Inquiry Statements	Mean Average	Max	Min
The instructions were clear.	3.57	4	3
The introductory presentation was interesting.	3.00	4	2
Enough background information was provided for the experiment.	3.14	4	2
The worksheet was adequate for the information asked.	3.14	4	2
The clean up procedure was too complicated.	0.14	1	0
There were too many discussion questions.	1.43	2	0
The discussion questions were too difficult.	0.57	3	0
The alternative methods of oil spill clean up descriptions were clear.	3.29	4	3
The alternative methods of oil spill clean up descriptions were informative.	3.43	4	2
The workshop was too complicated.	0.29	1	0
I saw clear results at the end of this workshop.	3.71	4	3
The workshop was too long.	0.71	3	0

Table 5 shows the evaluation results on the workshop development through time, materials, environment, and support staff. The statistics analysis shows that 100 % of the subjects voted “agree or strongly agree” with the amount of material given, enough support from the staff, and the space used for the experiment. Also the girls responded with different opinions through these categories:

- Materials:
    - I could use a sponge
    - More cotton balls and pipe cleaners
- Group size (we had groups of two and three)
    - Group of two responded: “I would have been better with three people”, “not preference”
    - Group of three responded: “ It was fine with 3 people”

Table 5: Workshop Materials Evaluation

Workshop Structure Inquiry Statements	Mean Average	Max	Min
Enough assistance was provided to complete the workshop successfully.	3.86	4	3
All necessary materials were provided.	3.71	4	3
The room was adequate for the experiment.	3.57	4	3

In general the girls comment was:

- “It was just Fun”
- “no complains”
- “I like a lot. It was really fun”
- “I like this workshop”
- “great workshop”

For the workshop improvement based on the evaluation results we recommend the following:

- The discussion section must be implemented in fast paced environment, to avoid the girls to get distracted.
- More material is recommended (cotton balls, pipe cleaners); however, the purpose of this activity is not to entirely clean the area affected by the oil, but to observe the effectiveness of different materials absorbing the spilled oil.
- To avoid accidents, it is crucial to have a staff member in charge of each station (group of girls) working in this workshop.
- In general, the slide show contains enough visual material for the subjects to understand the concepts explained; nevertheless, it is recommended that the presentation with the slide show be brief and simple to evade boredom.

7.0 SUMMARY

Over the past 2 terms we have successfully completed our Interactive Qualifying Project (IQP). Our goal was to improve upon the workshop component for Camp Reach, WPI's summer program for 12 year old girls. Camp Reach is an outreach program trying to increase the interest in math, science and engineering among young girls. To complete our project we reviewed professional literature, developed criteria and developed a workshop based upon our research and criteria. When the final workshop was developed we conducted a pilot test and made some modifications to the workshop based upon the results of the pilot test evaluation.

Our findings showed that one of the best ways to engage the girls in a workshop was to use a hands-on approach. If the girls can conduct their own experiment, see what happens with their own eyes and record their own findings, it is more likely that they will come to appreciate the workshop and the efforts of engineers, as well as improve the workshop component of Camp Reach. A hands-on workshop was absolutely necessary, but at the same time we needed to have something that was age appropriate. If the workshop was too difficult or they didn't get "correct" results, it may discourage the girls rather than encourage them. Any workshop we design must be in such a way that Camp Reach can conduct it year after year, so it must be economically and logistically feasible. In the end our workshop needed to be a hands-on, engaging experience that was easy enough for a 12 year old to successfully complete, that emphasized team work and showed the girls that engineers can make a positive difference in the world, and met the fiscal and logistical needs of Camp Reach.

From the brainstorming activity we generated 48 workshop ideas. After checking these against the criteria, all but three were eliminated. Fire Protection Engineering (FPE), Oilrig/Oil tanker, and the Industrial Engineering (IE) workshops were seemingly viable solutions. The FPE workshop was a "build it and burn it" activity where the girls would build a structure and burn it, examining the importance of fire prevention and suppression systems in industrial complexes and homes. The Oilrig/Oil tanker was an experiment where the girls would build an oil rig and small scale ocean shore line, create an oil spill then clean it up. The IE workshop was more of a skit than an experiment, some of the girls would be managers and the rest of the girls would be workers with a specific skill set. The managers would interview the girls, determine their skills and place them in the appropriate place on an organizational chart. Once the workshops were developed enough to be able to give an accurate comparison, FPE and IE were eliminated. FPE wasn't safe enough; we were concerned that the girls may get hurt during the experiment, or try and recreate the experiment once they got home. The only way we could make it safe enough was to have a demonstration and lecture, which didn't fit into our hands-on criteria. IE was eliminated because it wasn't engaging enough, and the idea of having some of the girls as managers and some as workers may have brought a competitive element into the workshop, and we were are trying to convey the idea that engineering is a cooperative rather than a competitive effort.

The Oilrig/Oil Tanker workshop was the workshop that we selected. The workshop has three parts, which are clearly outlined in the student manual and instructor manual. Part one starts with an introductory presentation followed by building an Oilrig from popsicle sticks and a styrofoam cup. After the oilrig was constructed the girls put some water into their pans, and then poured used motor oil into the water. Once the oil was in the water, the girls could observe and record the behavior of the oil when subjected to some of nature's forces such as low amplitude waves and wind. It was hands-on; the girls would be building things and trying to clean the oil out of the water and simulated animals (feather and artificial fur), and recording their findings. It was age appropriate; the presentations did not include too much in depth scientific information that would make it difficult for the girls to understand. It emphasized team work; the girls must work together in order to successfully design and build their oilrig, shore line, and then clean up the oil spill. The workshop is relatively inexpensive and should not put too much of a burden on the tight budget of Camp Reach. All of the materials can be purchased at stores within the Worcester area for a reasonable price, and the used motor oil is free.

If used motor cannot be obtained, vegetable or olive oil could be used as a substitute, although it may give different results than the motor oil. Vegetable and olive oil are both fairly transparent and could be difficult to see on the water, and they have very different physical properties than motor oil. The difference in density and viscosity could produce less realistic results. The oil may not stick to the sand and the walls of the pan like motor oil, and it probably wouldn't coat the fur and feathers like motor oil will. The odor of the used motor oil seemed to have quite an impact on the girls, and added a certain element of realism. If vegetable or olive oil were to be used you may be able to get results sufficient to convey the message, but there are certainly some draw backs. The advantages of using vegetable or olive oil are that it is non-toxic, and doesn't require any special disposal methods, and it will wash out of clothing, where motor oil doesn't possess any of these virtues. We recommend for the workshop that the used motor oil be used, due to the fact that it does add a level of realism to the experiment and it also shows the girls that it is ok to get dirty.

When we completed the workshop development we conducted a pilot test. We sent a letter of invitation to Camp Reach alumnae from the past 2 years and limited the participation to the first 15 responses. On the day of the pilot test 7 of the 10 girls that responded showed up. At the end of the pilot test we gave the girls an evaluation form to fill out, and received fairly positive feedback. The following table shows the average responses on the evaluation form.

We kept the evaluation ranking the same as the evaluation in the Camp Reach Annual Report, so we could directly compare our results to the Camp Reach results. The Camp Reach Co Directors told us that they wanted to improve or replace the workshops that scored lower than 3 on the student evaluation. The workshops that had lower scores were the candidates for improvement/replacement; they were not hands-on, and/or were found to be boring. We were mostly concerned with whether or not the girls thought our workshop was too long, boring, too difficult, and whether or not they enjoyed the experience. The responses indicated that the workshop was not too long, or that they were not bored during any of the three parts of the workshop. In the next section which contained questions about the workshop where the girls could give written comments included a question about the presentation on alternative clean up methods, which was in the Power Point presentation at the end of the workshop. Some of the girls indicated that the presentation was too long and/or boring. We also noticed that toward the end of this presentation the girls were getting bored and losing interest. We decided to shorten the concluding presentation to 10 minutes from 20 minutes, and recommend that each of the presentations don't exceed 10 minutes. A copy of the completed student evaluations can be seen in appendix G.

When the pilot test was completed, we cleaned up after the girls, rather than have them do it. The pans we provided for the girls were the disposable aluminum pans about 13 X 9 inches sold in grocery stores. They were somewhat flimsy, and had a tendency to twist in your hands when moved to pour out the liquid. We recommend a sturdier pan such as a plastic tub or a glass pan of approximately the same dimensions, to help prevent any accidental spills. We noticed when the girls were creating their waves and blowing across the oil and water mixture they sometimes got overzealous and splashed some of the oil out of the pan. If a non-disposable pan was used it will help eliminate some of the problems, such as the pan twisting in your hands and causing a spill, and if a pan is purchased with higher sides it will reduce the amount of liquid that is splashed out of the pan during the experiment. The reduction in waste is another benefit to purchasing non-disposable pans. The small size scale helped keep the solid and liquid waste to a minimum, but it was large enough so the three girls could work together without getting in each other's way.

We gave them all of the materials for the workshop at the beginning, and the girls had a tendency to use all of their pipe cleaners, cotton balls, and cloth in part I and II so we had to give them more materials for part III of the project. This generated a lot of waste, so giving the girls only enough materials to complete the part of the experiment they are working on will help prevent them from using all of their materials in part I and II and will help keep the waste to a minimum.

There were also some safety and cleanup issues discovered during the pilot test. One of the girls burned herself with the hot glue gun. Some of the hot glue dripped off of her oilrig and burned her arm. A brief safety talk before the girls begin their experiment will help reduce the likelihood of an accident. The girls in the workshop will also be under constant supervision by the Camp Reach staff, whereas in the pilot test we were not only trying to monitor the girls, but observe them to later optimize the workshop. Some of the girls got some oil on their clothes and skin. An apron or lab coat would help reduce the amount oil they get on their clothing, where the lab coat and gloves will prevent contact with their skin. Providing the girls with hair clips and/or elastics will prevent their hair from falling into the water while leaning over the pan to make observations.

In completing our IQP we followed a specific process. We reviewed professional literature, which helped us determine where the sources of the problem of under representation of women in engineering stem from. The Oilrig workshop was developed for 30 girls in the Camp Reach summer program. The student manual was developed at the appropriate age level so the girls will not have any trouble reading and understanding the scientific information presented. The instructor manual was written so a non-technical oriented instructor will be able to properly present the information to the girls as well as answer their questions.

In the end we have a workshop that fits into the goals of the IQP and Camp Reach. We produced a workshop that gets the attention of the girls, by showing them that oil spills are a problem that affect everyone, not just the people that live in the area where the spill takes place. The student evaluations showed that our workshop will improve upon the workshop component of Camp Reach. For the most part the girls that evaluated the workshop are the same girls that gave some of the workshops lower marks in the 2003 Camp Reach Annual Report. This helped us give a better comparison between our results and the evaluation results in the Camp Reach Annual Report. We could see how the girls that found some of the 2003 workshops less engaging reacted to our workshop. Only one of the seven girls attended Camp Reach in the summer of 2002. The high marks our workshop received from the girls shows that we successfully accomplished the goal of our project, improving the workshop component of Camp Reach.

APPENDIX A: Criteria

Learning Styles

1. Hands-On – multiple hands on activities – multitasking
2. Non competitive. Cooperative Learning
3. Small Group 3-5 girls per team
4. Must be enjoyable / fun. Must be engaging
5. No special talents or skills required
6. Not physically challenging

Context of the workshop

7. Real life application-involve professional from field interacting with girls
8. Show possible career paths in a specific field
9. Clearly relatable to people and social benefits – real solution to real problem
10. Contain knowledge usable in everyday life
11. Simple knowledge – age appropriate
12. Connect to other disciplines
13. Creative thinking
14. Reasoning ability
15. Use scientific methods
16. Female oriented-
17. Reinforce previously learned skills
18. Must be significantly different from exiting activities
19. Inspire more questions than can be answered by workshop – spark further interest to encourage further learning
20. Easy to explain by teachers to students
21. Easy
22. Memorable
23. to explain by us to teachers
24. Support CR goals
25. Show experimental results within the time frame of the Camp Reach experience
26. Must be relative to future school work
27. Will not repeat something they have already done school
28. Are modular self-contained programs

Logistic (time, money, weather)

29. One CR official assistant per team
30. Time to reflect on the presented material/concepts
31. Ability to repeat annually for campers
32. Low prep time
33. Experiments will not depend on unpredictable factors
34. Safety First
35. No travel time
36. Length of time
37. Must be affordable. Fiscally possible

Appendix B Possible Workshop List

1. Fire construction –build small-scale house or public building and burn it down. Fire, civil engineering, safety exit plans, chemicals in fabrics, fire retardation, napalm, pupu platter, tam pan Chinese food on fire

2. Motorcycle small engines sound pollution – different pipes on bikes make different noises. = noise pollution discuss decibel levels in different mechanical devices or noise pollution in a mfg environment # 2

3. Gear ratio Make a clock, or look at bicycle gears – use gears to make a hand move around clock

4. Power transfer, bearings, machine design # 2

5. Mems – transistors, smallest military machines. Chemicals electronics # 2

6. Oilrig, oil tanker –build their own oilrig and test its stability on the water –watch it float or sink Collaborative, real world issue, engineering design, oil safety oil fires, history oil firefighting explode oil to eliminate oxygen to put out pressure, combustion

7. Creating candlestick holders out of scrap metal-spot welding, soldering metal abrication, mechanical engineering # 31

8. Students were broken up into teams and given index cards, staples, and a stapler. They had 15 minutes to build the best structure to support a brick. Each index card, staple, stapler and fold they utilize cost a specific amount of "money
   Build something with Straws paperclips how many magazine can it hold
   Glue and paper, make it as tall as you can # 18

9. The girls took apart a toaster and identified the needs of the product (power, heat, hold bread in place, etc.). They identified parts that were needed, drew what they thought is inside of the toaster, and took the toaster apart. They were given a list of parts to find and we talked about how it works. Each girl got to take home a screwdriver. #18

10. Exercise done in organizational behavior class – three teams role playing – mge must place the person in the correct job and discuss the ramifications of placing chatty Cathy next to three other busy secretaries. Result is more or less efficiency

11. Build a kite, plane, helicopter-twist in your hand – air flow, co2, pulse jet to power plane # 11, 37
12. Helio-Lift, use, why they need two props, ways to get around that rotate in opposite directions # 18, 1

13. Build a bridge from Popsicle sticks # 1

14. Build a mechanical arm, bio engineering, assisted living, prosthetics, underwater rescue and robots Washburn lab tour # 27

15. Lens mirror reflection, build a telescope, space exploration, food solar system # 27

16. Periscope, prism, make a rainbow, Lens mirror reflection build a telescope, how we see light and color # 27

17. Generate G code CNC machine programming # 1

18. Electrical workshop similar to water flow, water motor and electrical motor compare the two, power simple machine, 7 segment led in Digital circuits, build electroscope # 18

19. Cylinder engine and combustion fuel mixture air flow and intake, how two and four stroke engines work, cut away models of engines # 1

20. Hybrid cars, friction, regenerative braking, cylinder combustion # 1

21. Pace maker basics, rhythm, amplitude electric shock, how the heart works # 37

22. Build a generator or transformer, flux, electric fields # 27

23. Materials and Sound Piezo electrics, frequency sand on plate similar to sound guitar violin, standing waves Sound waves, guitar with rubber band, string instrument, wave length frequency How different materials affect sound, guitar-sound proof wall in sound studio wind flow over sand dunes, flow lines. Echoes, anechoic chambers, sonograms.

24. Skyscrapers withstanding winds, how they are built and how it is related to animal's structures, height, design project, strength of materials, budget build tallest building for your budget management, economy, fire protection,

25. Boolean logic calculator, water gates

26. GPS position triangulation VOR in planes- hear where a sound is coming from, earthquakes how to determine where started

27. Catapult lord of the rings

28. Liquids flow volcanoes, touch it and it becomes a solid, stop touching it and it will liquefy, and quick sand is the opposite

29. Tornado, hurricane, how they form, how to survive both, how people survive them and study them

30. Photosynthesis: grow 3 or more different plants in different conditions (light, no light, not enough water, too much water) and see how it affects the plant. Place a white carnation into colored water and see it turn different color, explain concepts of fluid and nutrient flow in plants and plant engineering.

31. Pressure workshop: explain the air is a fluid, flow over a wing in a water tunnel, fountains, build a fountain, lying on tacks, snow shoes, fluid level, water tower, blow a dime into a cup, diving equipment.

32. Diving equipment: how it works, why it is needed, deep diving, pressure, density, buoyancy.

33. Space flight: explains rockets, solar system, build a water bottle rocket, rocket engines, nozzles, rocket trajectory, orbits, drag.

34. Hover craft: propellers, fans, uses of hover craft, benefits of hover craft.

35. Energy conversion: explains efficiency and energy and how it relates to heat, sound, movement, light, chemistry, electricity. Convert various energy types from one form to another. Use a waterfall to power a light.

36. Earthquakes: How they happen, how to survive them, how building stand them, earth motion, waves, earth structure.

37. Oscillation and rotation: SHM and its relevance to everyday life, springs, rotation, suspension, damping. Tacoma narrows, natural frequency, standing waves (exist on everything, even on the sun).

38. Part design: design a lock for a little diary

39. Waterfalls and dams: how they work, where the mist comes from, rainbows, where the noise comes from, soil erosion, dangers, power generation. Use a waterfall to power a light. Water jets in manufacturing.

40. Bird flight: how they fly, lift, thrust, planes, propellers, fluid flow, air is a fluid, blunt vs. smooth body, make a paper plane, play with wind up birds, Frisbees.

41. Boats: buoyancy, how they move, fluid flow, how metal boat float, test how much load can a boat hold, density, jet ski, sail, wind, navigation.

42. Sparks: what makes sparks, what they are, how they work

43. Blimps, balloons: how they work, why they fly, density, make a hot air balloon out of tissue paper and fly it.

44. Roller coasters: how different kinds work, friction, gravity, solid body motion, design a car loop.

45. Airbags: how they work, why they are needed, where they are used, damping, solid body motion.

46. Soap: how it works, how it is made, bubbles, fluid motion on a bubble, make your own soap, play with bubbles.

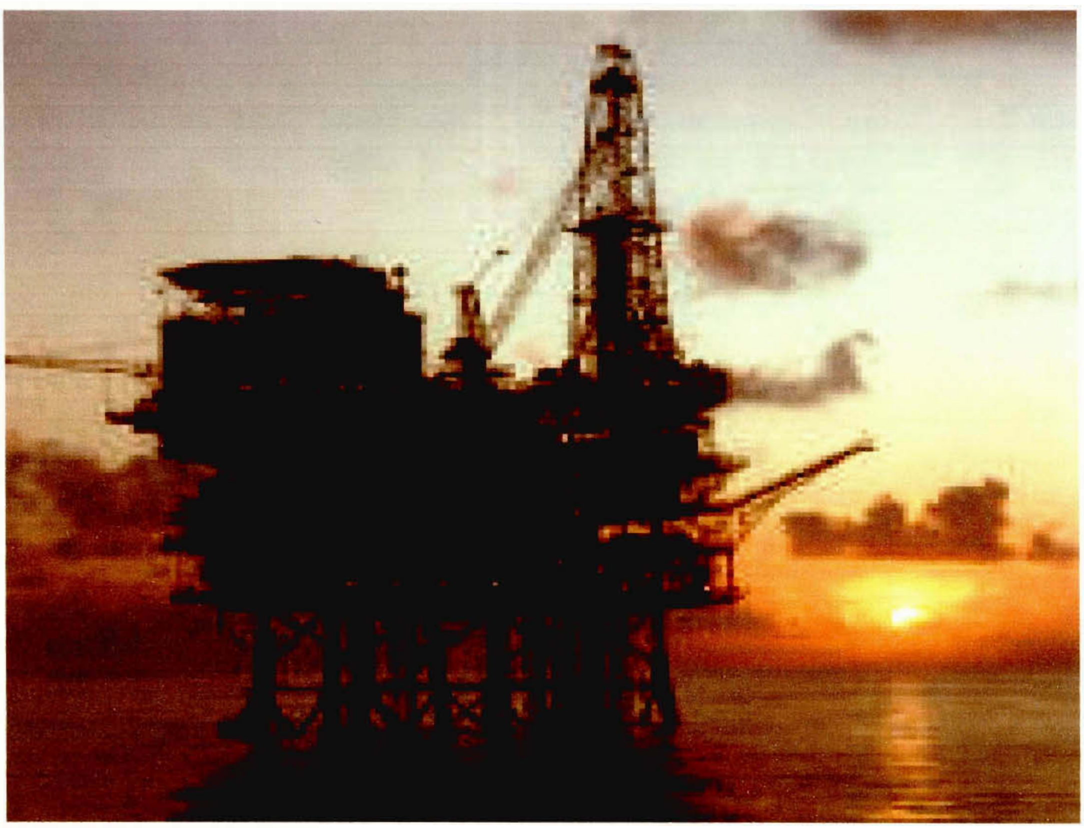
47. Building teardown: collapse patterns, strategy planning, explosives. Tear down a little building.

48. Center of gravity: what it is, how to find it, exotic rock formations, design a float.

APPENDIX C: Student Manual

Designing and Building an Oil Rig

And Oil Spill Clean Up



Designing and Building an Oil Rig
And Oil Spill Clean up

Activity Outline

1. Part I Design and build and oil rig
   a. Materials
      i. Styrofoam cup
      ii. Popsicle sticks
      iii. Glue gun,
   b. Specifications
      i. Using popsicle sticks and a glue gun, design a structure that will hold a Styrofoam cup above the water line to act as an offshore oil rig.
2. Part II Oil and water interaction
   a. Fill pan with water
   b. Slowly pour in oil
   c. Create waves
      i. By tapping
      ii. By lifting corner of pan
   d. Create wind
      i. Using a straw
   e. Clean up oil with available materials
      i. Pipe cleaners
      ii. Cloth
      iii. Cotton balls
      iv. Etc.
3. Part III Clean up an oil spill
   a. Fill pan with water
   b. Create a beach
   c. Spill oil
   d. Clean up oil

Time Line for the Oil Rig Workshop

Introduction	10 minutes
Part I	20 minutes
Part II	40 minutes
Snack	10 minutes
Part III	40 minutes
Clean up	10 minutes
Conclusion	10 minutes
Discussion	10 minutes
Evaluation	10 minutes
Optional Activity	10 minutes

Safety Discussion

Oil is a toxic substance

- Wear eye protection
- Wear gloves
- Wear apron to keep oil from staining clothing
- If necessary, pin back hair
- Wash skin thoroughly with soap if it comes in contact with oil

Glue guns can be dangerous

- Work slowly and carefully with glue gun to ensure proper safety
- Cover work surface to protect table top
- Do not touch hot tip of glue gun
- Do not touch one another with glue gun
- Do not touch the hot glue as it comes out of the glue gun
- Wash skin thoroughly with soap if it comes in contact with glue

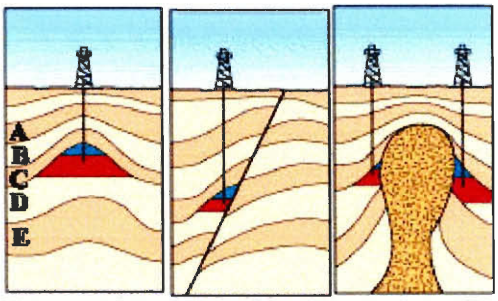
Objectives

- To provide a hands on interactive project in order to stimulate the camper's interest.
- To provide an activity that requires no special skills or talents in order to keep frustration level low.
- To show campers a real life application of several engineering disciplines
- To provide an affordable workshop in order to add value to the overall Camp Reach experience
- To provide a significantly different activity in order to keep the interest of the campers throughout the camping experience.
- To provide an exercise that does not duplicate 6^{th} or 7^{th} grade work to generate interest in engineering and technology and to enhance self-confidence and motivation toward education.
- To provide a repeatable activity that is easy to facilitate and prepare.
- To provide age-appropriate information in order keep frustration level low.

Introduction

Crude oil is a substance that occurs naturally. It is found trapped in certain rocks below the earth's crust. It is a dark, sticky liquid which, scientifically speaking, is classed as a hydrocarbon. Hydrocarbons are compounds containing only hydrogen and carbon. Because it is a hydrocarbon crude oil is highly flammable and can be burned to create energy.

Crude Oil
Courtesy of Syncrude Canada Ltd. Photographs



Oil reservoir rocks (red) and natural gas (blue) can be trapped by folding (left), faulting (middle) or pinching out (right).

It sometimes happens that the rocks that trap the oil are not only underground but also under water. In such cases the oil needs to be pumped from under the ocean or sea bottom. The pumps that are used in this case are called offshore oil rigs.

Offshore oil rig

Burning crude oil does not make use of its full potential. To extract the maximum value from crude, it first needs to be refined into other products. The best-known of these is gasoline, or petrol. However, other useful products that are not fuels can be manufactured by refining crude oil, such as lubricants and asphalt (used in paving roads). Also a range of sub-items like perfumes and insecticides are ultimately derived from crude oil. Furthermore, several of the products listed above which are derived from crude oil can themselves be used in the production of petrochemicals. There are more than 4,000 different petrochemical products, the main groups of which are plastics, synthetic fibers, synthetic rubbers, detergents and chemical fertilizers.

A ship designed for the carriage of oil in bulk is called an oil tanker. Her cargo space consists of several or many tanks that can store crude. Tankers load crude oil by gravity – by letting it flow into the lower cargo space on the ship from a higher storage tank on land, or by shore pumps – using specially designed pumps to pour the oil into the ship. Once the tanker has reached its destination the oil is usually pumped out of the ship, also using special pumps.

Courtesy of Odense Steel Shipyard Group

Double hull oil-tanker

When a tanker carrying crude runs aground, an oil spill may occur. In such cases hundreds of thousands of gallons of oil could be spilled into the ocean. (Read about Exxon Valdez tanker accident in appendix A.) This is not a regular occurrence, but accidents do happen. Offshore oil rigs can also be the cause of oil spills. If proper care is not taken during bad weather on the water the line connecting the rig and the oil well could break spilling oil into the water. Actually tanker and rig accidents contribute only about a tenth of the oil in our oceans. Other sources are storm-water runoff, leaks from storage facilities, and industrial processes. Cars use oil to run and after so many miles, that oil needs to be changed. Even if they change the oil correctly, they may not dispose of it properly. It should be taken to a gas station where it is picked up by a waste management company to be recycled or burned. If it isn't and instead emptied into landfills, storm drains, or backyards, it will carry toxic contaminants into ground water, streams, and lakes.

Oil spills on land, in oceans and fresh water lakes, can cause tremendous environmental damage to shorelines, wildlife habitat, drinking water supplies, wildlife, and private property. When an oil spill occurs a quick response by trained personnel, using the proper equipment, is required to contain and prevent the spill from traveling, which can cause additional damage. Oil spill cleanups and prevention require mechanical, chemical, and environmental engineers as well as high tech equipment, specialized materials and trained workers to work together. The engineers study behavior and interactions of oil, water, and various clean up methods and develop new and better ways to help both people and the environment. In this experiment you will be the team of engineers in charge of an oil spill clean up. Your goal is to explore and document oil and water interactions under various conditions. Analyze the workings and effectiveness of various clean up methods, then use your knowledge to effectively clean up an accidental oil spill.

Directions for Conducting Experiment

In this experiment you will learn about oil rigs, oil and water interaction, and environmental effects of oils spill.

Materials (per team)

1. Hot glue gun and sticks
2. Popsicle sticks
3. 2 Styrofoam cups
4. Puncturing device (cheap pen or pencil)
5. A bucket of water
6. 3 Styrofoam cups with oil labeled 1, 2, and 3.
7. Water
8. Smaller pan
9. Larger pan
10. Straw
11. Sand
12. Toy animals
13. Feathers
14. Pipe cleaners
15. Cloth
16. Cotton balls
17. Nylon stockings
18. Paper towels
19. Paper towels
20. Plastic spoons
21. Detergent
22. String
23. Pen
24. Cardboard piece to collect used materials
25. Sponge
26. Gloves
27. Safety goggles

Part I

In this part you will have 20 minutes to explore offshore oil rig design and build one of your own!

Step 1. Using available materials like hot glue and popsicle sticks, a styrofoam cup, and, of course, using your creativity, construct a structure that will support your cup and stand on the bottom of your pan. Do not connect the structure to the bottom of the pan.

Step 2. Secure the styrofoam cup onto your newly constructed oil rig.

Step 3. Try it out! Place your oil rig in the pan of water to be sure your oil rig can stand on the bottom of the pan without falling, tipping or floating. If not, make modifications to the oil rig until it does.

Step 4. When your oil rig is completed, draw it on the worksheet on page 10.

Note: The oil rig you have constructed is the type of oil rig that stands on the ocean floor and pumps most of the oil to the shore keeping some to use as fuel to pump more oil. When it is not possible to build a rig that stands on the bottom due to high water currents or when the bottom is too deep, a floating rig is constructed. In such cases, it is often impractical to pump the oil all the way to the shore, so the oil gets pumped directly into a tanker for delivery.

Part II

In this part you will have 40 minutes to explore oil and water interactions and develop methods to clean up an oil spill.

Step 1. If you have not already done so, fill one pan with water about ¾ of full. Also put on your gloves and goggles. This oil is not dangerous to touch, but can temporarily stain the skin and dangerous if you get it in your eyes.

Step 2. SLOWLY pour the oil into the water. Observe and record what happens to the oil and how it spreads.

Step 3. Create low amplitude waves by raising and lowering one corner of the pan. BE CAREFUL, make sure the pan does not over flow. Do the oil and water mix? Is one floating on top? Is the oil spreading any further or faster when waves are present? Observe and record your findings on the worksheet.

Step 4. Using a straw lightly blow air across the oil. What happens? Is the oil and water mixing? Separating? Is the oil moving? Observe and record your findings on the worksheet. **Do not** dip the straw in the oily water!

Step 5. Try to clean up the oil spill using some of the available materials at your station, except the detergent. Some methods work better than others, so try as many as you can. Once you've tried cleaning up the oil with different materials you may pour in the detergent and observe what happens. Record on the worksheet which methods you use, their effectiveness and how you judged it.

Step 6. Now that you have some understanding of water and oil interactions make a prediction about the effects of an oil spill on marine life. Is an oil spill a good or a bad thing? Why? What kinds of creatures might an oil spill at sea affect? Record in your worksheet.

Note: One noticeable difference between crude oil and used motor oil is the viscosity. Crude oil is more viscous (more gooey and thick) than used motor oil, but this does not change the results of the experiment.

Exxon Valdez Oil Tanker and Boom Containing an Oil Spill

Part III

You are now a team of engineers you have 40 minutes to complete your mission. Your mission is to clean up an oil spill that threatens a beach.

Step 1. In the pan provided, create a beach environment using the sand and water. Feel free to make trees and animals with some of the available material in order to simulate an actual beach environment. Do not to use all of your materials building the beach as you will need to use these materials to clean up the oil spill.

Step 2. Puncture the lower part of the side of the cup with a pencil. Tape the hole you just made until it is time to "spill" the oil.

Step 3. Carefully place the oil rig in the water. Fill the cup on your oil rig with oil. Take off the tape and observe and record what happens as the oil leaks out.

Step 4. You are free to use more than one method for the clean up. If the oil reaches the beach, observe its interaction with the sand and the environment. Record all your observations and methods of clean up.

Step 5. To explore what happens to animals that happen to wander into an oil contaminated environment, dip the fur and feathers into the oil. Attempt to remove the oil from the fur and feathers with any methods you choose. Record your methods and observations on the worksheet.

Worksheet

Draw your oil rig (Part I)	How did oil behave in the water when you first poured it in? (Part II)
How did oil behave in the water when you raised one side to create waves? (Part II)	How did oil behave in water when you blew on it through a straw? (Part II)

Write down your predictions of effects of an oil spill on marine life. (Part II)	Write down methods of clean up you used and how effective they were (Part II)
What happened as the oil leaked out of the oil rig? (Part III)	What methods did you use to clean up the oil rig spill? Why? (Part III)

What effects did the methods of cleanup you used have on the beach? (Part III)	What effects would oil have on fur covered animals? (Part III)
What effects would oil have on birds? (Part III)	**Final Conclusions (Part III)**

Clean up/ Disposal

1. Put away all the clean materials.

2. Place all oily materials including sand, water, and gloves into the disposal bins.

3. Wipe your work area with a soapy moist paper towel.

4. Dispose of the paper towels into the disposal bins.

5. Wash your hands and your goggles with dish washing liquid thoroughly in the bathroom.

Class Discussion Questions Asked by the Workshop Leader

1. What material and method was most successful in the water oil spill clean up? In the beach spill? Why?

2. What would you recommend be done to avoid water oil spills?

3. Speculate what would happen if an oil spill was not cleaned up?

4. Could clean up efforts cause further damage? How?

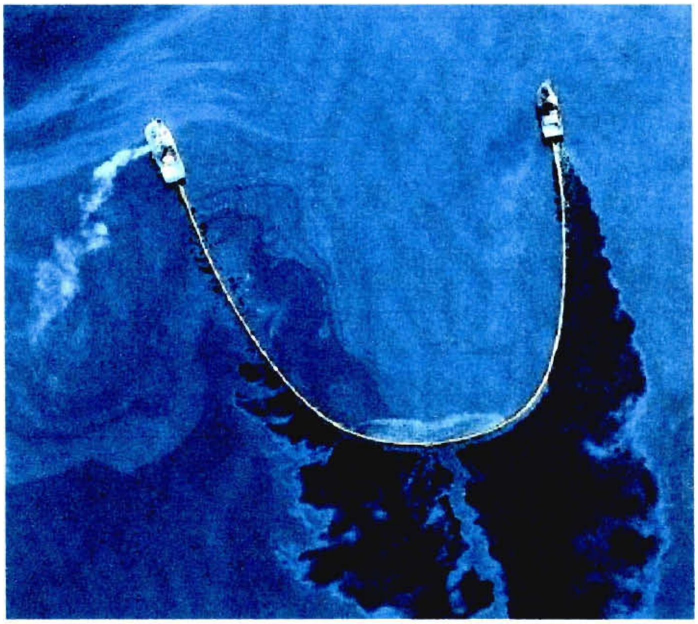
5. What effects might an oil spill have on people, animals, birds, and plants?

6. How might people be exposed to contaminants?

7. Can I myself do anything at all to prevent further marine oil pollution?

Alternative Clean-Up Methods

Boom Description



A boom is designed to work both on the water's surface, and just below. It is used as a barrier, deflector or an enclosure for collected oil. It is also used as an absorbent, and in conjunction with other techniques. A Boom is the backbone of most cleanup operations. It is stored in large rolls or accordion style to make for easy deployment off the side or stern of a ship. Some types of booms are very rugged and extend more than a foot above and two feet below the water line. Others booms extend only six inches above and below the waters surface. One of the downfalls of the boom is its need for constant attention. It quickly gets weighted down with oil and must be retrieved and cleaned. Thus, great manpower is used collecting, cleaning, transporting, and disposing of the boom.

Skimmer Description

A net of fluffy oil absorbent ropes is deployed behind the skimmer ship. This net is connected to the ship for quicker and easier collection.

Courtesy of OPEC Inc.

Once the net is fully deployed it is left in position and the skimmer ship begins to drag it until it is saturated with oil, the time needed for this depends on the thickness of the oil on the water, the size of the net, and the speed of the vessel.

Courtesy of OPEC Inc.

Once the net is saturated it is recovered, passing through the squeeze rollers and scrapers as it is wound onto the storage drum. The recovered oil falls into a collection tank where it is piped to the storage transport tanks by the integral transfer pumps. The cycle is then repeated.

Courtesy of OPEC Inc.

Sorbent Description

Adsorption is the process that causes one substance to be attracted to and stick to the surface of another substance, without actually penetrating its surface. This is different from absorption, where one substance penetrates the inside of another substance. In the case of oil spill clean-up, oil is drawn into porous sorbent materials. The picture below shows adsorbent material because the oil gets collected on its outside.

Courtesy of OPEC Inc.

In-Situ Burning Description

The IXTOC I exploratory well blew out on June 3, 1979 in the Bay of Campeche off Ciudad del Carmen, Mexico. By the time the well was brought under control in 1980, an estimated 140 million gallons of oil had spilled into the bay. Since crude oil is highly flammable, sometimes the easiest method of clean up is burning the oil off the surface of the water. This is called In-Situ burning and was chosen for this accident. In-Situ means "in place". The oil is not collected or moved but instead just set on fire where it is.

Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Bioremediation Description

Bioremediation is the application of fertilizers to increase the number of oil-eating microbes. The microbes that break up the oil do so by using the carbon found in the oil. Without the carbon, the oil breaks up as it loses its molecular bond.

Included in the down side of using these fertilizers are the unknown effects of releasing large concentrated amounts of nitrogen and phosphorus into the environment. Another drawback is the lethal properties large amounts of these chemicals have until portions of these chemicals evaporate.

High Pressure Washing Description

In this treatment method, used on many Prince William Sound beaches, oil is hosed from beaches, collected within a floating boom, then skimmed from the water surface. When crews cleaned a beach with high-pressure, hot-water washing, booms were used to prevent oil refloated by the cleaning operation from escaping back into Prince William Sound.

Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Workers use high-pressure, hot-water washing to clean an oiled shoreline.

The top photo shows a section of the Block Island coastline before treatment by high-pressure, hot-water washing; the lower photo shows the same section during high-pressure, hot-water washing.

Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

In the photo below, note the small black patch of refloated oil (next to the inner boom, on the right-hand side of the photo) ready to be skimmed, and the brown plume of oil and sediment drifting outwards from the beach.

Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Dispersants Description

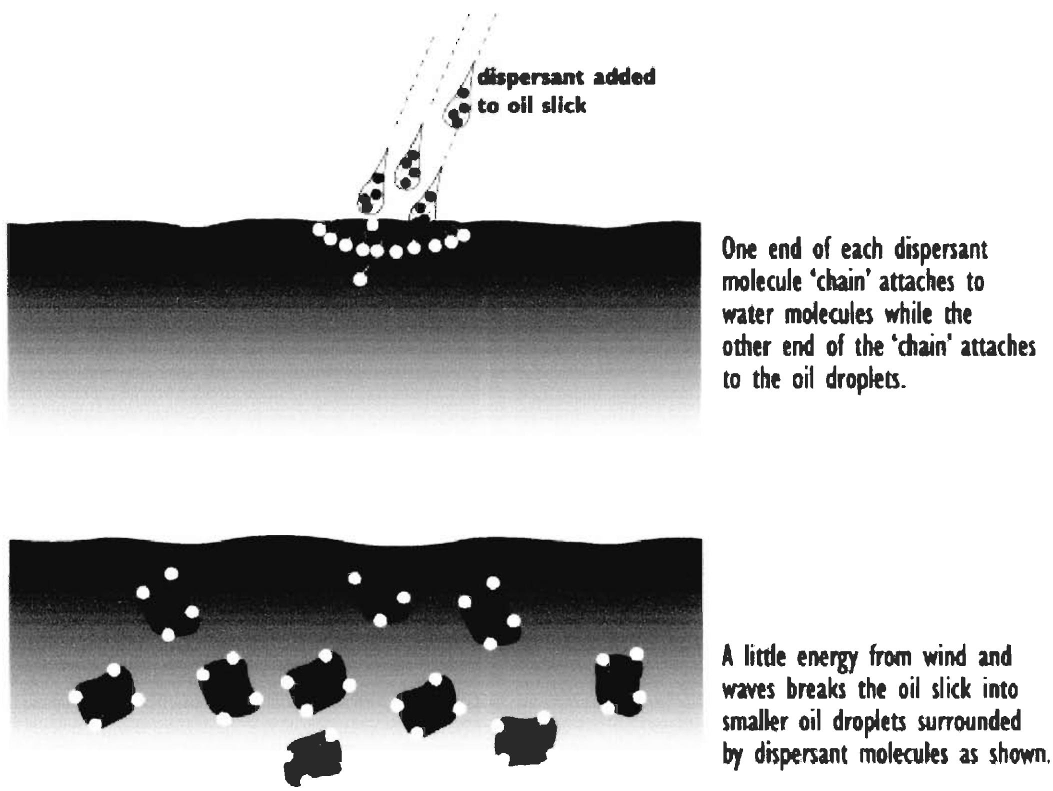
Dispersants are chemicals that are applied directly to the spilled oil in order to remove it from the water surface, where oil can be especially harmful. In the photo below, an airplane is applying dispersant to an oil slick.

Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Oil slicks on the water surface are particularly dangerous to seabirds and fur-bearing marine mammals. Dispersing an oil slick can prevent oil from coming ashore, minimizing the impact to biologically sensitive shoreline environments. Oil also interferes with the animal's or bird's ability to maintain its body temperature, often resulting in death from hypothermia. Sea otters are especially vulnerable. Removing oil from the sea surface as quickly as possible reduces the risk to birds and mammals.

Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Dispersants work much like the detergent soap that you use to clean grease from your dishes (but dispersants are less toxic). They contain molecules with a water-compatible ("hydrophilic") end and an oil-compatible ("lipophilic") end. These molecules attach to the oil, reducing the tension between oil and water, breaking up the oil spill.



Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Initially, dispersed oil moves down into the water column to depths ranging from 1 to 10 meters (about 3 to 30 feet). To avoid contaminating the sea floor, most dispersant use to date has been restricted to waters deeper than 10 meters (about 30 feet). Concentrations of dispersed oil drop within hours as currents and waves disperse the oil even further. Eventually, dispersed oil droplets degrade into naturally occurring substances.

Vocabulary

Absorption
Any process that causes one substance to penetrate the inside of another substance. In the case of oil spill clean-up, oil is drawn into porous sorbent materials.

Adsorption
The process that causes one substance to be attracted to and stick to the surface of another substance, without actually penetrating its surface.

Aromatic hydrocarbon
Carbon-hydrogen compound characterized by the presence of at least one six-carbon ring structure.

Bioremediation
The process of accelerating the rate of natural bio-degradation of hydrocarbons by adding fertilizer to provide nitrogen and phosphorus. Following a spill, there are too few of these chemicals compared with the amount of hydrocarbons.

Blowout
Uncontrolled flow of oil or gas from a well which occurs when formation pressure exceeds the pressure applied to it by the column of drilling fluid. Every modern rig has a set of large control valves, known as blowout preventers, to stop the flow of oil, gas and other well fluids if problems occur during drilling.

Boom
Containment booms are used to control the spread of oil to reduce the possibility of polluting shorelines and other resources, as well as to concentrate oil in thicker surface layers, making recovery easier.

Crude oil (crude oil petroleum)
A fossil fuel formed from plant and animal remains many million of years ago. It comprises organic compounds built up from hydrogen and carbon atoms and is, accordingly, often referred to as hydrocarbons. Crude oil is occasionally found in springs or pools but is usually drilled from wells beneath the earth's surface.

Crude oil tanker
An oil tanker engaged in the trade of carrying crude oil.

Crude oil washing
Crude oil washing (COW) is a system whereby oil tanks on a tanker are cleaned out between voyages not with water, but with crude oil - the cargo itself. The solvent action of the crude oil makes the cleaning process far more effective than when water is used. COW is mandatory on new tankers under the International Convention for the Prevention of Pollution by Ships.

Dispersant - Dispersing agent
Chemicals that are used to break down spilled oil in small droplets.

Hydrocarbons
A large group of organic compounds containing only carbon and hydrogen; common in petroleum products, vegetable oils etc.

Mechanical containment
The most common type of equipment for mechanical containment of oil following a spill is floating barriers, i.e., different types of booms, barriers and skimmers

Mechanical recovery
Recovery of oil from the water surface by mechanical means, e.g. skimmers and booms.

Oil seep
Crude oil and natural gas seeps naturally out of fissures in the ocean seabed and eroding sedimentary rock. These seeps are natural springs where liquid and gaseous hydrocarbons leak out of the ground (like springs that ooze oil and gas instead of water).

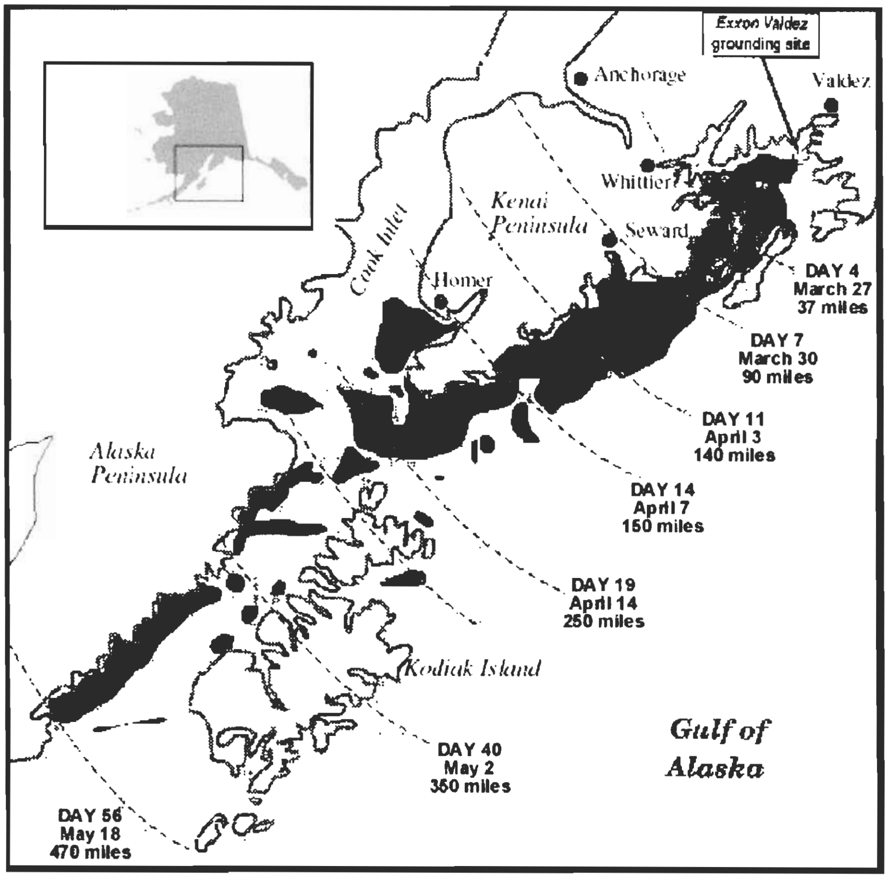
Oil slick
A layer of oil floating on the surface of water.

Oil spill
Accidental release of oil into the marine or terrestrial environment.

Skimmer
A skimmer is a device for recovering spilled oil from the water's surface. Skimmers may be self-propelled, used from the shore, or operated from vessels.

Sorbents
Substances that take up and hold water or oil. Sorbents that are used in oil spill cleanup are made of oleophilic materials.

Appendix A



<u>Exxon Valdez</u>

Length: 987 feet

Beam: 166 feet

Draft: 64 feet

Displacement: 211,469 tons

Maximum Speed: 16 knots

Capacity: 1.48 million barrels

Complement: 21 crew

The story

The Exxon Valdez departed from the Trans Alaska Pipeline terminal at 9:12 pm March 23, 1989. William Murphy, an expert ship's pilot hired to maneuver the 986-foot vessel through the Valdez Narrows, was in control of the wheelhouse. At his side was the captain of the vessel, Joe Hazelwood. Helmsman Harry Claar was steering. After passing through Valdez Narrows, pilot Murphy left the vessel and Captain Hazelwood took over the wheelhouse. The Exxon Valdez encountered icebergs in the shipping lanes and Captain Hazelwood ordered Claar to take the Exxon Valdez out of the shipping lanes to go around the icebergs. He then handed over control of the wheelhouse to Third Mate Gregory Cousins with precise instructions to turn back into the shipping lanes when the tanker reached a certain point. At that time, Claar was replaced by Helmsman Robert Kagan. For reasons that remain unclear, Cousins and Kagan failed to make the turn back into the shipping lanes and the ship ran aground on Bligh Reef at 12:04 am March 24, 1989. Captain Hazelwood was in his quarters at the time.

Get a sense of the size of an oil tanker (optional)

Materials:

1 **Exxon Valdez facts (Appendix A)**
2 **50 ft of Rope per group**
3 **(optional) graph paper – 1 sheet per group**
4 **(optional) pencils**
5 **(optional) rulers – 1 per group**

1. Ask students to share any knowledge they have about oil spills in the news.
2. Tell the story and discuss the length of a medium-sized tanker like the Exxon Valdez.
3. Measure the size of the Exxon Valdez outside your school and mark its size on the pavement to show to other students. Ask students to brainstorm various possible measuring strategies.
4. Using a tape measure, mark off a 50-foot or 100-foot piece of string or rope. Students simply lay the string down, making sure to accurately mark and record the number of times they step and repeat. As an example, using a 100-foot length, it would be necessary to step and repeat 10 times to lay out the distance of 1,000 feet.
5. Students can also measure the distance of their average stride. As an example, the stride of an adult is close to 3 feet. Knowing this, it is easy to estimate distances by counting the number of strides needed to cover a certain distance and multiply the number of strides by three (3 feet per stride). Allow students the opportunity

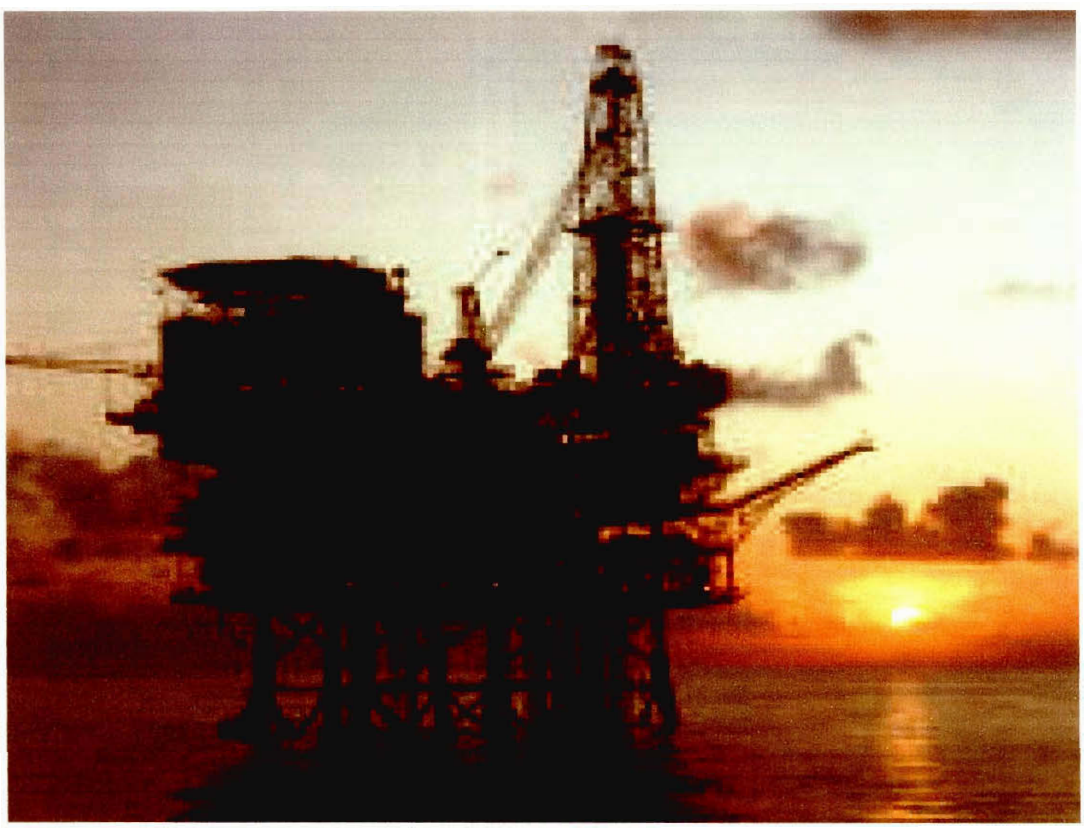
to determine their stride and then check for accuracy with a predetermined distance.

6. (optional) With the outside work complete, distribute a piece of graph paper (8 1/2" x 11") to students and ask them to determine the scale which would allow for the Exxon Valdez to be sketched on the graph paper. An appropriate scale, assuming that you are using 1/4" grid paper, would be to have each square equal 25 feet. See if the students can determine the scale for themselves first.

APPENDIX C: Teacher Manual

Designing and Building an Oil Rig

And Oil Spill Clean Up



Designing and Building an Oil Rig
And Oil Spill Clean up

Activity Outline

4. Part I Design and build and oil rig
    a. Materials
        i. Styrofoam cup
        ii. Popsicle sticks
        iii. Glue gun,
    b. Specifications
        i. Using popsicle sticks and a glue gun, design a structure that will hold a Styrofoam cup above the water line to act as an offshore oil rig.
5. Part II Oil and water interaction
    a. Fill pan with water
    b. Slowly pour in oil
    c. Create waves
        i. By tapping
        ii. By lifting corner of pan
    d. Create wind
        i. Using a straw
    e. Clean up oil with available materials
        i. Pipe cleaners
        ii. Cloth
        iii. Cotton balls
        iv. Etc.
6. Part III Clean up an oil spill
    a. Fill pan with water
    b. Create a beach
    c. Spill oil
    d. Clean up oil

Time Line for the Oil Rig Workshop

Introduction	10 minutes
Part I	20 minutes
Part II	40 minutes
Snack	10 minutes
Part III	40 minutes
Clean up	10 minutes
Conclusion	10 minutes
Discussion	10 minutes
Evaluation	10 minutes
Optional Activity	10 minutes

Safety Discussion

Oil is a toxic substance

- Wear eye protection
- Wear gloves
- Wear apron to keep oil from staining clothing
- If necessary, pin back hair
- Wash skin thoroughly with soap if it comes in contact with oil

Glue guns can be dangerous

- Work slowly and carefully with glue gun to ensure proper safety
- Cover work surface to protect table top
- Do not touch hot tip of glue gun
- Do not touch one another with glue gun
- Do not touch the hot glue as it comes out of the glue gun
- Wash skin thoroughly with soap if it comes in contact with glue

Objectives

- To provide a hands on interactive project in order to stimulate the camper's interest.
- To provide an activity that requires no special skills or talents in order to keep frustration level low.
- To show campers a real life application of several engineering disciplines
- To provide an affordable workshop in order to add value to the overall Camp Reach experience
- To provide a significantly different activity in order to keep the interest of the campers throughout the camping experience.
- To provide an exercise that does not duplicate 6th or 7th grade work to generate interest in engineering and technology and to enhance self-confidence and motivation toward education.
- To provide a repeatable activity that is easy to facilitate and prepare.
- To provide age-appropriate information in order keep frustration level low.

Workshop Preparation Instructions

(Please read entire packet carefully)

Materials

1. *Four days prior to workshop date set up a meeting with Dave Messier (WPI Mgr Environment & Occupational Safety at dmessier@WPI.EDU) to set up a way to receive disposal bins for the oiled workshop waste and set up for return of the bins. Plan to have half a trash bag of solid waste and 3 quarts of liquid (and sand) waste per team.*

2. *Contact a Jiffy Lube or similar business and arrange a way to receive about 5.5 quarts (for 30 students) of used motor oil. Oil should be transported in a plastic container with a secure screw cap. Place the filled container into a plastic bag for further security*

3. *Collect the rest of the needed materials, in amounts specified on the materials and costs sheet for each group. All participants will be separated to work in groups of 3.*

4. *For class demo of adsorbents prepare the following:*
    a. *Sorbent sheets. These may be provided by Dave Messier if they are requested in advance and are available, or, if this is not the case, they can be ordered from a manufacturer such as Opec (http://www.opec.co.uk/opec/index.html).*
    b. *Pan. This pan could be same size as those provided to participants.*
    c. *Water. Enough to fill pan about ¾ full.*

5. *Prepare for each student a copy of the student manual for the experiment.*

Room

1. *Ensure the presence of a computer that is able to project onto a large screen. The computer should be equipped with Power Point software and have access to the internet.*

2. *Ensure that the room has electrical outlets for hot glue guns*

3. *Consider providing instructions and materials for the optional activity (page 26 of this document).*

Prior to Workshop

1. *Review and practice the introduction and alternate methods Power Point presentations on the large projection screen in the room that the experiment will be performed in to get familiar with technology and surroundings.*
2. *Prepare the materials.*
3. *If necessary, practice the experiment.*
4. *Read disposal instructions.*
5. *Study the class discussion questions and answers on page 16 of this document.*
6. *If necessary, practice the demos and descriptions.*
7. *Review vocabulary.*
8. *Review optional activity. If you choose to prepare for it make copies for each student of page 26, and prepare materials listed on page 26 as specified.*
9. *Instructions written in italics do not appear in student manual.*

Day of Workshop

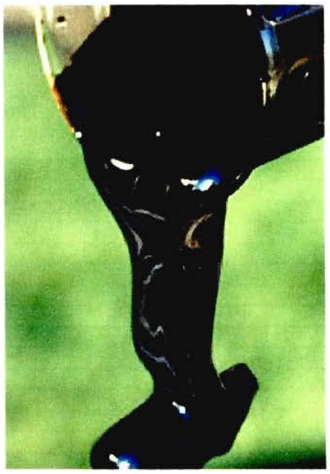
1. *Prepare the room and the Power Point presentation.*
2. *Prepare the materials such that there is a station for each group. Place all clean-up materials inside the pans placed at each station. Keep the water, sand and dish soap at the teacher's station, and supply the students as needed.*
3. *Fill three cups per group with 5 oz. of used motor oil, for each of the three parts of the workshop.*
4. *Prepare the extra pan filled with water about ¾ full, left over used motor oil and sorbent pads for the sorbent demonstration at the teacher's station.*
5. *Separate girls into groups of three.*

Demo Instructions

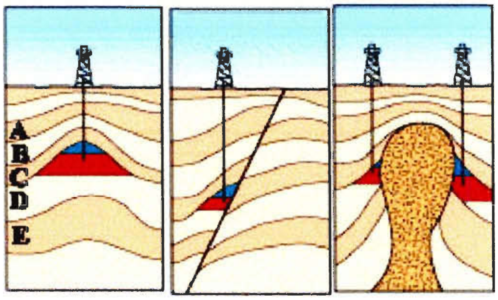
1. *Fill the extra pan ¾ full of water.*
2. *Pour left over used motor oil slowly into the water. If the oil is not poured slowly it may get partially trapped on the bottom of the pan due to water pressure.*
3. *Place the adsorbent sheet on top of the oily water, do not push it under the surface.*
4. *Let the oil soak into the sheet for approximately 7-10 sec.*
5. *Now you can pick up the sheet and show the students that the oil is stuck to it though not all oil may be picked by at that time.*
6. *You may need to use more than one sheet to collect all the oil of the surface of the water.*

Introduction

Crude oil is a substance that occurs naturally. It is found trapped in certain rocks below the earth's crust. It is a dark, sticky liquid which, scientifically speaking, is classed as a hydrocarbon. Hydrocarbons are compounds containing only hydrogen and carbon. Because it is a hydrocarbon crude oil is highly flammable and can be burned to create energy.



Crude Oil
Courtesy of Syncrude Canada Ltd. Photographs



Oil reservoir rocks (red) and natural gas (blue) can be trapped by folding (left), faulting (middle) or pinching out (right).

It sometimes happens that the rocks that trap the oil are not only underground but also under water. In such cases the oil needs to be pumped from under the ocean or sea bottom. The pumps that are used in this case are called offshore oil rigs.

Offshore oil rig

Burning crude oil does not make use of its full potential. To extract the maximum value from crude, it first needs to be refined into other products. The best-known of these is gasoline, or petrol. However, other useful products that are not fuels can be manufactured by refining crude oil, such as lubricants and asphalt (used in paving roads). Also a range of sub-items like perfumes and insecticides are ultimately derived from crude oil. Furthermore, several of the products listed above which are derived from crude oil can themselves be used in the production of petrochemicals. There are more than 4,000 different petrochemical products, the main groups of which are plastics, synthetic fibers, synthetic rubbers, detergents and chemical fertilizers.

A ship designed for the carriage of oil in bulk is called an oil tanker. Her cargo space consists of several or many tanks that can store crude. Tankers load crude oil by gravity – by letting it flow into the lower cargo space on the ship from a higher storage tank on land, or by shore pumps – using specially designed pumps to pour the oil into the ship. Once the tanker has reached its destination the oil is usually pumped out of the ship, also using special pumps.

Courtesy of Odense Steel Shipyard Group

Double hull oil-tanker

When a tanker carrying crude runs aground, an oil spill may occur. In such cases hundreds of thousands of gallons of oil could be spilled into the ocean. (Read about Exxon Valdez tanker accident in appendix A.) This is not a regular occurrence, but accidents do happen. Offshore oil rigs can also be the cause of oil spills. If proper care is not taken during bad weather on the water the line connecting the rig and the oil well could break spilling oil into the water. Actually tanker and rig accidents contribute only about a tenth of the oil in our oceans. Other sources are storm-water runoff, leaks from storage facilities, and industrial processes. Cars use oil to run and after so many miles, that oil needs to be changed. Even if they change the oil correctly, they may not dispose of it properly. It should be taken to a gas station where it is picked up by a waste management company to be recycled or burned. If it isn't and instead emptied into landfills, storm drains, or backyards, it will carry toxic contaminants into ground water, streams, and lakes.

Oil spills on land, in oceans and fresh water lakes, can cause tremendous environmental damage to shorelines, wildlife habitat, drinking water supplies, wildlife, and private property. When an oil spill occurs a quick response by trained personnel, using the proper equipment, is required to contain and prevent the spill from traveling, which can cause additional damage. Oil spill cleanups and prevention require mechanical, chemical, and environmental engineers as well as high tech equipment, specialized materials and trained workers to work together. The engineers study behavior and interactions of oil, water, and various clean up methods and develop new and better ways to help both people and the environment. In this experiment you will be the team of engineers in charge of an oil spill clean up. Your goal is to explore and document oil and water interactions under various conditions. Analyze the workings and effectiveness of various clean up methods, then use your knowledge to effectively clean up an accidental oil spill.

Directions for Conducting Experiment

In this experiment you will learn about oil rigs, oil and water interaction, and environmental effects of oils spill.

Materials (per team)

28. Hot glue gun and sticks
29. Popsicle sticks
30. 2 Styrofoam cups
31. Puncturing device (cheap pen or pencil)
32. A bucket of water
33. 3 Styrofoam cups with oil labeled 1, 2, and 3.
34. Water
35. Smaller pan
36. Larger pan
37. Straw
38. Sand
39. Toy animals
40. Feathers
41. Pipe cleaners
42. Cloth
43. Cotton balls
44. Nylon stockings
45. Paper towels
46. Paper towels
47. Plastic spoons
48. Detergent
49. String
50. Pen
51. Cardboard piece to collect used materials
52. Sponge
53. ***Dish soap***
54. Gloves
55. Safety goggles

Part I

In this part you will have 20 minutes to explore offshore oil rig design and build one of your own!

Step 1. Using available materials like hot glue and popsicle sticks, a styrofoam cup, and, of course, using your creativity, construct a structure that will support your cup and stand on the bottom of your pan. Do not connect the structure to the bottom of the pan.

Step 2. Secure the styrofoam cup onto your newly constructed oil rig.

Step 3. Try it out! Place your oil rig in the pan of water to be sure your oil rig can stand on the bottom of the pan without falling, tipping or floating. If not, make modifications to the oil rig until it does.

Step 4. When your oil rig is completed, draw it on the worksheet on page 10. ***Page 12 in teacher's manual.***

Note: The oil rig you have constructed is the type of oil rig that stands on the ocean floor and pumps most of the oil to the shore keeping some to use as fuel to pump more oil. When it is not possible to build a rig that stands on the bottom due to high water currents or when the bottom is too deep, a floating rig is constructed. In such cases, it is often impractical to pump the oil all the way to the shore, so the oil gets pumped directly into a tanker for delivery.

Part II

In this part you will have 40 minutes to explore oil and water interactions and develop methods to clean up an oil spill.

Step 1. If you have not already done so, fill one pan with water about ¾ of full. Also put on your gloves and goggles. This oil is not dangerous to touch, but can temporarily stain the skin and dangerous if you get it in your eyes.

Step 2. SLOWLY pour the oil into the water. Observe and record what happens to the oil and how it spreads.

Step 3. Create low amplitude waves by raising and lowering one corner of the pan. BE CAREFUL, make sure the pan does not over flow. Do the oil and water mix? Is one floating on top? Is the oil spreading any further or faster when waves are present? Observe and record your findings on the worksheet.

Step 4. Using a straw lightly blow air across the oil. What happens? Is the oil and water mixing? Separating? Is the oil moving? Observe and record your findings on the worksheet. **Do not** dip the straw in the oily water!

Step 5. Try to clean up the oil spill using some of the available materials at your station, except the detergent. Some methods work better than others, so try as many as you can. Once you've tried cleaning up the oil with different materials you may pour in the detergent and observe what happens. Record on the worksheet which methods you use, their effectiveness and how you judged it.

Step 6. Now that you have some understanding of water and oil interactions make a prediction about the effects of an oil spill on marine life. Is an oil spill a good or a bad thing? Why? What kinds of creatures might an oil spill at sea affect? Record in your worksheet.

Note: One noticeable difference between crude oil and used motor oil is the viscosity. Crude oil is more viscous (more gooey and thick) than used motor oil, but this does not change the results of the experiment.

Exxon Valdez Oil Tanker and Boom Containing an Oil Spill

Part III

You are now a team of engineers you have 40 minutes to complete your mission. Your mission is to clean up an oil spill that threatens a beach.

Step 1. In the pan provided, create a beach environment using the sand and water. Feel free to make trees and animals with some of the available material in order to simulate an actual beach environment. Do not to use all of your materials building the beach as you will need to use these materials to clean up the oil spill.

Step 2. Puncture the lower part of the side of the cup with a pencil. Tape the hole you just made until it is time to "spill" the oil.

Step 3. Carefully place the oil rig in the water. Fill the cup on your oil rig with oil. Take off the tape and observe and record what happens as the oil leaks out.

Step 4. You are free to use more than one method for the clean up. If the oil reaches the beach, observe its interaction with the sand and the environment. Record all your observations and methods of clean up.

Step 5. To explore what happens to animals that happen to wander into an oil contaminated environment, dip the fur and feathers into the oil. Attempt to remove the oil from the fur and feathers with any methods you choose. Record your methods and observations on the worksheet.

Worksheet

Draw your oil rig (Part I)	How did oil behave in the water when you first poured it in? (Part II)
How did oil behave in the water when you raised one side to create waves? (Part II)	How did oil behave in water when you blew on it through a straw? (Part II)

Write down your predictions of effects of an oil spill on marine life. (Part II)	Write down methods of clean up you used and how effective they were (Part II)
What happened as the oil leaked out of the oil rig? (Part III)	What methods did you use to clean up the oil rig spill? Why? (Part III)

What effects did the methods of cleanup you used have on the beach? (Part III)	What effects would oil have on fur covered animals? (Part III)
What effects would oil have on birds? (Part III)	Final Conclusions (Part III)

Clean up/ Disposal

Contact Dave Messier (dmessier@WPI.EDU) four days prior to the workshop for his disposal instructions.

6. Put away all the clean materials.

7. Place all oily materials including sand, water, and gloves into the disposal bins.

8. Wipe your work area with a soapy moist paper towel.

9. Dispose of the paper towels into the disposal bins.

10. Wash your hands and your goggles with dish washing liquid thoroughly in the bathroom.

After the workshop return the waste bins to Dave Messier.

Class Discussion Questions Asked by the Workshop Leader

5. What material and method was most successful in the water oil spill clean up? In the beach spill? Why?
6. What would you recommend be done to avoid water oil spills?

   Well-trained crews - Strict fire safety regulations on board - Better navigational equipment - Traffic separation schemes in busy shipping corridors - Frequent inspection of ship - Further improvements of ship's designs - Better facilities in ports for ships to leave oily liquid waste.

7. Speculate what would happen if an oil spill was not cleaned up?
   - *Oil does not dissipate, evaporate or disintegrate, but floats*
   - *Wildlife and people affected*
   - *Pollution would spread*
8. Could clean up efforts cause further damage? How?
   - *Chemicals used can cause harm to wildlife and vegetation*
   - *Heavy equipment and machinery may destroy animal habitat*

5. What effects might an oil spill have on people, animals, birds, and plants?
   - *Pneumonia, congested lungs, intestinal or lung hemorrhage, kidney damage*
   - *Begin a discussion on how animal's fur and bird's feathers act as insulation. Ask students if they have ever been caught in the rain in a wool sweater. Did they get cold? Were they wearing other layers of clothes that kept them warm? Contrast the insulation that seals have (blubber) and otters don't (no excess body fat). What difference does that make when their coat becomes oil-soaked?*

6. How might people be exposed to contaminants?
   - *People can be exposed through the water they drink, air they breathe, or by eating contaminated crops, fish, or meat.*

7. Can I myself do anything at all to prevent further marine oil pollution?
   - *Don't flush oil into the sewers or pour it into the storm sewer systems*
   - *Clean up spilled oil on the ground and don't hose it into the street, where they can eventually reach local streams and lakes.*
   - *Leave used engine oil for recycling.*
   - *Reduce your private consumption of fossil fuels, including oils, by using a bus or carpool whenever possible.*

Alternative Clean-Up Methods

Boom Description

A boom is designed to work both on the water's surface, and just below. It is used as a barrier, deflector or an enclosure for collected oil. It is also used as an absorbent, and in conjunction with other techniques. A Boom is the backbone of most cleanup operations. It is stored in large rolls or accordion style to make for easy deployment off the side or stern of a ship. Some types of booms are very rugged and extend more than a foot above and two feet below the water line. Others booms extend only six inches above and below the waters surface. One of the downfalls of the boom is its need for constant attention. It quickly gets weighted down with oil and must be retrieved and cleaned. Thus, great manpower is used collecting, cleaning, transporting, and disposing of the boom.

Skimmer Description

A net of fluffy oil absorbent ropes is deployed behind the skimmer ship. This net is connected to the ship for quicker and easier collection.

Courtesy of OPEC Inc.

Once the net is fully deployed it is left in position and the skimmer ship begins to drag it until it is saturated with oil, the time needed for this depends on the thickness of the oil on the water, the size of the net, and the speed of the vessel.

Courtesy of OPEC Inc.

Once the net is saturated it is recovered, passing through the squeeze rollers and scrapers as it is wound onto the storage drum. The recovered oil falls into a collection tank where it is piped to the storage transport tanks by the integral transfer pumps. The cycle is then repeated.

Courtesy of OPEC Inc.

Sorbent Description

Adsorption is the process that causes one substance to be attracted to and stick to the surface of another substance, without actually penetrating its surface. This is different from absorption, where one substance penetrates the inside of another substance. In the case of oil spill clean-up, oil is drawn into porous sorbent materials. The picture below shows adsorbent material because the oil gets collected on its outside.

Courtesy of OPEC Inc.

In-Situ Burning Description

The IXTOC I exploratory well blew out on June 3, 1979 in the Bay of Campeche off Ciudad del Carmen, Mexico. By the time the well was brought under control in 1980, an estimated 140 million gallons of oil had spilled into the bay. Since crude oil is highly flammable, sometimes the easiest method of clean up is burning the oil off the surface of the water. This is called In-Situ burning and was chosen for this accident. In-Situ means "in place". The oil is not collected or moved but instead just set on fire where it is.

Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Bioremediation Description

Bioremediation is the application of fertilizers to increase the number of oil-eating microbes. The microbes that break up the oil do so by using the carbon found in the oil. Without the carbon, the oil breaks up as it loses its molecular bond.

Included in the down side of using these fertilizers are the unknown effects of releasing large concentrated amounts of nitrogen and phosphorus into the environment. Another drawback is the lethal properties large amounts of these chemicals have until portions of these chemicals evaporate.

High Pressure Washing Description

In this treatment method, used on many Prince William Sound beaches, oil is hosed from beaches, collected within a floating boom, then skimmed from the water surface. When crews cleaned a beach with high-pressure, hot-water washing, booms were used to prevent oil refloated by the cleaning operation from escaping back into Prince William Sound.

Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Workers use high-pressure, hot-water washing to clean an oiled shoreline.

The top photo shows a section of the Block Island coastline before treatment by high-pressure, hot-water washing; the lower photo shows the same section during high-pressure, hot-water washing.

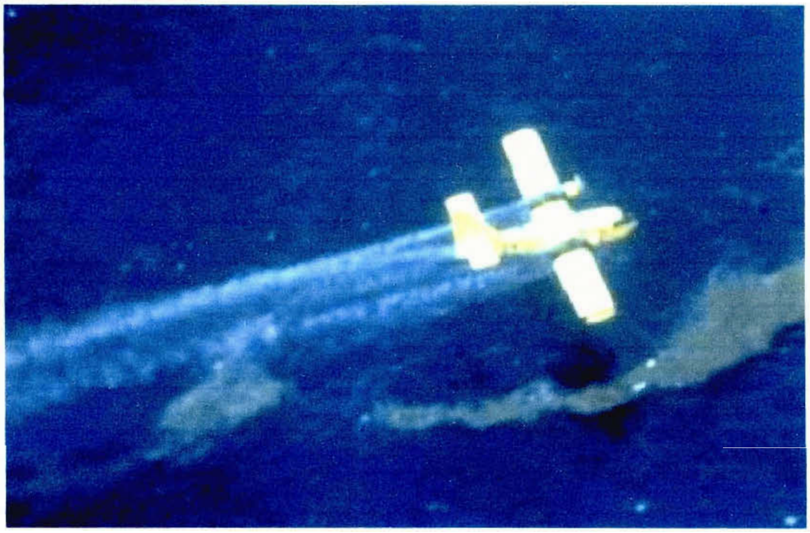
Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

In the photo below, note the small black patch of refloated oil (next to the inner boom, on the right-hand side of the photo) ready to be skimmed, and the brown plume of oil and sediment drifting outwards from the beach.

Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Dispersants Description

Dispersants are chemicals that are applied directly to the spilled oil in order to remove it from the water surface, where oil can be especially harmful. In the photo below, an airplane is applying dispersant to an oil slick.

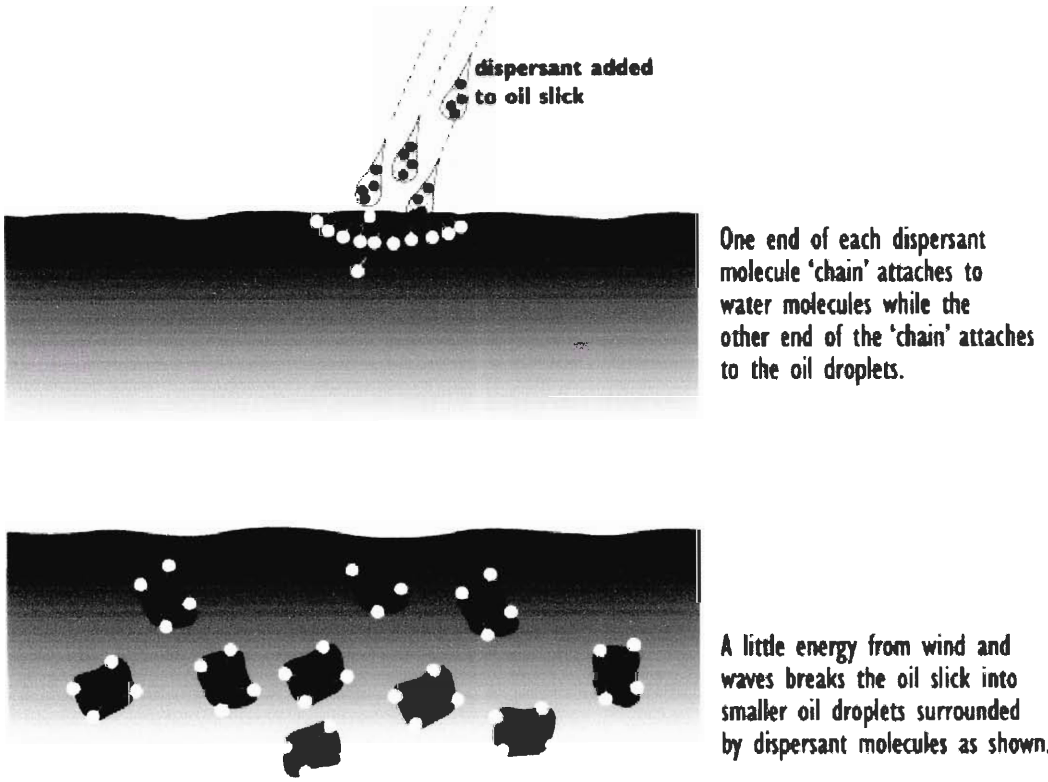


Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Oil slicks on the water surface are particularly dangerous to seabirds and fur-bearing marine mammals. Dispersing an oil slick can prevent oil from coming ashore, minimizing the impact to biologically sensitive shoreline environments. Oil also interferes with the animal's or bird's ability to maintain its body temperature, often resulting in death from hypothermia. Sea otters are especially vulnerable. Removing oil from the sea surface as quickly as possible reduces the risk to birds and mammals.

Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Dispersants work much like the detergent soap that you use to clean grease from your dishes (but dispersants are less toxic). They contain molecules with a water-compatible ("hydrophilic") end and an oil-compatible ("lipophilic") end. These molecules attach to the oil, reducing the tension between oil and water, breaking up the oil spill.



Courtesy of Office of Response and Restoration, National Ocean Service, National Oceanic and Atmospheric Administration

Initially, dispersed oil moves down into the water column to depths ranging from 1 to 10 meters (about 3 to 30 feet). To avoid contaminating the sea floor, most dispersant use to date has been restricted to waters deeper than 10 meters (about 30 feet). Concentrations of dispersed oil drop within hours as currents and waves disperse the oil even further. Eventually, dispersed oil droplets degrade into naturally occurring substances.

Vocabulary

Absorption
Any process that causes one substance to penetrate the inside of another substance. In the case of oil spill clean-up, oil is drawn into porous sorbent materials.

Adsorption
The process that causes one substance to be attracted to and stick to the surface of another substance, without actually penetrating its surface.

Aromatic hydrocarbon
Carbon-hydrogen compound characterized by the presence of at least one six-carbon ring structure.

Bioremediation
The process of accelerating the rate of natural bio-degradation of hydrocarbons by adding fertilizer to provide nitrogen and phosphorus. Following a spill, there are too few of these chemicals compared with the amount of hydrocarbons.

Blowout
Uncontrolled flow of oil or gas from a well which occurs when formation pressure exceeds the pressure applied to it by the column of drilling fluid. Every modern rig has a set of large control valves, known as blowout preventers, to stop the flow of oil, gas and other well fluids if problems occur during drilling.

Boom
Containment booms are used to control the spread of oil to reduce the possibility of polluting shorelines and other resources, as well as to concentrate oil in thicker surface layers, making recovery easier.

Crude oil (crude oil petroleum)
A fossil fuel formed from plant and animal remains many million of years ago. It comprises organic compounds built up from hydrogen and carbon atoms and is, accordingly, often referred to as hydrocarbons. Crude oil is occasionally found in springs or pools but is usually drilled from wells beneath the earth's surface.

Crude oil tanker
An oil tanker engaged in the trade of carrying crude oil.

Crude oil washing
Crude oil washing (COW) is a system whereby oil tanks on a tanker are cleaned out between voyages not with water, but with crude oil - the cargo itself. The solvent action of the crude oil makes the cleaning process far more effective than when water is used. COW is mandatory on new tankers under the International Convention for the Prevention of Pollution by Ships.

Dispersant - Dispersing agent
Chemicals that are used to break down spilled oil in small droplets.

Hydrocarbons
A large group of organic compounds containing only carbon and hydrogen; common in petroleum products, vegetable oils etc.

Mechanical containment
The most common type of equipment for mechanical containment of oil following a spill is floating barriers, i.e., different types of booms, barriers and skimmers

Mechanical recovery
Recovery of oil from the water surface by mechanical means, e.g. skimmers and booms.

Oil seep
Crude oil and natural gas seeps naturally out of fissures in the ocean seabed and eroding sedimentary rock. These seeps are natural springs where liquid and gaseous hydrocarbons leak out of the ground (like springs that ooze oil and gas instead of water).

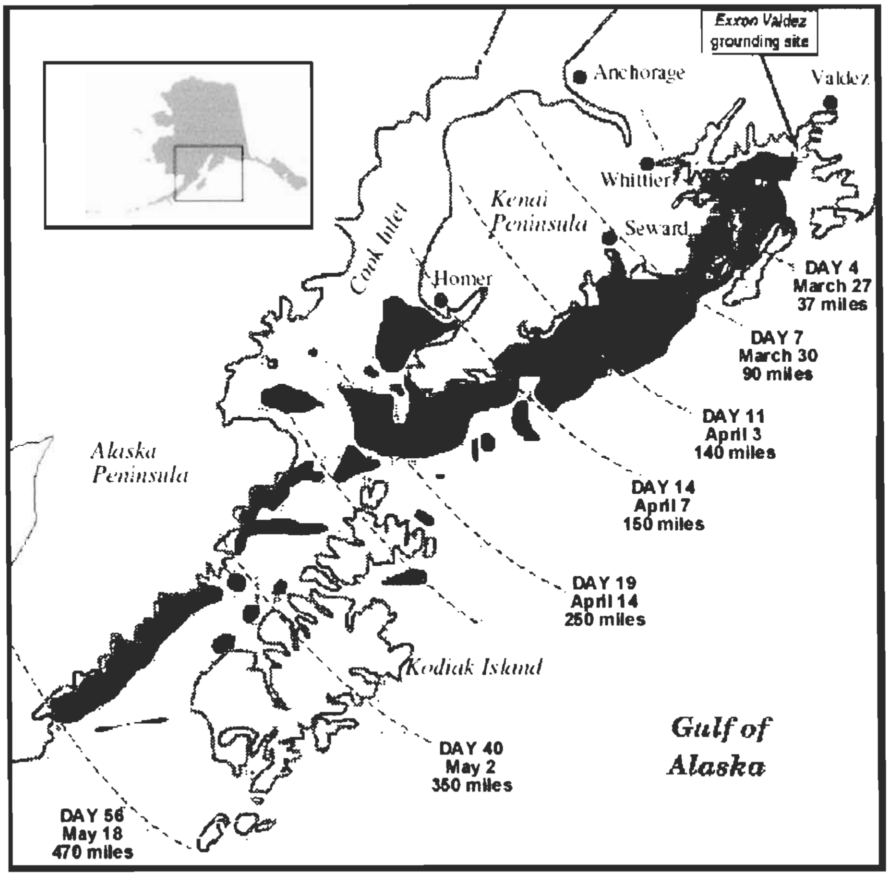
Oil slick
A layer of oil floating on the surface of water.

Oil spill
Accidental release of oil into the marine or terrestrial environment.

Skimmer
A skimmer is a device for recovering spilled oil from the water's surface. Skimmers may be self-propelled, used from the shore, or operated from vessels.

Sorbents
Substances that take up and hold water or oil. Sorbents that are used in oil spill cleanup are made of oleophilic materials.

Appendix A



<u>Exxon Valdez</u>

Length: 987 feet

Beam: 166 feet

Draft: 64 feet

Displacement: 211,469 tons

Maximum Speed: 16 knots

Capacity: 1.48 million barrels

Complement: 21 crew

The story

The Exxon Valdez departed from the Trans Alaska Pipeline terminal at 9:12 pm March 23, 1989. William Murphy, an expert ship's pilot hired to maneuver the 986-foot vessel through the Valdez Narrows, was in control of the wheelhouse. At his side was the captain of the vessel, Joe Hazelwood. Helmsman Harry Claar was steering. After passing through Valdez Narrows, pilot Murphy left the vessel and Captain Hazelwood took over the wheelhouse. The Exxon Valdez encountered icebergs in the shipping lanes and Captain Hazelwood ordered Claar to take the Exxon Valdez out of the shipping lanes to go around the icebergs. He then handed over control of the wheelhouse to Third Mate Gregory Cousins with precise instructions to turn back into the shipping lanes when the tanker reached a certain point. At that time, Claar was replaced by Helmsman Robert Kagan. For reasons that remain unclear, Cousins and Kagan failed to make the turn back into the shipping lanes and the ship ran aground on Bligh Reef at 12:04 am March 24, 1989. Captain Hazelwood was in his quarters at the time.

Get a sense of the size of an oil tanker (optional)

Materials:

6 **Exxon Valdez facts (Appendix A)**
7 **50 ft of Rope per group**
8 **(optional) graph paper – 1 sheet per group**
9 **(optional) pencils**
10 **(optional) rulers – 1 per group**

7. Ask students to share any knowledge they have about oil spills in the news.
8. Tell the story and discuss the length of a medium-sized tanker like the Exxon Valdez.
9. Measure the size of the Exxon Valdez outside your school and mark its size on the pavement to show to other students. Ask students to brainstorm various possible measuring strategies.
10. Using a tape measure, mark off a 50-foot or 100-foot piece of string or rope. Students simply lay the string down, making sure to accurately mark and record the number of times they step and repeat. As an example, using a 100-foot length, it would be necessary to step and repeat 10 times to lay out the distance of 1,000 feet.
11. Students can also measure the distance of their average stride. As an example, the stride of an adult is close to 3 feet. Knowing this, it is easy to estimate distances by counting the number of strides needed to cover a certain distance and multiply the number of strides by three (3 feet per stride). Allow students the opportunity

to determine their stride and then check for accuracy with a predetermined distance.

12. (optional) With the outside work complete, distribute a piece of graph paper (8 1/2" x 11") to students and ask them to determine the scale which would allow for the Exxon Valdez to be sketched on the graph paper. An appropriate scale, assuming that you are using 1/4" grid paper, would be to have each square equal 25 feet. See if the students can determine the scale for themselves first.

APPENDIX D: Evaluation Form

Thank you for taking the time to fill it out completely, your candid input means a lot to us and will help us continue the tradition of enjoyable and educational experience at Camp Reach.

Please rate the following statements on the scale of 0 to 4

0=Strongly Disagree; 1=Disagree; 2=Neutral; 3=Agree; 4=Strongly Agree

Statements to rate	**0**	**1**	**2**	**3**	**4**
This workshop was very hands on.					
This workshop was more cooperative than competitive.					
I see real life applications for the knowledge I've gained.					
I see possible career paths for someone who might be interested in this topic.					
I have gained knowledge that I might use in everyday life.					
The workshop was too complicated.					
I see connections between some engineering disciplines as a result of this workshop.					
I utilized my creative thinking and reasoning abilities.					
This workshop has sparked an interest in this subject for me.					
The instructions were clear.					
I think this is an appropriate addition to activities in Camp Reach that I have already participated in.					
I saw clear results at the end of this workshop.					
I think the knowledge I've gained today will help me with future school work.					
Enough assistance was provided to complete the workshop successfully.					
I had ample time in the discussion to reflect upon the material I've learned.					
The workshop was too long.					
All necessary materials were provided.					
The room was adequate for the experiment.					
The introductory presentation was interesting.					
Enough background information was provided for the experiment.					
The worksheet was adequate for the information asked.					
The clean up procedure was too complicated.					
There were too many discussion questions.					
The discussion questions were too difficult.					
This workshop is similar to activities I have done before in school.					
The alternative methods of oil spill clean up descriptions were informative					
The alternative methods of oil spill clean up descriptions were clear.					
I enjoyed this workshop a lot.					
I learned a lot from this workshop.					
I was bored during part I					
I was bored during part II					
I was bored during part III					

Was the group size too big or too small? What size group would you suggest?

What special skills, if any, did this workshop require?

What similar workshops have you participated in before?

What instructions, if any, were unclear? What suggestion would you make to improve them?

Was the workshop too long? What part would you like to remove? Was it too short?

Was the discussion too long? Which discussion questions would you like to remove? Was it too short?

Were you supplied with enough materials to complete the experiment? Which ones, if any, were not enough?

Do you have any comments on the introductory and alternative cleanup methods presentations? Were they too long? Too short? Too boring? What would you suggest to improve them?

Was the worksheet complete? Was there enough space for your comments? Was it clear?

Do you have any suggestions, complaints, or thoughts on the workshop parts I?
Do you have any suggestions, complaints, or thoughts on the workshop parts II?

Do you have any suggestions, complaints, or thoughts on the workshop parts III?

APPENDIX E: Evaluation Results

0=Strongly Disagree; 1=Disagree; 2=Neutral; 3=Agree; 4=Strongly Agree

Statements to rate	Average Responses
This workshop was very hands on.	3.71
This workshop was more cooperative than competitive.	3.71
I see real life applications for the knowledge I've gained.	3.14
I see possible career paths for someone who might be interested in this topic.	2.43
I have gained knowledge that I might use in everyday life.	2.57
The alternative methods of oil spill clean up descriptions were informative	3.43
I see connections between some engineering disciplines as a result of this workshop.	2.86
I utilized my creative thinking and reasoning abilities.	3.14
This workshop has sparked an interest in this subject for me.	2.14
The instructions were clear.	3.57
I think this is an appropriate addition to activities in Camp Reach that I have already participated in.	3.71
I saw clear results at the end of this workshop.	3.57
I think the knowledge I've gained today will help me with future school work.	3.00
Enough assistance was provided to complete the workshop successfully.	3.86
I had ample time in the discussion to reflect upon the material I've learned.	3.71
The alternative methods of oil spill clean up descriptions were clear.	3.29
All necessary materials were provided.	3.71
The room was adequate for the experiment.	3.57
The introductory presentation was interesting.	3.00
Enough background information was provided for the experiment.	3.14
The worksheet was adequate for the information asked.	3.14
I enjoyed this workshop a lot.	3.57
I learned a lot from this workshop.	3.29
There were too many discussion questions.	1.43
The discussion questions were too difficult.	0.57
This workshop is similar to activities I have done before in school.	0.29
The workshop was too complicated.	0.29
The workshop was too long.	0.71
The clean up procedure was too complicated.	0.14
I was bored during part I	0.00
I was bored during part II	0.14
I was bored during part III	0.00

Table 6 Evaluations Results

Appendix F Invitation Letter

April 10, 2004

Nancy Boyd
85 Karen Circle
Holliston, MA 01746

Dear Nancy,

My team members and I would like to invite you back to Worcester Polytechnic Institute to give us your opinion of a new workshop for Camp Reach.

Can we count on you for this important event?

Who: Camp Reach Alumni
What: Workshop Pilot Test
Where: Worcester Polytechnic Institute, Campus Center Lobby
When: Saturday, April 24, 2004, 12:30pm - 4:30pm
Why: To help ensure a fantastic engineering experience for future Camp Reach Campers

RSVP by April 16, 2004, participation will be limited to the first 15 respondents.

Stephanie Blaisdell, Co-Director, Camp Reach
Phone: (508) 831-5819
Email- reach@wpi.edu

Sincerely,

Dawn Stanley
WPI undergraduate Student

References

[1] National Science Foundation, Division of Science Resources Studies, SESTAT (Scientist and Engineers Statistical Data System), cited in *Women, Minorities, and Persons with Disabilities in Science and Engineering*: 2003 (NSF)
[2] National Science Foundation, Division of Science Resources Studies, SESTAT (Scientist and Engineers Statistical Data System), cited in *Women, Minorities, and Persons with Disabilities in Science and Engineering*: 2003 (NSF)
[3] Girls and Careers, U.S. Bureau of Census (2001) Statistical Abstract of the United States Washington , DC http://www.girlsinc.org/ic/content/GirlsandCareers.pdf
[4] Hecker, Daniel, Occupational employment projections to 2010, US Department of Labor, Monthly Labor review November 2001, page 3
[5] Boskin, M.J. and L.J. Lau. *Generalized Slow-Neutral Technical Progress and Postwar Economic Growth.* Stanford Institute for Economic Policy Research. November 2000.
[6] Mankiw, Gregory, *Principles of Macroeconomics 3rd edition*, South Western Manson OH, 2004.
[7] Blaisdell, Stephanie, cited Foss and Stanley, 1986, in *Factors in the Underrepresentation of Women in Science and Engineering*, WEPAN
[8] Women's College Coalition, in conjunction with the Ad Council http://www.academic.org/work.html
[9] http://wwwonlineethics.com/text/ecsel/abstracts/women-indust.html Wan, Deborah J. Women Scientists and Engineers Employed in Industry: Why so few?
[10] Chu Clewell, Beatriz, Campbell, Patricia B., *Taking Stock: Where We've Been, Where We Are, Where We're Going* Journal of Women and Minorities in Science and Engineering, vol 8, pp255-284, 2002
[11] Vickers, Mary H, Ching, Hilda L, and Dean, Charmaine B., "Do Science Programs Make a Difference?", More Than Just Numbers Conference, New Brunswick, May 1995
[12] Kellogg School of Management Northwestern University, *The Chronicle of Higher Education*, ACE Fulfillment Services, Department 191, Washington DC, January 11, 2002
[13] Carole Beal, Ph.D., author of *Boys and Girls: The Development of Gender Roles.*
[14] William Sears, M.D., Pediatrician and Anita Sethi, Ph.D Psychologist Contributing Editors, Parenting Magazine http://www.parenting.com/parenting/article/article_general/0,8266,8765,00.html
[15] Auerbach, Stevanne, Phd http://www.drtoy.com/main.htm
[16] Huttenlocher, Janellen and Nora Newcombe University of Chicago professor and Temple University professor respectively, *Making Space; The Development of Spatial Representation and Reasoning*
[17] Women's College Coalition at Mount Holyoke College http://www.academic.org/work.html
[18] William Sears, M.D., Pediatrician and Anita Sethi, Ph.D Psychologist Contributing Editors, Parenting Magazine http://www.parenting.com/parenting/article/article_general/0,8266,8765,00.html
[19] Chu Clewell, Beatriz, Campbell, Patricia B., *Taking Stock: Where We've Been, Where We Are, Where We're Going*, Journal of Women and Minorities in Science and Engineering, vol 8, pages 255-284, 2002
[20] Hamilton, Laura S. (1998) Gender differences on high school science achievement tests: Do format and content matter? Educational Evaluation and Policy Analysis, 20(3), 179-195
[21] Brewster, Cori, Fager, Jennifer. *Parents Partners: Using Parents to Enhance Education* Norwest Regional Educational Laboratory, March 1999
[22] Women's College Coalition at Mount Holyoke College. http://www.academic.org/work.html
[23] Campbell, Patricia B. *Girls are... Boys are....: Myths, Stereotypes and Gender differences* http://www.campbell-kibler.com/Stereo.pdf
[24] Eccles (Parsons), Jacquelynne, Adler, Terry F., Futterman, Robert, Goff, Susan B., Kaczala, Caroline M., Meece, Judith L., & Midgley, Carol (1983 1985) *Expectancies, values, and academic behaviors* and *Self perceptions, task perceptions, socializing influences and the decision to enroll in mathematics*
[25] Ethington, Corinna A. (1992) *Gender Differences in a Psychological Model of Mathematics Achievement.* Journal for Research in Mathematics Education
[26] Gilbert, Lucia A., June Mgallessich, and Sherri L. Evans, *Sex of Faculty Role Model and Students' Self-Perceptions of Competency.* Sex Roles: A Journal of Research, 9 (1983) 597-607
[27] A Gender Lens on Rowan University's College of Engineering. Page 35 NAMEPA/WEPAN 2001 Joint National Conference

[28] Johnson, D.W., Maruyama, G., Johnson, R., Nelson, D., & Skon, L. (1981). Effects of cooperative, competitive, and individualistic goal structures on achievement: A meta-analysis. Psychological Bulletin, 89(1), 47-62
[29] Gilligan, Carol. (1982). *In a Different Voice*. Cambridge, MA: Harvard University Press
[30] Belenky, Clinchy, Goldberger & Tarule, (1986) *Women's Ways of Knowing: The Development of Self Voice and Mind* as cited in "Taking stock"
[31] Rubin, Zick. Children's Friendships. Harvard University Press. Cambridge, MA 1980
[32] George, P., Lawrence, G., Bushnell, *Handbook for Middle School Teaching*. Longman Press, NY 1998
[33] National Science Foundation, Division of Science Resources Studies, *Women, Minorities, and Persons with Disabilities in Science and Engineering*: 2003 (NSF)
[34] National Science Foundation, Division of Science Resources Studies, SESTAT (Scientist and Engineers Statistical Data System), cited in *Women, Minorities, and Persons with Disabilities in Science and Engineering*: 2002 (NSF)
[35] U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 2000 Mathematics Assessment, 2000 Science Assessment, http://www.nces.ed.gov/nationsreportcard/naepdata/.
[36] National Science Foundation, Division of Science Resources Studies, SESTAT (Scientist and Engineers Statistical Data System), cited in *Women, Minorities, and Persons with Disabilities in Science and Engineering*: 2002 (NSF)
[37] Shakesshaft, C. (1995) *Reforming Science Education to Include Girls*. Theory into Practice, 34 (1), 74-79
[38] Chu Clewell, Beatriz, Campbell, Patricia B., *Taking Stock: Where We've Been, Where We Are, Where We're Going, Journal of Women and Minorities in Science and Engineering,* vol 8, pages 255-284, 2002
[39] Women College Coalition at Mount Holyoke College, 2003, http://www.womenscolleges.org/whoweare.html.
[40] http://clte.asu.edu/active/mainde.htm
[41] Executive Summary of Johnson, David W., Roger T. Johnson, and Karl A. Smith. *Cooperative Learning Increasing College Faculty Instructional Productivity* ASHE-ERIC Higher Education Report Number 4. Washington, D.C.; The George Washington University, School of Education and Human Development, 1991. Find at: http://www.ntlf.com/html/lib/bib/cooplearn.htm
[42] Herreid, Clyde F. Director, National Center for Case Study Teaching in Science, Distinguished Teaching Professor, Department of Biological Sciences. 03/18/2004 at: http://ublib.buffalo.edu/libraries/projects/cases/case.html
[43] http://www.stolaf.edu/people/schodt/casebib.htm
[44] Cross, Patricia, Angelo, Thomas. "*Classroom Assessment Techniques: A Handbook for College Teachers 2nd edition*. San Francisco: Jossey-Bass Publishers, c1993. LB2822.75.A54 1993
[45] Rutgers, Camden. *"Insight, Advancing Learning Through Faculty Study"*. Newsletter of the Teaching Excellence Center, Volume 6, Number 2. Fall 98
[46] Young, Art. 2002 *Teaching Writing Across the Curriculum, Third Edition.* WAC Clearinghouse Landmark Publications in Writing Studies: http://wac.colostate.edu/aw/books/young_teaching/. May 29, 2002
[47] Romberger, Julia. "Writing Across the Curriculum" OWL at Purdue University. 1995-2004. at: http://owl.english.purdue.edu/handouts/WAC/
[48] Chu Clewell, Beatriz, Campbell, Patricia B., *Taking Stock: Where We've Been, Where We Are, Where We're Going*, Journal of Women and Minorities in Science and Engineering, vol 8, pages 255-284, 2002
[49] Farrell, Elizabeth F., *Engineering a Warmer Welcome for Female Students*, The Chronicle of Higher Education, February 22, 2002
[50] Kuhl, Craig, CED Contributing Editor *Girls just wanna have fun*. Study: young women view technology careers as "geeky" http://www.cedmagazine.com/ced/0006/june7.htm
[51] U.S. Department of Labor http://www.dol.gov/wb/factsheets/nontrad2000_txt.html
[52] Chu Clewell, Beatriz, Campbell, Patricia B., *Taking Stock: Where We've Been, Where We Are, Where We're Going* Journal of Women and Minorities in Science and Engineering, vol 8, pp255-284, 2002
[53] Boskin, M.J. and L.J. Lau. *Generalized Slow-Neutral Technical Progress and Postwar Economic Growth.* Stanford Institute for Economic Policy Research. November 2000.
[54] Mankiw, Gregory, *Principles of Macroeconomics 3rd edition*, South Western Manson OH, 2004.

[55] http://wwwonlineethics.com/text/ecsel/abstracts/women-indust.html Wan, Deborah J. Women Scientists and Engineers Employed in Industry: Why so few?
[56] Greive, Angela, *Encouraging Women to Train as Engineers*, Canadian Coalition of Women in Engineering Science and Technology, 1996.
[57] Adamson, Lauren, Foster, Martha, Roark, Martha and Reed, Donna, *Doing a Science Project: Gender Differences during Childhood,* Journal of Research in Science Teaching, 1998, pages 845 – 857.
[58] Campbell, Patricia and Sanders, Jo, *Challenging the System: Assumptions and Data Behind the Push for Single Sex Schooling*, New York: Routledge Falmer, 2002, pages 31 - 46.
[59] Rowan University's College of Engineering, *A Gender Lens*, NAMEPA/WEPAN Joint National Conference, 2001, Page 35
[60] Demetry, Chrysanthe, Camp Reach Annual Report 2003
[61] Vickers, Mary, Ching, Hilda, Dean, Charmaine B. "Do Science Programs Make a Difference? More Than Just Numbers Conference, New Brunswick, May 1995
[62] Murphy, Tim, "How to cleanup oil spills", December 2000
[63] ACTUA, "Oilrigs"
[64] Watt Watchers, U.S. Department of Energy, "Oil Spill Activity"
[65] Franklin Institute, "Slick Sea Spills"
[66] Broje, Victoria, University of California Santa Barbara, "How to clean up an oil spill"
[67] Bond, Sally L., Boyd, Sally E., and Rapp, Kathleen A. Taking Stock: A Practical Guide to Evaluating Your Own Program. Horizon Research, Inc. 1997
[68] Wheeler, Julie, Evaluation of Camp Reach. WPI IQP 00E022I
[69] Blaisdell, Stephanie, Demetry, Chrysanthe. *"Camp Reach Annual Report for 2003"*. Worcester Polytechnic Institute, 2004.