AC 2011-1028: INTRODUCTION OF A GLOBAL PERSPECTIVE USING A TEAM PROJECT IN A STRENGTH OF MATERIALS COURSE

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Introduction of a Global Perspective Using a Team Project in a Strength of Materials Course

Abstract

Engineering Mechanics is an important fundamental area of study for many engineering fields, including mechanical, civil, nuclear, aerospace, and biomedical, to name a few. Strength of Materials (a.k.a. Mechanics of Materials) at Penn State Erie, The Behrend College is one course that introduces students to the concept of and relationship between stress and strain, how to calculate stresses and strains under different forces and moments, and how to design structural components to prevent failure due to expected loading conditions. As an introductory course, textbook materials are typically simplified so that underclassmen are able to solve problems. This can make it difficult for students to relate how all the concepts can have a unified effect on a real-world problem. A design project component near the end of this course has been used to give the students a “big-picture” perspective on how the material can be applied in a problem they would be expected to solve on the job.

While the students have previously found the project to be a beneficial learning experience, it did not engage the students and interest them in engineering. The scope of the project description was very limited so that other factors, such as building codes, would not have to be fully understood to complete the design, so it could be considered a longer open-ended homework problem. The project was simple enough for student teams of two students to complete, and little of a formal design procedure was required. Also, graduating student opinion has shown a lack of global engineering problems in the curriculum.

A new design project for the Strength of Materials course was presented in the Spring 2010 semester that still focuses on designing structural components, but the application was changed to meet a given need in another country, in this case designing structural components of a piece of playground equipment to pump water that will be utilized in sub-Saharan Africa. Students were required to research reasons behind this global need as well as local resources available for building the structure to make students aware of local and cultural differences that could exist in application/use of the structure. Documentation of a formal design process along with the research requirement allowed for teams of four students, which gave an opportunity to learn or reinforce effective teaming skills. The changes to the project allowed flexibility in the design solutions that encouraged the students to be more innovative and creative in the design process.

The purpose of this paper is to describe the team design project including how it was able to improve the student’s learning experience. Assessment strategies and results will be shared. Preliminary findings indicate that the project increased the students’ awareness of the world, their teamwork skills and reinforced the application of a formal design procedure. Individuals who are involved in the development of design projects, international projects, or teaching engineering mechanics may be interested in this paper.

Introduction

One goal of engineering education is to produce world-class engineers who use their technical and professional skills to innovatively solve problems in the world around them. "U.S. engineers must become global engineers. They will have to know how to replenish their knowledge by self-motivated, self-initiated learning."[1] In order to achieve this goal, students need to be given opportunities to address and develop the desired attributes of world-class engineers including being aware of the world, innovative, and effective in teams. To do this more effectively, students can be given multiple experiences throughout their college experience, including early in their undergraduate educational career. It is important to teach future engineers to be creative and flexible, along with being curious and imaginative.[1]

Traditionally, many engineering majors will include an Introduction to Design course for freshmen to give them an understanding of the engineering design process which includes one or more projects that the students work on in teams. Additionally, many students take a Strength of Materials course (a.k.a. Mechanics of Materials) at Penn State Erie, The Behrend College in the sophomore or possibly junior year. This course provides basic theory and application of the relationship between loading conditions on a body and the resulting stresses and strains in the body, giving the students grounding in solid mechanics. Previously, the Strength of Materials course in this study contained a design project with the primary goal of selecting standard beams, girders, and columns to construct a two-story structure that is able to hold a specified amount of weight with the weight being unevenly distributed around the structure. The project description and requirements were somewhat limiting in allowing for innovative solutions, though, since the structure had to be a specified rectangular size at a specified height and most creative approaches were not practical or feasible for implementation. The project was completed in teams of only two students over a period of three weeks, so little teaming skills were gained in the experience. This was the only design project and teaming opportunity given between the freshman-level Introduction to Design course and the upper-level junior courses.

Project Development

The development of the new Strength of Materials project consisted of researching possible global needs to determine a potential structure to design, writing the project description to be given to the student teams, and development of a rubric for assessment. A number of items were considered in project selection: the scope had to be simple enough for a sophomore-level student to design using basic stress and deflection calculations; the project had to solve an international need to introduce a global perspective to the course; and there had to be a potential access to a local supply of materials for construction. Once selected, the project background, requirements, constraints, and deliverables were identified and written for presentation to the students. In order to fairly grade potentially 70 students (18-24 teams) a semester, an evaluation tool needed to be developed that could also be given to the students with the project assignment.

Project Objectives

A new design project was proposed for the Strength of Materials course to provide an experience that implements the attributes of a world-class engineer. This course was chosen due to a gap in effective design projects between the freshmen and upper-class courses and the wide variety of applications that use technical skills taught in this course. Five objectives were identified in implementing the changes to the project: one was related to course content, one was for applying the design process, and three were based on the attributes of a world-class engineer.

To assess the ability of the students to apply the theory from the course, the project had to include designing structural components to prevent failure. It was also important to have the application be an open-ended problem where many possible answers could be possible to truly make it a design project. This was the primary objective for the project, but was also the main objective of the previous project.

While still focusing on the design of structural components, the application in the new project was changed to meet a given need in a different country. Students would be required to research the reasons behind this global need as well as the resources available locally for building the structure (e.g., naturally, manufactured, recycled). The additional project requirement to research a global need was intended to increase the students' awareness of the world around them and the cultural differences that could exist in application/use of the structure. Preferably, the need would be from a third-world nation to expose the students to challenges that exist outside the United States. One advantage to this is that the actual need could be changed in future courses to update the project or prevent potential violations of academic integrity.

Additionally, expanding the requirements would allow for larger teams of three or four students and would require a longer time period during the semester to complete it. This would give them more opportunities to learn how to work more effectively on a team during the sophomore year and reinforce teaming skills taught in their freshman design course. The students could be assigned roles to serve on the team, which was difficult to implement on the previous project.

The restrictions on the project were loosened from the previous project, while still limiting them to express their knowledge of the course materials, making the project more open-ended and allowing for more diverse solutions. This opened the possibility of the students to be more innovative and encouraged creativity in the design process.

The freshman Introduction to Design course was used to teach a formal process for conducting engineering design with specified steps and documentation that was collected from students as they worked on their projects. The previous project did little to encourage following this formal process, and many students ended up using a trial-and-error method to find a solution. Deliverables were included in the new project that required the students to follow the same formal design process as their freshman course. Revisiting these design steps reinforces the process that they were taught and are expected to use again on their capstone design project in their senior year. Since the process was taught previously, it was not necessary to take time from teaching the technical theory in the course to address the required design steps.

Project Description

The chosen application for the global need was a pumping device to address the lack of fresh water throughout rural sub-Saharan Africa. Groundwater may exist in the region, and wells can be drilled, but pumps are needed to make it accessible, and electrical supplies may be unreliable or unavailable. A piece of playground equipment that serves as a manually-powered pumping device was chosen as the application. This type of device currently exists in the form of a merry-go-round, but the project was to examine any type of playground equipment as a possible solution. A brief description of the need for fresh water was given to the students, an internet video describing the need and showing the current design was shown in class, and the students were asked to further research the problem (see Appendix A for the provided project description). They were required to pick a specific area or country to place their design and research how the need applies to that region.

The primary technical aspects of the project requirements specified that the piece of equipment had to produce rotational motion to operate a specified pump and include structural members that needed to be sized properly to prevent failure. These had to include members that could be classified as beams (slender members under transverse loads), shafts (members under torsional and/or tensile axial loads), and columns (slender members under compressive axial loads). Safety was very important since the intended users were children, and cost was to be feasible for a charity to provide. Students were also asked to ensure that the equipment would be durable and not require frequent maintenance, which would likely not be available.

Participants and Teams

The project was first implemented in the spring semester of 2010 and repeated in the fall semester. Two sections with a total of 62 students (7 female, 55 male) took the course in the spring and one section of 20 students (3 female, 17 male) were enrolled in the fall. Almost all of the students were in their fourth semester in the spring and fifth semester in the fall. The engineering students required to take this course include mechanical, civil, nuclear, industrial, aerospace, biological, bioengineering, and engineering science.

The students were allowed to self-select teams with most having four team members and a few having three. Four roles were given to be assigned within the group. A project leader was needed to call and run meetings, assign tasks, and deal with other management issues. A lead researcher was assigned to collect and organize all the research from the team members. The over-all organization and documentation role was assigned to a project administrator who would keep a three-ring binder of all the project work, which was to be submitted at the end of the project for their final grade. Someone with good technical skills was asked to serve as the technical leader of the team and be in charge of determining what analysis was needed on the project and to check over the accuracy of the results produced by the team.

Activities/Deliverables

The project was introduced around the fourth week of the semester to allow much of the research and background work to be addressed early. This gave them project activities to complete as they were learning the technical skills of the course through the semester. The teams were asked to submit preliminary work at specific dates during the semester, which were not graded, but reviewed and returned to the groups with feedback. The work could then be revised and included in their project notebook to be graded at the end of the semester.

The first deliverable requested was a memo with their own background description, needs analysis, and choice of regional location with description of conditions (power, rainfall, current water supply). In addition, each team was asked to write and submit a team contract that specified their team's performance expectations and any penalties for not meeting these expectations. Each team needed to submit these documents at six weeks into the semester.

At week nine, a complete list of engineering specifications that were based on their needs analysis was required along with all their initial conceptual approaches. Basic sketches or photos with a short description of how the playground equipment would provide the pumping motion would suffice. Progress reports with updated specifications, sketches of design concepts, final design selection with justifications for their decisions were required by week 12 along with the expected loading conditions to be applied on their structure that they determined.

The final project report was due at the end of the semester. Each group needed to submit a notebook that was organized into sections to document their entire design process: their updated background research report stating the needs, locations, and specifications for the project; concept sketches and descriptions with a document selection process; a final design approach describing what type of playground equipment they chose, how it would provide the pumping motion and an estimated cost; a summary of the loads applied to the structure; all the analytical calculations completed to support their choice of structural members showing how they determined the member would not fail under the expected loads as well as their factor of safety for each member; CAD drawings of the members and the assembled structure; and an appendix of all their supporting information and necessary documentation. This project notebook was the document that was graded according to the rubric provided in Appendix B.

Assessment

Assessment for the project had two threads, assessment of the success of student learning (student performance final grades) and if the project was making a difference in students' perceptions related to the outcomes of innovation, aware of the world, and working in teams. Formative assessment was collected using pre and post test surveys and an end of semester questionnaire. Summative assessment was the final grade for the project. Students' consent to use survey data was obtained according to the policies of the university's Office of Research Protections.

In order to evaluate how well the objectives were addressed in the project, the students were asked to complete pre and post tests (Appendix C and D for surveys and results). One survey was given at the very beginning of the semester, prior to introducing the project to the students, in order the obtain their prior knowledge and experiences working in teams, and to determine a baseline of their awareness of the problem with the lack of fresh water supplies in many parts of the world. The same surveys were repeated at the end of the semester to assess how their opinions had changed. Another survey was given at the end of the semester to obtain student perception of learning directly related to the project outcomes (Appendix E). A Focus Group was scheduled at the end of the semester after grades were submitted. The purpose of this was to have a conversation with students to hopefully obtain more rich and detailed information from the students. However, few students volunteered and the focus group was cancelled. It is believed this was because students were either finished for the semester or taking final exams and interest at that time was low.

The results collected from the surveys were very positive. Much was learned about achievement of the outcomes, teamwork, aware of the world and innovation. Student comments follow.

Teamwork comments:
When asked what you learned most by working on a team project to design a water pump for a country in sub-Saharan Africa, students said:

- "I leaned about the difference something simple, like clean water, can make for the quality of life of the people living in Africa."
- "I leaned that teamwork is important and that engineers can make a legitimate difference to improve the world."
- "Teamwork is not always easy and occasionally not seeing eye to eye is ok."

Regarding improvement to the team project, students recommended that the project start earlier in the semester and not be due during finals week. Students were concerned about time management of the project. Students also felt that the project should be worth more points because of the amount of work required. "Make it worth more of the grade. 5% is very low and it's a ton of work for only 5%. It should be like 15%." And, "I think each team should have to meet with a faculty member once or twice to go over plans and thought processes. I realize nobody will be holding our hand in the 'real world', but for now we are still in training; no member or my tam felt extremely confident about what we were turning in at the end." These and other honest comments by the students will be extremely helpful for future students working on the project.

Students were concerned about the amount of time spent on all the assignments for the course, with 78% of the students admitting they worked more than 3 hours per week, while 22% said they spent 2-3 hours per week.

Aware of the world comments:
When asked if the students felt that participating in this project increased their awareness of world issues and global needs, the outcome was 83% yes and 17% no.

- "This project made me realize that even though these issues exist half way around the world, we as engineers have the ability to solve these problems."
- "I didn't realize that designing a simple pump can make the lives of Africans better."

And, most encouraging, that showed students leaned outside the scope of the project, "I knew that people in that area of the world (and others) suffered from a lack of clean water, and are therefore affected by a high rate of disease and mortality. What I wasn't aware of is the direct effect it has on the children's education, nor that there are such simple and affordable solutions in existence."

Innovation comments:

When asked, “Do you feel working with a team encouraged innovation and creative thinking?” response was unanimous, 100% said yes! Students shared some very insightful comments.

- “Working with a group, you get 4 different ideas that you can all discuss and improve upon. Working by yourself might be more efficient, but you only have your own ideas and opinions.”
- “For us, coming up with creative solutions became a sort of game to outdo one another.”
- “How do you take examples from class and apply them to real life? That takes creative thinking.”

Results from the surveys validated that student’s did learn the outcomes, the objectives of the project were fulfilled, and the project did make a difference in student’s perceptions and global awareness.

Conclusions and Recommendations

The proposed project for sophomore-level student teams for the Strength of Materials course helped to achieve the goals of incorporating the attributes of a world-class engineer while incorporating the technical aspects of the course material into a formal design process. The presentation of the project introduced these attributes to the students, integrated new global/international elements to the course, and gave an opportunity for innovation and creativity in design solutions. The scope of the proposed project was realizable and sustainable for multiple semesters because it can be easily modified to address other global needs. The formal design process was reinforced in the project while keeping enough emphasis on the technical aspects of the course. It should be noted that students welcomed and were challenged by the application of engineering principles to solve real-world problems. The project was successfully used by a different faculty member who was teaching the Strength of Materials course following the first semester of implementation. To test transferability, a future iteration could have the students begin this project in the fall semester course and complete the project during the next course in the sequence the following spring semester. This could allow for a depth of learning that was not possible in one semester. This would require that the scope of the project be broadened and more detailed requirements be included. This will also foster collaboration across courses by faculty in the department.

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Bibliography

[1] Katehi, L., (2005) “The Global Engineer”, Educating the Engineer of 2020: Adapting Engineering to the New Century, pp 151-155. Referenced from NAE (National Academy of Engineering). 2004. *The Engineer of 2020: Visions of Engineering in the New Century.*

Appendix A: Project Description Provided to Students

Background:

Many people who live in under-developed rural areas in sub-Saharan Africa lack accessible clean water. Fresh water sources can be scarce and far from central villages, requiring much time and effort in retrieving fresh drinking water. Underground fresh water supplies exist, but require resources to make the water accessible. One-time well-drilling expenses and equipment can be arranged by charitable organizations. Another problem with accessing these water sources is the lack or unreliability of electrical power to run the water pump. Other sources of power can be used, including solar and manual power. Children using playground equipment have been harnessed as a manual power source for well pumps. Some criticism has been made of the current playground piece, a merry-go-round, due to its cost, complexity and skill required for repair, and lack of use by the children.

Statement of Design Problem:

Design the structural components of a piece of playground equipment to be used to power a water pump.

Teams:

You will be working on teams of four students. You can choose your team members, but any students without a team will be assigned to a group. Groups of less than four students may be assigned additional team members.

- Roles to be assigned to the four team members:
  - Project leader – Calls and runs meetings, assigns tasks
  - Lead researcher – Collects and organizes all project research from members
  - Project administrator – Keeps project notebook, organizes report & deliverables
  - Technical leader – Determines technical analysis needed, checks accuracy of results

Requirements:

- Equipment must provide rotational motion to run a pump.
- Equipment must include designed structural members that can be classified as beams (slender members under transverse loads), shafts (members under torsional or tensile axial loads), and columns (slender members under compressive axial loads).
- Equipment must be reasonably safe for children to play on. Refer to the Playground Safety Handbook on the course website for guidelines.
- Equipment must be durable for a long life expectancy (use a design factor of safety of 3 for all structural members).
- Equipment must be financially feasible for a charitable organization to provide.

Structural Materials:

- Materials should be regionally available for purchase for sustainability (near your choice of location).
- Steel tubing and wide-flange beams should be used for strength and life. Use a modulus of elasticity for these steels of 29,000,000 psi.
- Your selection of grade of steel will determine the yield stress and the price.

Pump Specifications:

- The pump will be located in a 100 meter-deep well.
- Power: 0.5 – 1.5 hp; Speed: 3450 rpm, 5 gallons per minute.
- Assume it will be available when well drilled.
- See course website for specification sheet for the required pump.

General Guidelines

- You must include the weight of structural members when designing their supporting structures, but not when designing the actual member.
- The maximum deflection of all beams is to be limited to the span divided by 360.
- Your design is limited to a total of four types of cross-section.
- Members under compressive axial loads must be designed to prevent both yield failure and buckling failure.
- Assume that as many kids as possible will be playing on the equipment when in use.

Deliverables

- Week 6: Memo with your own background description, needs analysis, choice of regional location with description of conditions (power, rainfall, current water supply), a discussion of how the pump system will affect the lives of the villagers and any ethical considerations that may arise from installing the pump system, (3 pages max); Team process guidelines (2 pages max).

- Week 9: Complete list of marketing specifications (customer needs), engineering specifications, and initial conceptual approaches.

- Week 12: Progress report with updated specs, sketches of design concepts, final design selection with screening and/or decision matrices, and expected loading conditions.

- Week 14: Final design report containing the following items in a 3-ring binder with tabbed sections:
  - Revised (if necessary) background description, needs analysis, choice of regional location, ethical considerations, and engineering specifications
  - Design concept sketches with appropriate explanations and a logical selection process;
  - A description of your final design including amount, type, and cost of structural materials;
  - A summary of the loading conditions used in the analysis;
  - Neatly prepared calculations to support the choice of your selected structural members and joint connection: Analysis should include free-body diagrams of the entire system as well as each designed member, static/equilibrium analysis, and stress analysis for all shafts, beams and columns; loading condition, failure criteria, and actual factor of safety should be clearly indicated for each member;
  - Simple CAD drawings including an assembly drawing of the equipment; detailed drawings of all designed structural members;
  - An appendix containing information on regional material supply, regional conditions important in your selection process, team process guidelines, and any other necessary documentation

Appendix B: Grading Rubric

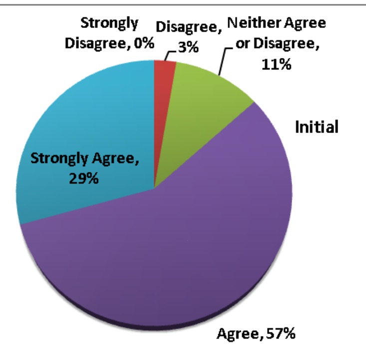
Notebook:		
Organization – use of tabbed dividers	______/5	
Previously graded work corrected	______/5	
Completeness of appendices	______/5	
Overall quality of work	______/5	
Total for notebook		______/20
Non-technical Work:		
Research of problem	______/5	
Research & selection of location	______/5	
Research of regional material suppliers	______/5	
Discussion of ethical considerations	______/5	
Total for non-technical work		______/20
Design Process:		
Customer needs analysis	______/5	
Product specifications	______/5	
Concept generation	______/5	
Concept selection	______/5	
Final design drawings	______/5	
Total for design process		______/25
Technical Analysis:		
Applied loading & static analysis with FBD's	______/5	
Design/stress analysis of shafts	______/10	
Design/stress analysis of beams	______/10	
Design/stress analysis of columns	______/10	
Total for technical analysis		______/35
Total points for group		______/100

Appendix C: Pre-test Results

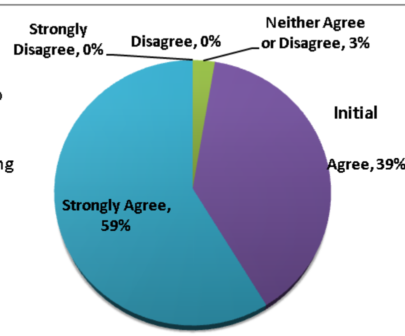
Teamwork: Please answer the following questions based on your experience working on teams.

a. Working on a team helped me to better understand the purpose of team projects.
b. It is important to be able to ask a teammate to explain something to me that they know.
c. I am comfortable in giving feedback to members of my team.
d. I am comfortable in dealing with conflict on a team.
e. Accountability is important to the success of the team.
f. I like working on a team.

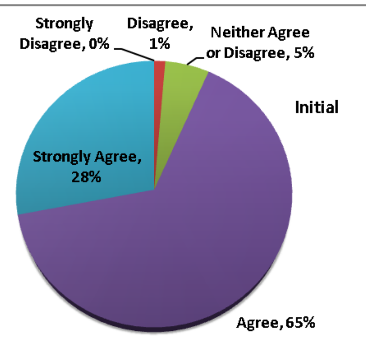
Working on a team helped me to better understand the purpose of team projects.



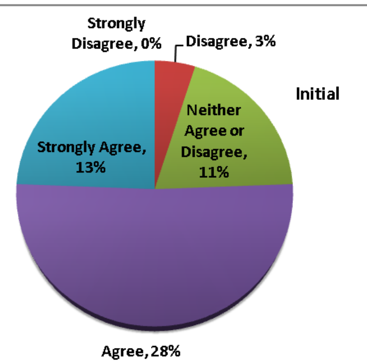
It is important to be able to ask a teammate to explain something to me that they know.



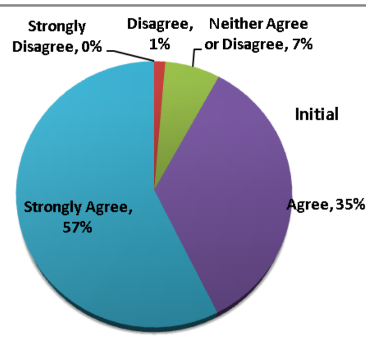
I am comfortable in giving feedback to members of my team.



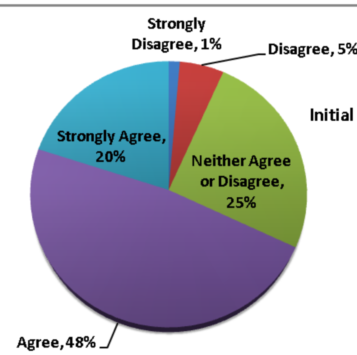
I am comfortable in dealing with conflict on a team.



Accountability is important to the success of the team.

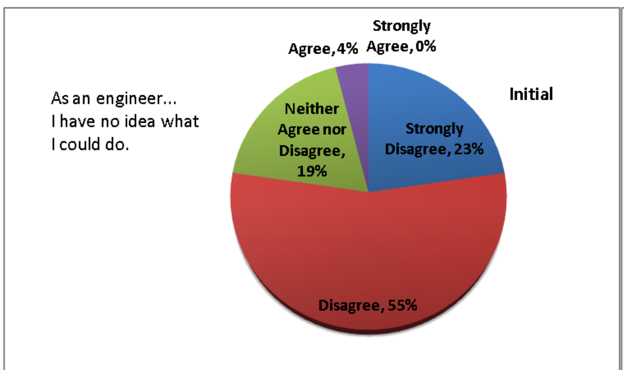


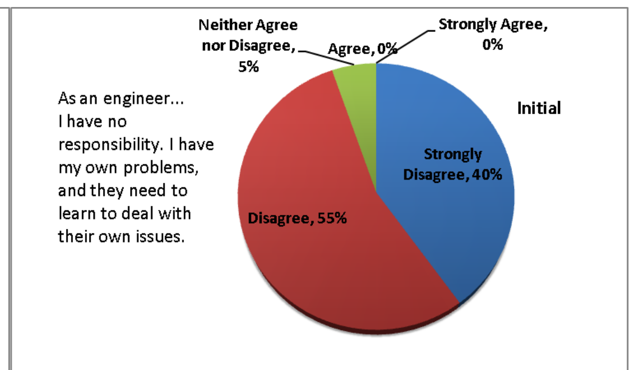
I like working on a team.

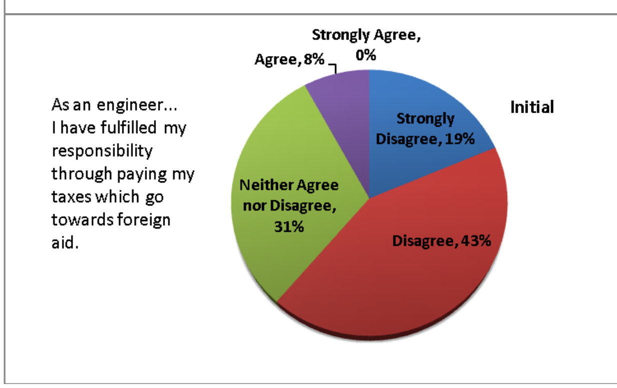


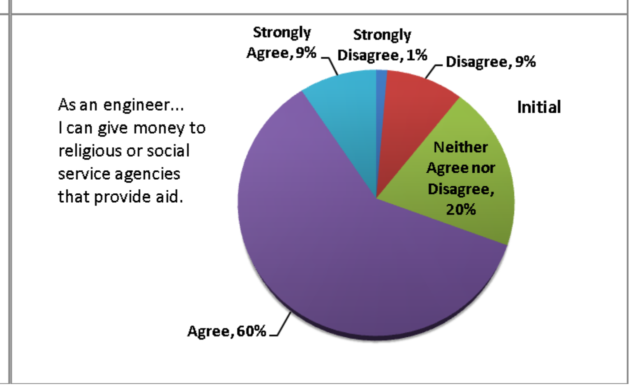
Engineer's Responsibility: People around the world face serious issues every day. What do you feel is your level of responsibility as an engineer in facing these issues?
As an engineer...

a. I have no idea what I could do.
b. I have no responsibility. I have my own problems, and they need to learn to deal with their own issues.
c. I have fulfilled my responsibility through paying my taxes which go towards foreign aid.
d. I can give money to religious or social service agencies that provide aid.
e. I can go serve for a week or two to help a needy community.
f. I can volunteer regularly for an aid organization (Habitat for Humanity, Red Cross, homeless shelter, etc).
g. I can choose to work for a "green" company.
h. I can provide technical services for an aid organization for a period of time (Peace Corps, Engineers without Borders, etc).
i. I can work for or start a company that provides products or services to fulfill needs in underdeveloped regions of the world.
j. I can choose to work in an under-developed area to use engineering principles to improve quality of life.

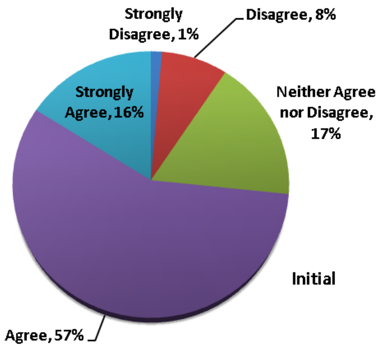




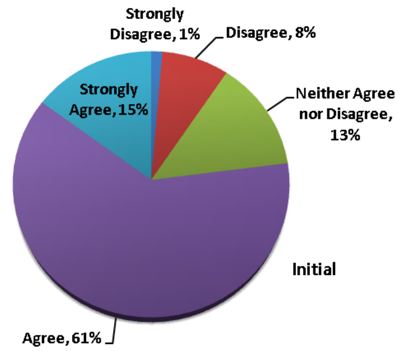




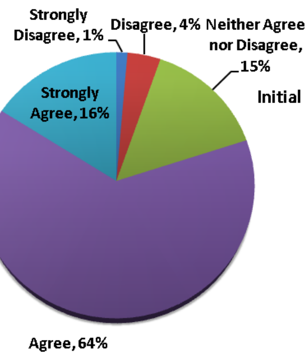
As an engineer...
I can go serve for a week or two to help a needy community.



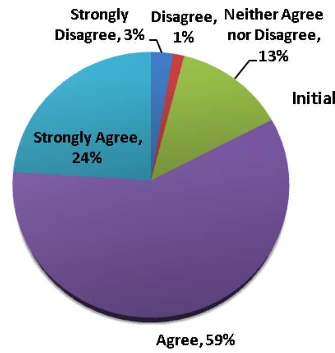
As an engineer...
I can volunteer regularly for an aid organization (Habitat for Humanity, Red Cross, homeless shelter, etc).



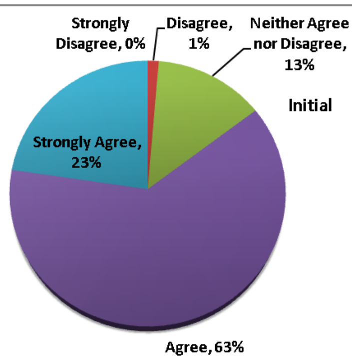
As an engineer...
I can choose to work for a “green” company.



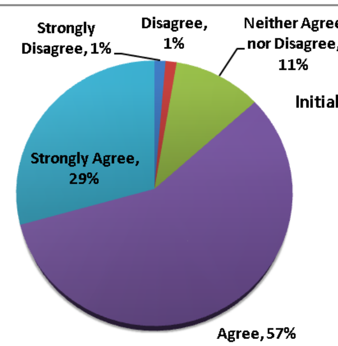
As an engineer...
I can provide technical services for an aid organization for a period of time (Peace Corps, Engineers without Borders, etc).



As an engineer...
I can work for or start a company that provides products or services to fulfill needs in underdeveloped regions of the world.

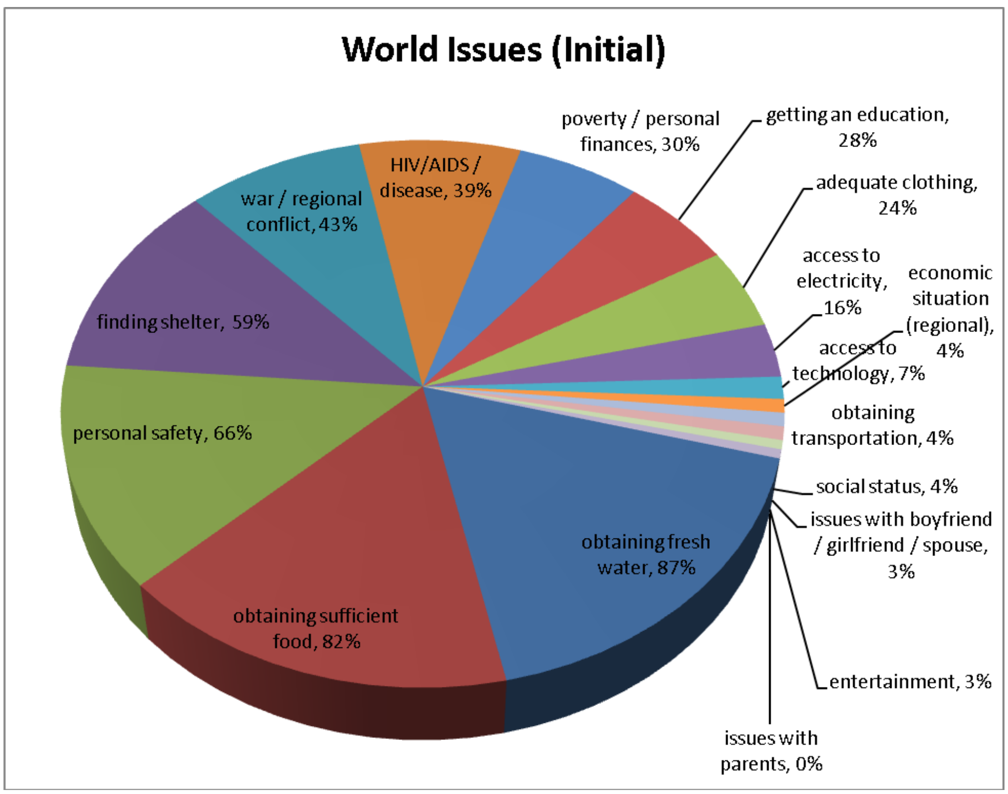


As an engineer...
I can choose to work in an under-developed area to use engineering principles to improve quality of life.



World Issues: What do you think are the top FIVE daily concerns of a typical high-school-age person living in a rural area of an underdeveloped country in sub-Saharan Africa?

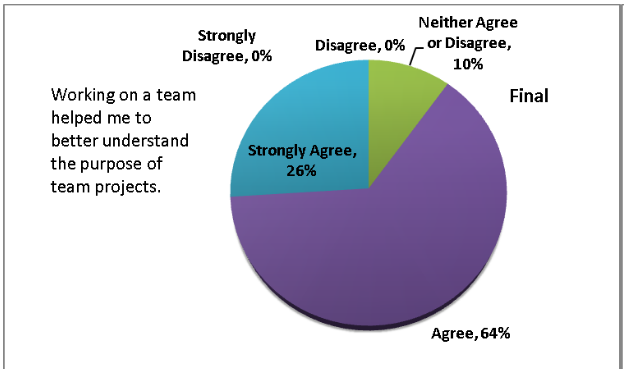
obtaining fresh water	87%
obtaining sufficient food	82%
personal safety	66%
finding shelter	59%
war / regional conflict	43%
HIV/AIDS / disease	39%
poverty / personal finances	30%
getting an education	28%
adequate clothing	24%
access to electricity	16%
access to technology	7%
economic situation (regional)	4%
obtaining transportation	4%
social status	4%
issues with boyfriend / girlfriend / spouse	3%
entertainment	3%
issues with parents	0%

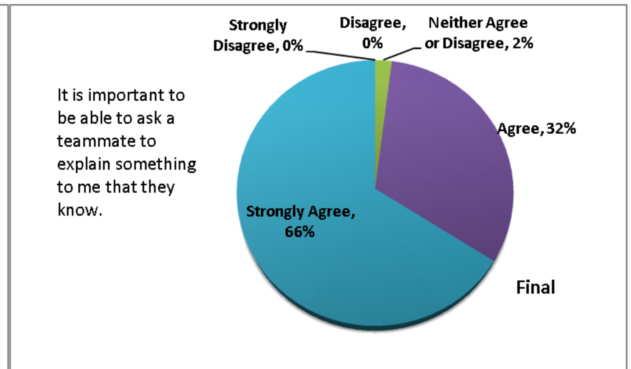


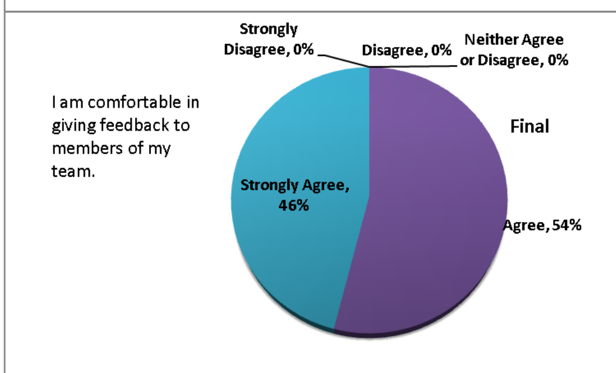
Appendix D: Post-test survey results

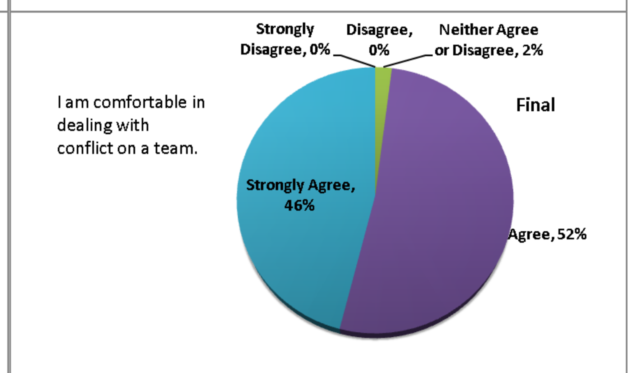
Teamwork: Please answer the following questions based on your experience working on teams.

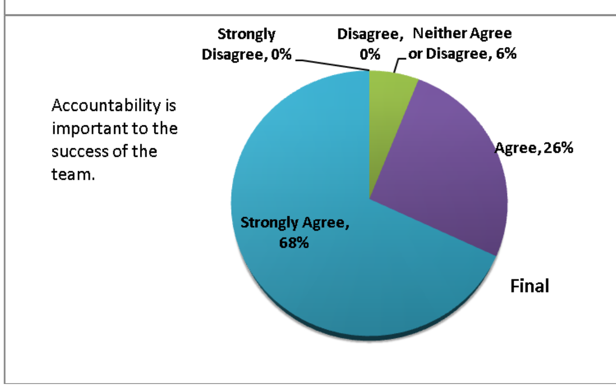
a. Working on a team helped me to better understand the purpose of team projects.
b. It is important to be able to ask a teammate to explain something to me that they know.
c. I am comfortable in giving feedback to members of my team.
d. I am comfortable in dealing with conflict on a team.
e. Accountability is important to the success of the team.
f. I like working on a team.

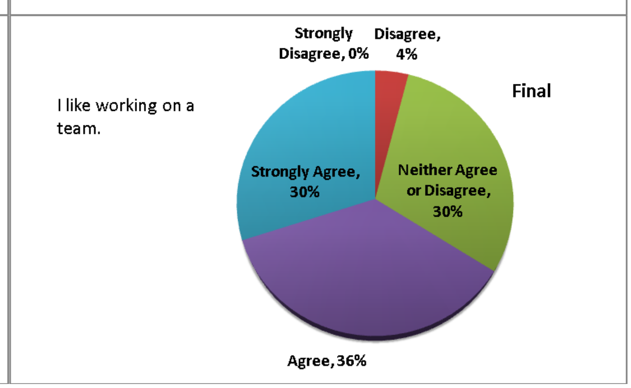






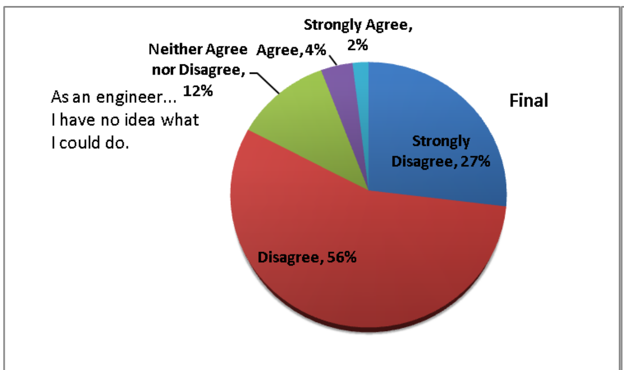


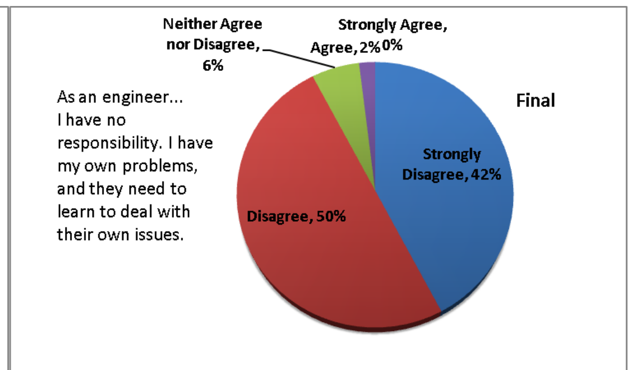


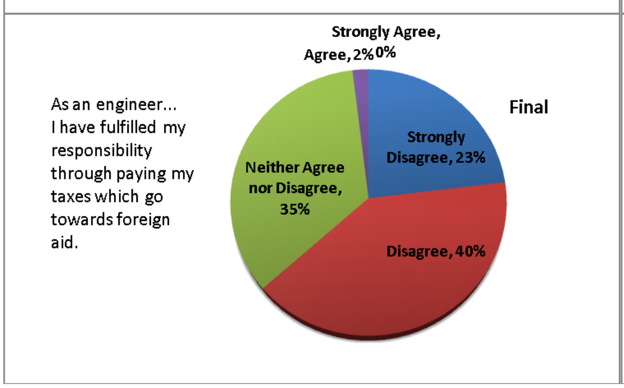


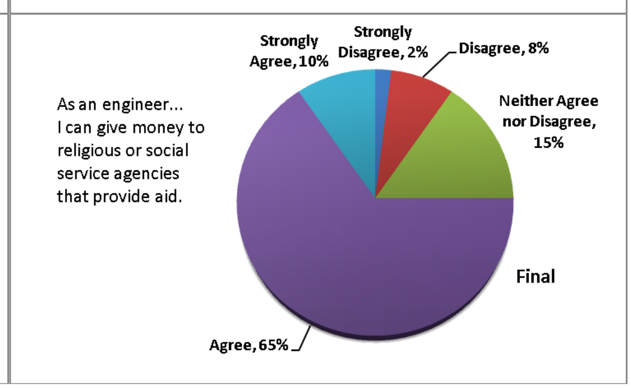
Engineer's Responsibility: People around the world face serious issues every day. What do you feel is your level of responsibility as an engineer in facing these issues?
As an engineer...

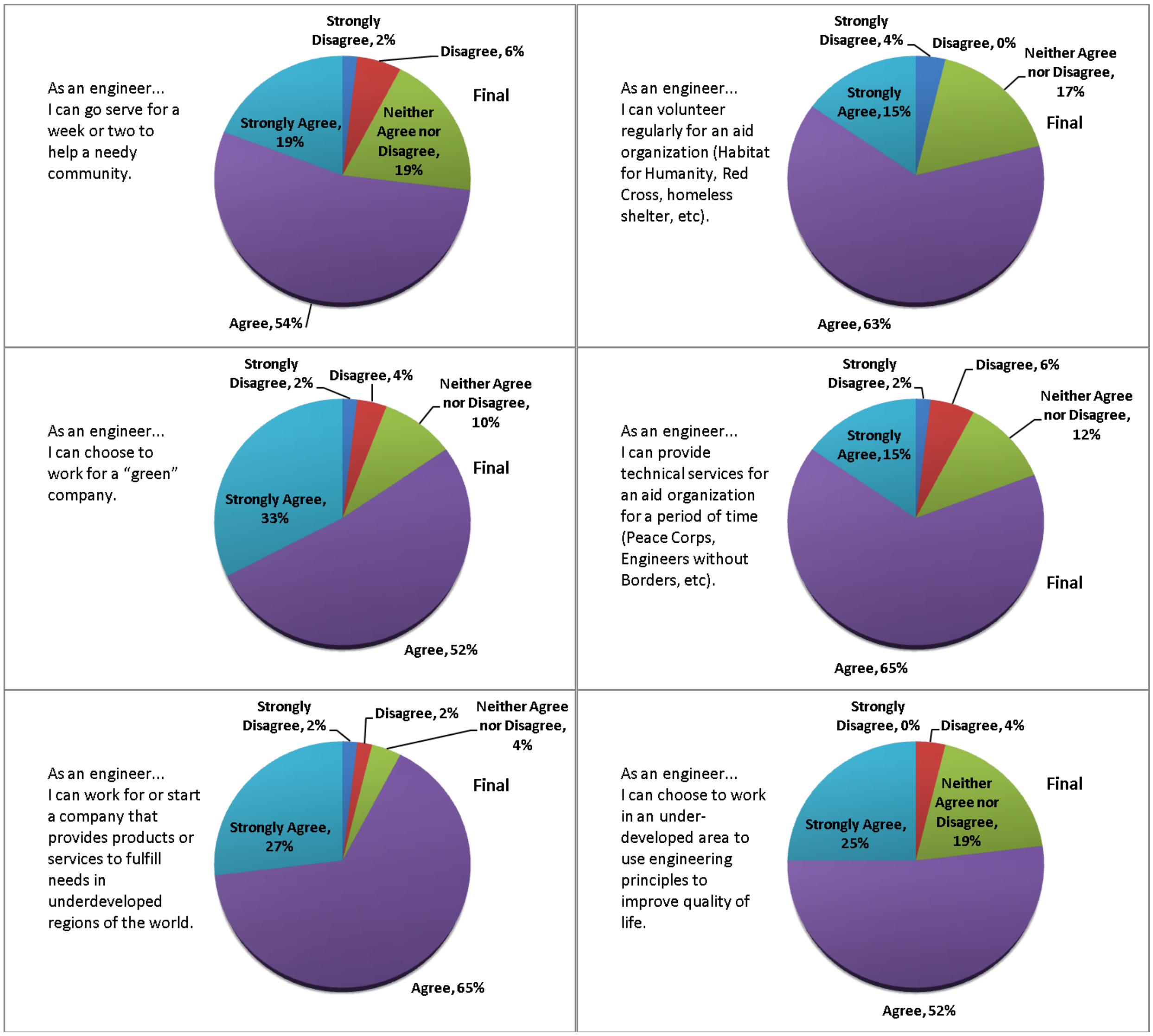
a. I have no idea what I could do.
b. I have no responsibility. I have my own problems, and they need to learn to deal with their own issues.
c. I have fulfilled my responsibility through paying my taxes which go towards foreign aid.
d. I can give money to religious or social service agencies that provide aid.
e. I can go serve for a week or two to help a needy community.
f. I can volunteer regularly for an aid organization (Habitat for Humanity, Red Cross, homeless shelter, etc).
g. I can choose to work for a "green" company.
h. I can provide technical services for an aid organization for a period of time (Peace Corps, Engineers without Borders, etc).
i. I can work for or start a company that provides products or services to fulfill needs in underdeveloped regions of the world.
j. I can choose to work in an under-developed area to use engineering principles to improve quality of life.





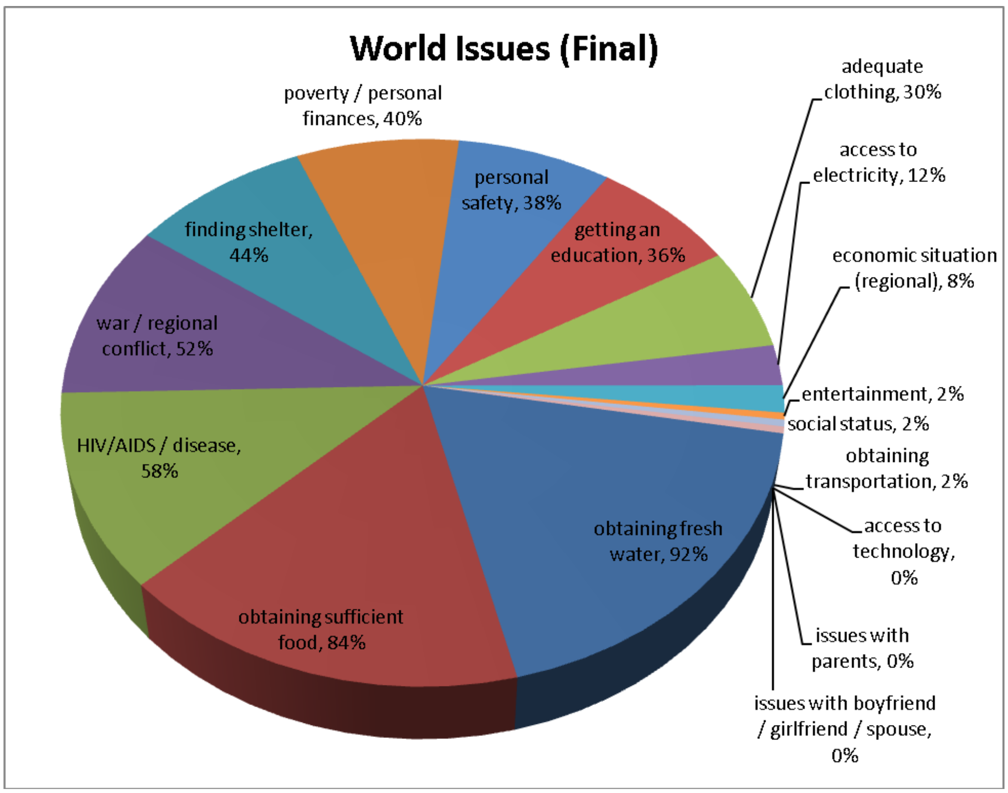





As an engineer...
I can go serve for a week or two to help a needy community.
Final
Strongly Disagree, 2%
Disagree, 6%
Neither Agree nor Disagree, 19%
Agree, 54%
Strongly Agree, 19%
As an engineer...
I can volunteer regularly for an aid organization (Habitat for Humanity, Red Cross, homeless shelter, etc).
Final
Strongly Disagree, 4%
Disagree, 0%
Neither Agree nor Disagree, 17%
Agree, 63%
Strongly Agree, 15%
As an engineer...
I can choose to work for a "green" company.
Final
Strongly Disagree, 2%
Disagree, 4%
Neither Agree nor Disagree, 10%
Agree, 52%
Strongly Agree, 33%
As an engineer...
I can provide technical services for an aid organization for a period of time (Peace Corps, Engineers without Borders, etc).
Final
Strongly Disagree, 2%
Disagree, 6%
Neither Agree nor Disagree, 12%
Agree, 65%
Strongly Agree, 15%
As an engineer...
I can work for or start a company that provides products or services to fulfill needs in underdeveloped regions of the world.
Final
Strongly Disagree, 2%
Disagree, 2%
Neither Agree nor Disagree, 4%
Agree, 65%
Strongly Agree, 27%
As an engineer...
I can choose to work in an under-developed area to use engineering principles to improve quality of life.
Final
Strongly Disagree, 0%
Disagree, 4%
Neither Agree nor Disagree, 19%
Agree, 52%
Strongly Agree, 25%

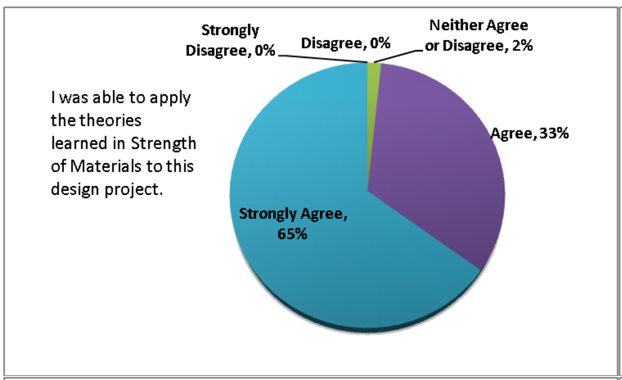
World Issues: What do you think are the top FIVE daily concerns of a typical high-school-age person living in a rural area of an underdeveloped country in sub-Saharan Africa?

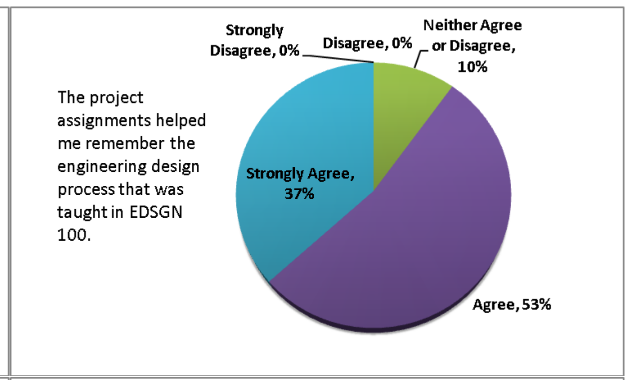
obtaining fresh water	92%
obtaining sufficient food	84%
HIV/AIDS / disease	58%
war / regional conflict	52%
finding shelter	44%
poverty / personal finances	40%
personal safety	38%
getting an education	36%
adequate clothing	30%
access to electricity	12%
economic situation (regional)	8%
entertainment	2%
social status	2%
obtaining transportation	2%
access to technology	0%
issues with parents	0%
issues with boyfriend / girlfriend / spouse	0%

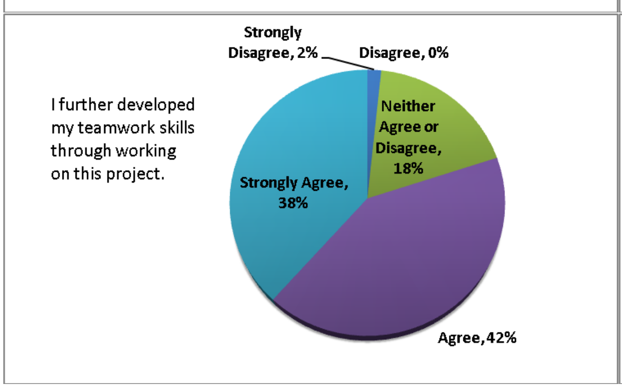


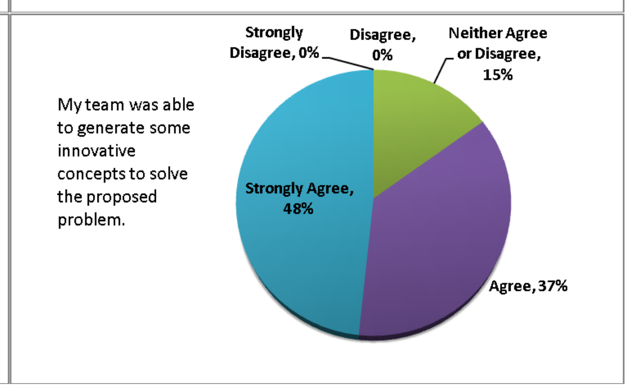
Project Outcomes
Questions:

a) I was able to apply the theories learned in Strength of Materials to this design project.
b) The project assignments helped me remember the engineering design process that was taught in EDSGN 100.
c) I further developed my teamwork skills through working on this project.
d) My team was able to generate some innovative concepts to solve the proposed problem.
e) I am more aware of world issues after this project.
f) I am confident in my technical analysis behind my group's proposed design.
g) I was able to apply the engineering design process taught in EDSGN 100 to the design project.
h) Working with my team was a positive experience.
i) My final design was an innovative approach to solve the proposed problem.
j) I have a deeper understanding of how engineering can be used to help solve world issues.

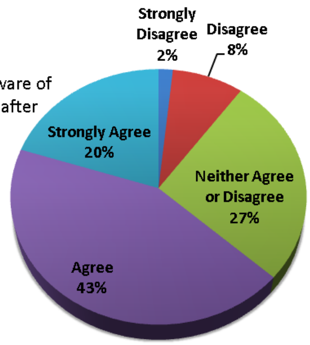




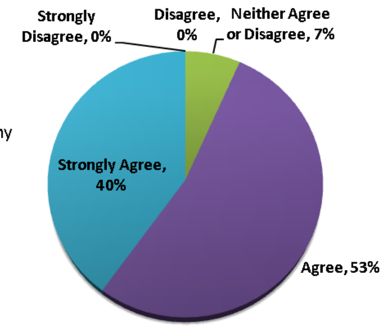




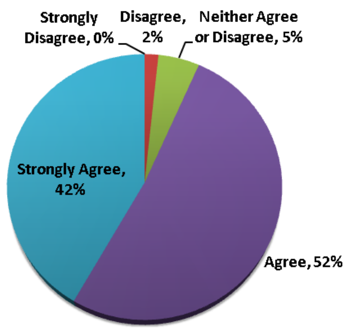
I am more aware of world issues after this project.



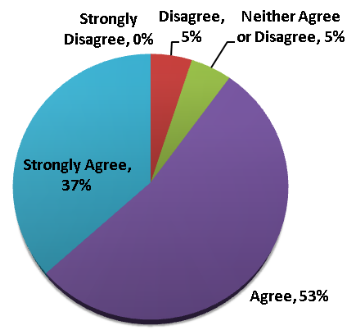
I am confident in my technical analysis behind my group's proposed design.



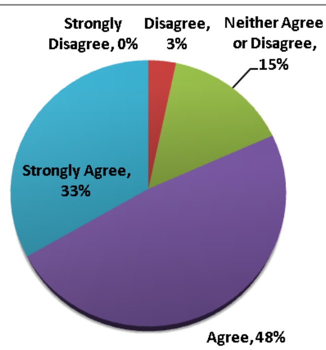
I was able to apply the engineering design process taught in EDSGN 100 to the design project.



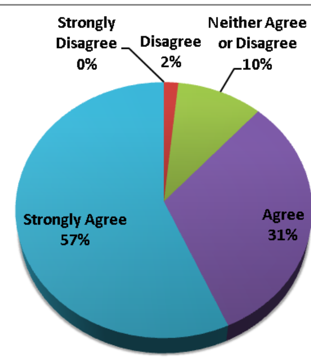
Working with my team was a positive experience.



My final design was an innovative approach to solve the proposed problem.



I have a deeper understanding of how engineering can be used to help solve world issues.



Appendix E: End of semester survey of student perceptions of learning outcomes

1. What did you learn most by working on the team project to design a water pump for a country in sub-Saharan Africa?
2. What changes should be made to the team project to best help student learning?
3. How much time did you spend on all the assignments for the course?
4. How much time did you spend on class preparation and project management for the course?
5. Do you feel that participating in this project increased your awareness of world issues and global needs?
6. Why do you feel that your awareness has been increased?
7. Why do you feel that your awareness has not been increased?
8. Would you briefly explain what you feel is the engineer's responsibility to world issues?
9. Do you feel that working with a team encouraged innovation and creative thinking?
10. Can you please give an example?
11. In one word how would you describe your experience in the team project to a fellow student who will be taking this course next semester?
12. Would you recommend this course to a friend?
13. Why or why not?