AC 2007-1849: A COMPARISON OF ATTITUDES ABOUT ENGINEERING BETWEEN INTRODUCTORY DESIGN STUDENTS IN DIFFERENT PROGRAMS

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A Comparison of Attitudes about Engineering between Introductory Design Students in Different Programs

Abstract

This paper discusses the difference in attitudes about engineering between students enrolled in two different types of engineering design courses: standard introduction to engineering design offered to freshman engineering majors and a course in engineering design offered to in-service secondary math and science teachers. This latter course is part of a series of courses, offered through the NSF-sponsored MSP (Math and Science Partnership): Project Pathways,[1] designed to help integrate mathematics and science, and can be taken as partial fulfillment of a Master's degree in Science/Math Education. An attitude survey, based on the well-documented PFEAS (Pittsburgh Freshmen Engineering Attitude Survey),[2] was taken by both sets of learners. Both groups completed the survey at the beginning and end of the Fall 2006 semester. Initial data shows a statistically significant difference between the two groups in attitudes about engineering. The greatest difference in the two groups' attitudes at the beginning and end of the semester was in the area of the subjects' perception of how engineers contribute to society. At the beginning of the semester, on a 5-point Likert scale student and teacher mean responses to the group of questions regarding engineering and society had a statistically significant mean difference of .72, $p<.01$; the two groups showed statistically significant differences on two other scales as well (general impressions of engineering and perceptions of engineering as an 'exact' science). At the end of the semester, student and teacher mean responses to the same three groups of still had statistically significant differences, but the gaps between the two groups were narrowed on two of the scales (general impressions of engineering and perceptions of engineering as an 'exact' science). However, there was a notable change in attitudes among the teachers in their perceptions of engineering as an "exact" science with a mean difference of -.64, $p<.01$.

Introduction

Until recently, little attention has been paid to the attitudes of high school teachers about the field of engineering. One recent study was conducted by ASEE (American Society for Engineering Education), who surveyed teachers across the country about their attitudes regarding engineering and other fields, which was then published on their website.[3] Another recent survey addressed K-12 teachers perceptions and needs for design, engineering and technology (DET), including their perceived importance of DET in the curriculum, their familiarity with DET and their views about engineers in general.[4] As teachers are very influential in assisting students' career selection, their attitudes about the field of engineering will likely influence whether and how they promote engineering as a career choice for their students. A survey conduct with college students showed that teachers did have some influence in the students choice of post-secondary STEM education.[5] One of the goals of Project Pathways is to positively influence secondary school teachers' attitudes about engineering.

In this study, a survey based on the PFEAS (Pittsburgh Freshman Engineering Attitudes Survey) was used to measure the attitudes of four groups of Project Pathway's secondary school teachers and a group of engineering majors at the beginning and end of introductory engineering design courses that shared the same basic curriculum. Historically, the PFEAS has been used to make many comparisons among freshman engineering students, such as those across gender and ethnicity,[6] institutional differences in attitudes,[7] and determining causes of student attrition in engineering programs,[8] in studies centered on traditional students in engineering degree programs across the country. As both the reliability and validity of this survey has been well documented,[2] it was determined to be the best model on which to base this comparison survey.

Methodology

Participants

Two groups of students taking introductory level engineering design courses participated in the study. The first group of students, hereafter referred to as "the teachers," were secondary school mathematics and science teachers taking courses through the MSP: Project Pathways, a series of four courses designed to assist the teachers in integrating mathematics and science in their teaching. The second group of students, hereafter referred to as "the students," was engineering majors enrolled in Introduction to Chemical Engineering, a traditional "freshman" engineering design course. There were a total of 97 subjects from both groups involved in the study.

There were 47 teachers involved in the study, each of whom participated in one of four sections (numbered 1-4) of the introductory engineering design course, Connecting Engineering, Science and Mathematics (CESM). As a group, the teachers were 23.4% male and 76.6% female and taught grades 8-12 (see Table 1 for complete breakdown of gender and grades taught by group). The teachers were math and science teachers, who taught a variety of different subjects, such as math, chemistry and physics (see Table 2 for breakdown of courses taught by group).

Table 1. Teachers by Gender and Grades Taught

	Male	**Female**	**8th***	**9th***	**10th***	**11th***	**12th***
Section 1 (N=8)	2 *25.0%*	6 *75.0%*	0 *0.0%*	6 *75.0%*	8 *100.0%*	8 *100.0%*	8 *100.0%*
Section 2 (N=20)	4 *20.0%*	16 *80.0%*	2 *10.0%*	9 *45.0%*	11 *55.0%*	13 *65.0%*	10 *50.0%*
Section 3 (N=14)	2 *14.3%*	12 *85.7%*	0 *0.0%*	5 *35.7%*	10 *71.4%*	10 *71.4%*	11 *78.6%*
Section 4 (N=5)	3 *60.0%*	2 *40.0%*	0 *0.0%*	1 *20.0%*	4 *80.0%*	5 *100.0%*	3 *60.0%*
Total (N=47)	**11** ***23.4%***	**36** ***76.6%***	**2** ***4.3%***	**21** ***44.7%***	**33** ***70.2%***	**36** ***76.6%***	**32** ***68.1%***

* Percentages for grades taught do not add up to 100% as teachers may teach more than one grade

Table 2. Teachers by Subject

	Math	Biology	General Science	Earth Science	Chemistry	Physics
Group 1	5	1	1	1	1	0
(N=8)	*62.5%*	*12.5%*	*12.5%*	*12.5%*	*12.5%*	*0.0%*
Group 2	11	4	4	0	5	3
(N=20)	*55.0%*	*20.0%*	*20.0%*	*0.0%*	*25.0%*	*15.0%*
Group 3	5	5	2	1	4	2
(N=14)	*35.7%*	*35.7%*	*14.3%*	*7.1%*	*28.6%*	*14.3%*
Group 4	3	2	0	0	0	1
(N=5)	*60.0%*	*40.0%*	*0.0%*	*0.0%*	*0.0%*	*20.0%*
Total (N=47)	**24**	**12**	**7**	**2**	**10**	**6**
	51.1%	***25.5%***	***14.9%***	***4.3%***	***21.3%***	***12.8%***

* Percentages for grades taught do not add up to 100% as teachers may teach more than one subject

Fifty undergraduate engineering majors participated at the beginning of this study. The gender breakdown for these students was 64.0% male and 36.0% female. The students ranged in age from 18 to 27 years old, with an average age of 19.2 years old. Although the class had a large percentage of freshman students (74%), there were also sophomores (14.0%) and juniors (12.0%) taking the course. The majority of these students were Chemical Engineering majors at the beginning of the semester (96.0%); however by semester's end only 78.8% of the 33 students who completed the post-test were still in Chemical engineering, 15.2% had decided to change

Table 3. Students by Major

	Chemical Engineering	Engineering (Other Field Specified)	Major Undecided
Pretest (N=50)	48 *96.0%*	0 *0.0%*	2 *4.0%*
Posttest (N=33)	26 *78.8%*	5 *15.2%*	2 *6.1%*

Table 4. Students by Gender and Class

	Gender		Class		
	Male	Female	Freshman	Sophomore	Junior
Pretest (N=50)	32 *64.0%*	18 *36.0%*	37 *74.0%*	7 *14.0%*	6 *12.0%*
Posttest (N=33)	23 *69.7%*	10 *30.3%*	21 *63.6%*	7 *21.2%*	5 *15.2%*

majors within engineering, and 6.1% had not decided on their field as yet (see Table 3 for a complete breakdown of students' declared majors on the pre- and post-tests). Of the seventeen students who did not complete the post-test, nine had dropped the course, and eight were absent on the date of the post-test. Most of the attrition and absentees occurred among the freshman students, changing the class percentages somewhat for the post-test with 63.6% freshmen, 21.2% sophomores and 15.2% juniors (see Table 4). The gender breakdown for the post-test was similar to those of the pre-test (See Table 4).

Course Descriptions

For the most part, the texts, course content, lectures, and projects in both courses were very similar and chosen/designed by the same faculty. In both courses, the main focus was centered on the learning of the engineering design process, including formulating the problem, generating and choosing solutions, planning and implementing solutions, documenting the design process, and using engineering/mathematical/physical principles. The activities used to practice/learn the tools used in the engineering design process, such as Kepner-Tregoe Decision Analysis[9] and modeling,[10] were identical in both courses; both groups of students spent the first part of the course learning these tools in order to implement them later for the semester projects.

The course objectives for the teachers' course were as follows:

1. Participants will be able to demonstrate applied knowledge of the ***engineering design process***, including the skills of problem definition/formulation, outlining solution approaches, documenting the design process, and using scientific, mathematical, and engineering principles in the process.
2. Participants will be able to compare and contrast the process behaviors / habits of mind of mathematics, science, and engineering, and describe how mathematics, science and engineering concepts and processes support and influence each other
3. Participants will be able to identify the kinds of problems and design challenges relevant to the major engineering disciplines.
4. Participants will be able to demonstrate knowledge of and skills for creating, implementing, and using various kinds of models of artifacts and processes, with particular focus on problem solving approaches, and mathematical models implemented using spreadsheets.
5. Participants will be able to develop both curricular materials relevant to their discipline, and to design (using the engineering design process) instructional artifacts relevant to instructing within their discipline

The course objectives for the undergraduate Introduction to Chemical Engineering were:

1. Students will be able to demonstrate applied knowledge of the ***engineering design process***, including the skills of problem definition/formulation, outlining solution approaches, planning for implementation of solutions, applying quality principles, documenting the design process, and using scientific, mathematical, and engineering principles in the process, with special emphasis on problems relevant to chemical engineering.
2. Students will be able to demonstrate knowledge and skills relevant to working cooperatively and collaboratively in teams, including familiarity with team dynamics, group communication, identifying and choosing group norms, and knowledge of conflict management strategies.
3. Students will be able to demonstrate knowledge of the professions of engineering (chemical engineering in particular), including the types of problems solved by (chemical) engineers, and professional and ethical expectations of engineers.

4. Students will be able to demonstrate knowledge and behaviors relevant to engineering career success, including life-long learning (learning to learn), self-assessment and peer assessment, and time management.
5. Students will be able to demonstrate applied knowledge of organizing and presenting technical work, including oral reports, extended written reports, graphical presentation, and basic skill in relevant use of media and information resources.
6. Students be able to demonstrate knowledge of and skills for creating, implementing, and using various kinds of models of artifacts and processes, with particular focus on problem solving approaches, and mathematical models implemented using spreadsheets.

There were many similarities between the two courses. First, comparison of the course objectives shows similarity in the focus of the two courses in terms of the learning of the engineering design process, as can be seen in objective #1 in both courses. Though the students did spend more time on solution implementation and quality principles during the semester, these topics were presented to the teachers as part of the course materials but were not emphasized to the extent that they were in the students' case. Second, objective #3 for both courses was very much alike in scope, with the exception that the students had more of a focus on chemical engineering as a profession and the professional and ethical expectations of the engineering profession. However, engineering professionalism and ethics were discussed as part of the teachers' course as a topic of interest, though not emphasized in the course objectives. Next, objective #4 for the teachers' course and objective #6 for the students' course, dealing with modeling are identical, and the development of these skills were dealt with in similar manners in the two courses. Finally, both groups completed projects during the course that were similar, to design, implement and fly a hot air balloon that met specific design criteria using the engineering design process and all of the tools that they learned in the course. The students did this as part of a two project sequence (design and redesign of a balloon, one building on their knowledge of the first). The teachers followed the same design specifications, but completed the balloon as their first project for the course.

The students' course included many foci necessary for the education of future engineers that were either deemed unnecessary or were expected to be more fully developed in professionals, such as teachers. These included those listed in objective #2, #4 and #5, such as group organization/dynamics, collaboration with others, life-long learning, time management, written and oral presentation, etc. However, some time was spent with the teachers discussing teaming, both for the engineering profession and their classrooms, such using the tools developed for selecting teams used in both the courses.

The teachers' course included objectives related to those of Project Pathways, as outlined in objective #2. In addition, the final design project for the teachers was to design an 'artifact' to be used as a tool in their classrooms, as outlined in course objective #5.

Generally, the two courses were quite similar in material and presentation. They were both designed with an active learning approach, with short segments of lecture, complimented with exercises using the material discussed in the classroom and that presented in the course textbooks (which were the same for the two courses). The materials relating to the engineering design process and its tools were virtually identical in scope and presentation in both of the courses.

Course Instructors

The teachers' courses, with one exception, Section 4, were taught by teams of instructors (one male & one female in each team). The instructors for Section 1 consisted of a female professor of Chemical Engineering, whose research interests are in engineering education, and a male graduate student from Math Education, who had extensive experience as a professional engineer. The female chemical engineering professor was also the head of the course design team for the teachers' course and the instructor/course designer for the students' engineering design course. For Section 2, the instructors were an experienced male high school teacher, who had a degree in engineering, and a female graduate student from Math Education, who also had extensive experience as a professional engineer. Next, the instructors for Section 3 were the male high school teacher, who was also an instructor for Section 2, and a female instructor, who has experience as a middle/high school mathematics teacher, mathematics learning researcher and in professional development in the K-12 environment. Finally, the instructor for Section 4 was a graduate student in Mechanical Engineering, who had experience in teaching introductory engineering design in the community colleges. The instructors for all sections met weekly to coordinate presentation of the course material and were all involved in the development of the course, as presented to the teachers.

Survey Description

As the two groups of subjects had very different perspectives on taking the engineering design courses, it was determined that administering the standard version of the PFEAS directly to both groups would not be an effective method of measuring the teachers' attitudes and beliefs about engineering as a profession. The original survey was directed toward freshman students majoring in engineering; therefore, many of the questions did not apply to the standpoint of the teachers taking the design course. The survey questions asked of the students were based on those from the PFEAS,[11] using the wording as seen on their website, but the wording of some of the statements was altered in the teachers survey to fit their perception of engineering in general and as a career choice for their students (See Appendix A for complete wording of questions asked of both groups). Altogether, the comparison includes 16 statements regarding attitudes about engineering, with responses on a 5-point Likert scale: strongly disagree, disagree, neutral, agree, and strongly agree. The comparisons were made only on topics related to their general impressions of engineering (how the students like engineering or how the teachers feel about the field of engineering), general impression of the work engineers do and the engineering profession (whether they consider engineering to be a respected and innovative profession), general impressions of how engineers contribute to society, and general impressions of engineering as an "exact" science.[2]

The survey was administered twice during the Fall 2006 semester to both groups of introductory design students. The first form of the survey was given during the first regular class meeting of the semester in each of the classes (five sections total). The second form was given during the last regular instructional class meeting, prior to project presentations and final exams. T-tests were used to compare means between the groups' pre-/post-course survey results; and, Mann-

Whitney non-parametric tests were used to obtain *p*-values for the comparisons, as the data was shown to violate the normality assumption.

Results

Table 5 provides a summary of the statistical comparison of the four engineering attitudes categories between the groups, pre- and post-course comparisons between the students and teachers, and comparisons pre-course to post-course for the teachers and students, separately. There were significant differences between the teachers and students in the same three categories in the pre- and post-course surveys, general impressions of engineering, general impressions of how engineers contribute to society, and general impressions of engineering as an "exact" science. At first look, this could appear to be a situation of no change; however, due to the relatively small sample size, outliers have a significant effect on the outcomes, so the results were also analyzed by a second method, to be discussed later, which makes changes in teacher

Table 5. Comparison of Teachers'/Students' Pre-/Post-course Means on Four Categories Related to Their Attitudes about Engineering

	General Engineering Impressions	**Engineering & Society**	**Engineering Profession**	**Engineering as an "Exact" Science**	**Total**
Pre-course:					
Teachers:	3.96	2.72	4.08	3.06	3.44
SD:	*0.45*	*0.78*	*0.37*	*0.81*	*0.30*
Students:	4.51	3.45	4.22	3.48	3.70
SD:	*0.38*	*0.69*	*0.45*	*0.73*	*0.29*
Mean Difference:	0.55	0.72	0.13	0.36	0.26
SE:	*0.09*	*0.15*	*0.08*	*0.16*	*0.06*
	p<.01	*p<.01*	*ns*	*p=0.03*	*p<.01*
Post-course:					
Teachers:	4.00	2.76	4.18	2.42	3.63
SD:	*0.63*	*0.85*	*0.35*	*0.88*	*0.40*
Students:	4.32	3.59	4.35	2.97	3.82
SD:	*0.41*	*0.61*	*0.38*	*0.81*	*0.33*
Mean Difference:	0.32	0.83	0.17	0.55	0.19
SE:	*0.12*	*0.17*	*0.08*	*0.20*	*0.09*
	p=.01	*p<.01*	*ns*	*p=.01*	*p=.05*
Teachers:					
(Pre- vs. Post-course)					
Mean Difference:	0.04	0.03	0.09	-0.64	0.19
SE:	*0.12*	*0.17*	*0.08*	*0.18*	*0.08*
	ns	*ns*	*ns*	*p<.01*	*p=.01*
Students:*					
(Pre- vs. Post-course)					
Mean Difference:	-0.19	0.14	0.13	-0.45	0.12
SE:	*0.09*	*0.15*	*0.10*	*0.18*	*0.07*
	ns	*ns*	*ns*	*p=.02*	*ns*

attitudes over the semester clearer. The teachers did have a statistically significant change in their impressions of engineering as an "exact" science with a mean difference of -0.64, $p<.01$, showing that they now have a greater understanding of the engineering field and its use of models and estimation. In fact, the teachers had a better grasp of this concept of engineering as an "inexact" science than did the engineering students, posting a higher mean difference during the semester than the students, although the students also showed a statistically significant change in attitude before and after the course with a mean difference of -0.45, p=.02. The teachers showed an overall improvement in their attitudes about engineering with a mean difference of 0.19, p=.01.

Table 6. 5-point Likert Scale Percentages, by category

		Teachers (Pre/**Post**) **Students** (Pre/**Post**)				
	Teachers(T) Students(S)	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
Average: General Impressions of Engineering	T	0.0%	0.0%	4.3%	63.0%	32.6%
	T	**2.3%**	**0.0%**	**2.3%**	**51.2%**	**44.2%**
	S	0.0%	0.0%	0.0%	16.7%	83.3%
	S	**0.0%**	**0.0%**	**0.0%**	**34.5%**	**65.5%**
Average: General Impression of the Work Engineers Do and the Engineering Profession	T	0.0%	0.0%	0.0%	60.9%	39.1%
	T	**0.0%**	**0.0%**	**0.0%**	**51.2%**	**48.8%**
	S	0.0%	0.0%	2.1%	41.7%	58.3%
	S	**0.0%**	**0.0%**	**0.0%**	**31.0%**	**69.0%**
Average: General Impression of How Engineers Contribute to Society	T	2.2%	26.1%	50.0%	19.6%	2.2%
	T	**2.3%**	**30.2%**	**41.9%**	**18.6%**	**7.0%**
	S	0.0%	2.1%	45.8%	41.7%	12.5%
	S	**0.0%**	**0.0%**	**27.6%**	**62.1%**	**10.3%**
Average: General Impression of Engineering as an Exact Science	T	2.2%	11.1%	46.7%	35.6%	4.4%
	T	**7.0%**	**46.5%**	**34.9%**	**7.0%**	**4.7%**
	S	0.0%	4.2%	39.6%	43.8%	14.6%
	S	**0.0%**	**27.6%**	**27.6%**	**41.4%**	**3.4%**

Table 6 provides a summary of percentages for the four engineering attitudes categories and the total survey based on the 5-point Likert scale responses, which show a clearer picture of changes in student and teacher attitudes over the semester. In the category of general impressions of engineering, there was a small change in the teachers' attitudes over the semester (a larger percentage 'strongly agree' with statements in this category); however, the students, as a whole, showed a small decline in positive attitudes, moving in the opposite direction from 'strongly agree' to simply 'agree.' Both groups, as a whole remained very positive about the general impressions of the work that engineers do and the engineering profession, showing a small change over the semester with a greater percentage choosing 'strongly agree' on the posttest. In the category of how engineers contribute to society, the teachers showed a bit of movement at both ends of the scale, while the engineering majors showed some positive movement from 'neutral' to 'agree.' The attitude shift in engineering as an "exact" science is even clearer here; though the engineering students showed some shift in understanding the nature of the field, it is clear that the teachers' attitudes showed a much greater understanding, with many of them moving from away from the neutral and agree selections to the negative end of the scale (believing that engineering is not an "exact" science).

Conclusions and Future Work

Several statistically significant differences were found between the teachers and engineering majors in three of the four attitude categories: general impressions of engineering, general impressions of how engineers contribute to society, and general impressions of engineering as an "exact" science. The teachers showed very small gains that were not statistically significant in three of the categories (general impressions of engineering, general impressions of how engineers contribute to society and general impression of how engineers contribute to society), while the students showed similar small gains that were not statistically significant in two of these categories (general impressions of how engineers contribute to society and general impression of how engineers contribute to society). For the students, the small decrease in their attitude about engineering in general may be due to the timing of the post-course survey, as it was given in the week just prior to finals. Overall, there were not the attitude gains that were expected from the teachers in these three categories; however, this could be due to the group involved in the course, as teachers who chose to take such a course would be inclined to be positive about engineering to begin with, as can be seen from their pre-course survey .

Both groups saw the largest change in their understanding of engineering as it relates to engineering as an "exact" science. The extensive work done in the courses with such tools as modeling and estimation had a positive effect on both groups of students, increasing their understanding of the fact that engineering is not an 'exact' science, but relies on solutions that are 'good enough' to meet the criteria of the specific problem being addressed at the time. The teachers showed the greatest increase in understanding of this category in both the pre- and post-tests, in both cases, posting greater statistically significant differences from the students (pretest, mean difference=0.36, p=.03, and posttest, mean difference=0.55, p=.01). The teachers also had the greatest gain in understanding in this category with a statistically significant mean difference of -.64, $p<.01$, versus the students mean difference of -0.45, $p<.01$. Therefore, both courses were successful in introducing this concept of engineering as an 'inexact' science to both groups of introductory design students.

One of the strengths of this study is the comparison of attitudes about engineering between engineering majors and non-engineering majors, specifically high school teachers, taking similar courses in introductory engineering design. Using an instrument whose validity and reliability was previously well-documented is an additional strength of this work. Though many studies have been conducted with engineering students and a few studies with high school teachers regarding their attitudes about engineering, a comparison between these two groups has not previously been made. Since the two courses were very similar in content and presentation, differences in the amount of attitude change are likely related to differences in the groups. One weakness of the study was its relatively small sample size for both groups. However, in order to accomplish the comparison, both groups needed to be taking similar courses, which limited the number of participants in each group.

Future work will include several comparisons of these survey results to other data gathered during this semester in both courses. The data from the teachers' surveys will be used in conjunction with analysis of videotaped classroom sessions, individual reflective writing portions of assignments and other surveys completed during the course (on STEM behaviors and beliefs) to look at both the teachers changes in attitudes and their learning processes in general over the semester. Additional data will also be gathered in the coming semesters from different groups of teachers and students in these same courses, to look at how changes in the presentation of the course material will affect the attitudes of the teachers about the field of engineering. The student surveys will be used in conjunction with several reflective writing assignments, other class work and grades to make qualitative comparisons of possible reasons for attitude changes in the engineering majors. The comparisons of the qualitative and quantitative results for each of the groups individually will give a clearer picture of both groups as a whole, including changes in attitude over the semester and their learning processes during the semester.

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Appendix A. Wording of Survey Questions: Teachers (*Students*)

Note: If no *italicized* statement is included for the students' survey, then the wording on both surveys was identical.

General Impressions of Engineering:

- I expect that engineering would be a rewarding career. *(I expect that engineering will be a rewarding career.)*
- I expect that studying engineering would be rewarding. *(I expect that studying engineering will be rewarding.)*
- The advantages of studying engineering outweigh the disadvantages.
- The future benefits of studying engineering will* be worth the effort (*post = was, for the teachers only)
- The rewards of getting an engineering degree would not be worth the effort. *(The rewards of getting an engineering degree are not worth the effort.)*
- From what I know, engineering is boring.

Work and the Engineering Profession:

- Engineers are innovative.
- Engineering is an occupation that is respected by other people.
- Professionalism goes with being an engineer. *(I like the professionalism that goes with being an engineer.)*
- Engineers are creative.
- Engineers enjoy figuring out how things work. *(I am studying engineering because I enjoy figuring out how things work)*
- Technology plays an important role in solving society's problems.

Engineers' Contributions to Society:

- Engineers contribute more to making the world a better place then people in most other professions.
- Engineering is more concerned with improving the welfare of society than most other professions.

Engineering as an "Exact" Science:

- Engineering is an exact science.
- Engineering involves finding precise answers to problems.