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Mechanical Engineering Design at King Saud University: An Outcome Assessment

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Abstract. In the past, the main issues in engineering design revolved around making things work. Now, things are more complicated. The design engineer and the design educator must also struggle with issues on environmental, legal, manufacturing, marketing, maintenance, life cycle, intellectual property, cultural, and global considerations. Therefore, undergraduate engineering students need more than just a good technical background. They need educational experience that can help them develop such skills as interacting effectively with people of widely varying social and educational background, ability to participate in a group and work with team members, managing and leading a project, the art of solving technical problems, good communication, motivating people, awareness of ethical issues, organizational skills, resource-fulness (creativity, originality, etc.).

The goals of engineering design educators at King Saud University are: (a) to enhance a heightened awareness of engineering design as an important element of engineering education and practice; (b) to encompass modern concepts of engineering design principles; and (c) to promote design education across the engineering curriculum.

In this paper, the mechanical engineering design education at King Saud University is highlighted. The different courses' structure and management are explained. An assessment methodology for the measurable learning outcomes is drawn up. The relationships of the design courses to program objectives as stated by ABET EC 2000 Criterion are examined and the students' achievements are then presented.

Introduction

Modern engineering education is slowly realizing the importance of design, manufacturing and teamwork. Design and manufacturing are the synthetic part of engineering practice. Design is an integral part of manufacture and can be viewed as planning for manufacturing. The improvement of manufacturing processes, while vital, is pointless without excellent design. The importance of these issues in education is being driven by industry. The greatest deficiency occurs because design is not integrated throughout the engineering science courses from the first year to the last one. This area is also where the least attention has been paid; because many of the faculty members in these courses have little industrial and /or engineering design experience.

The team work forms a broad based forum for exploring ideas, sharing experiences, and developing new approaches to handling problems in design. In the past, the main issues in engineering design revolved around making things work. Nowadays things are more complicated. The design engineer and the design educator must also grapple with issues on environmental, legal, manufacturing, marketing, maintenance, life cycle, intellectual property, cultural, and global considerations, as well as a host of influencing factors once considered far outside the realm of engineers, (ABET Engineering Criteria 2000; Dixson, 1991; Faste *et al.,* 1993; Aldridge and Lewis, 1997; Pimmel, 2001).

Engineering design is the process of devising a system, component or process to meet the desired needs. It is a decision making process, in which the basic sciences and mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. The engineering design component of the curriculum must include the following features: the development of student creativity, use of open-ended problems, development and use of modern design theory and methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility considerations, production processes, and detailed system descriptions. Furthermore, it is essential to include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics, and social impact (Dahir, 1993).

Accreditation for an engineering program is intended to ensure that the program is designed to prepare graduates for the practice of engineering at a professional level. General criteria for accreditation are intended to assure an adequate foundation in science, the humanities and the social sciences and engineering design methods. In addition, preparation is assured in a higher engineering specialization appropriate to the challenge presented by today's complex and difficult problems (Valenti, 1996; Oakes *et al*., 2000; ElMadany, 2003).

Recently, the Accreditation Board for Engineering and Technology (ABET) has approved new criteria for evaluating engineering programs. These criteria, known as Engineering Criteria 2000 (EC2000) (Dahir, 1993), have a strong outcome-based component in addition to the conventional content-based component. Part of this outcome-based component involves a continual on-going assessment and evaluation process not only for ABET accreditation but also for the improvement of the program (McCreanor, 2001).

The ABET a-k outcomes include technical and non-technical (or 'soft') skills which faculty members are expected to teach and therefore measure. Improving performance with respect to skills, as opposed to transferring information, requires alternative approaches to instruction (Collins and Davidson, 2002). Woods *et al.* (1997) showed that students do not develop problem solving skills by (a) watching faculty work problems, (b) watching other students work problems, or (c) working many problems (even open-ended problems) themselves. Instead, problem-solving skills were learned in a workshop environment. Students need an opportunity to develop and practice soft skills. Student-student interaction has been shown to be an effective way of learning, which is often neglected in the traditional lecture course (Mourtos, 1997; Seat and Lord, 1999; Seat *et al*., 2001).

In this paper, the mechanical engineering design education at King Saud University is highlighted. The different courses' structure and management are explained. An assessment methodology for the measurable learning outcomes is drawn up. The relationships of the design courses to program objectives as stated by ABET EC 2000 Criterion are examined and the students' achievements are then presented.

Mechanical Engineering Department

Mission of the department

- To prepare students with the innovative engineering, design, and problem solving skills needed to develop and bring to the market place competitive products and services for the benefit of society.
- To help students develop character, self-reliance, and leadership skills through a high degree of choice, involvement, and responsibility in their engineering design projects and senior projects.
- To engage in leading-edge, interdisciplinary research and service to industry and society.
- To provide high-quality, state-of-the-art courses of service to the college, the university, and the community at large.

Educational objectives

- To understand basic principles, science, mathematics, engineering sciences, mechanical systems, and computational skills, with an ability to model, analyze, synthesize, ideate, iterate, and implement engineering solutions in the areas of thermal and mechanical systems.
- To understand product design, development and manufacturing, and acquire the capability to work effectively as individuals and in teams.
- To comprehend quantitative, analytical and experimental methods, including data analysis techniques.
- To communicate ideas verbally, graphically and in writing.
- To develop an ethical approach to engineering, and to understand professional responsibilities, with concern for society and the environment.
- To acquire the knowledge base, confidence, and mental discipline for self-education and life-long learning.

Program outcomes

Each student in receiving a BSME degree from the program will demonstrate:

a) An ability to apply knowledge of mathematics, science, and engineering.
b) An ability to design and conduct experiments, as

well as to analyze and interpret data.

c) An ability to design a system, component, or process to meet desired needs.
d) An ability to function on multi-disciplinary teams.
e) An ability to identify, formulate and solve engineering problems.
f) An understanding of professional and ethical responsibility.
g) An ability to communicate effectively.
h) The broad education necessary to understand the impact of engineering solutions in a global and societal context.
i) A recognition of the need for, and a ability to engage in life-long learning.
j) A knowledge of contemporary issues.
k) An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.
l) An ability to apply advanced mathematics through multivariate calculus and differential equations.
m) An ability to apply statistics and linear algebra to problems in mechanical engineering.
n) An ability to demonstrate knowledge of chemistry and physics.
o) An ability to work professionally in both thermal and mechanical systems areas.

Curriculum

The undergraduate program offered by the Department of Mechanical Engineering provides an opportunity for students with an aptitude for physical sciences, mathematics and use of computers to fully develop their capabilities and apply them to the engineering program. The graduates of Mechanical Engineering acquire an excellent background in mechanics and thermal sciences to analyze the conversion and transmission of energy in its many forms. Mechanical engineers use this knowledge to solve new problems and to make things work better, more efficiently, and more economically.

The Mechanical Engineering curriculum is designed as a sequence of increasingly specialized experience. The entering student's first two years are spent in studying the basics of science: mathematics, physics, chemistry, English language, computer skills, Arabic language, Islam, and some fundamental courses such as statics, dynamics, materials engineering and the mechanics of materials. Building on this base, in the third year, students take more fundamental courses such as thermodynamics, introductory fluid mechanics, basic elements of circuits and electronics, and manufacturing processes. By the fourth year, students study specialized Mechanical Engineering courses in the subfields of fluid mechanics, heat transfer, dynamic systems, automatic control, and engineering design. Finally, during the fifth year, the program offers the opportunity to both broaden and deepen the students' knowledge of the field through additional technical courses. Furthermore, in the final year, students take a senior project, in which the knowledge and skills they have learned are applied. Engineering design, technical communication, teamwork, and laboratory experiences are integrated throughout the curriculum.

Design Courses Information

Engineering design is described as a continuous process whereby scientific knowledge and technological information are used to create or modify a system, device, or process that will benefit society. This concept is introduced in the first design course and forms the philosophical basis for other design courses and for general engineering courses.

Before taking design courses, we tend to apply drawing classes to improve the creativity and imagination skills in our students. As a result, extensive drawing classes prior getting into design courses are considered to be serious implements for engineering students. They help them understand how to draw, assemble, and simulate mechanical systems using engineering computer software such as AutoCAD, and SolidWorks.

The first design course, offered at the seventh level, gives students an introduction to the fundamentals of mechanical engineering design which covers the basic concepts and principles in the design and analysis of machine and structural components. A balance between theory and design methods is emphasized. This can be done by preparing students for more advanced real practice in design and for using computer aided engineering as an important tool in the design process.

The second course, offered at the eighth level, introduces design methodology and techniques for approaching open-ended problems. Students will work on a design-and-build project. The design project incorporates realistic constraints and a majority of the following considerations: ethical, economic, environmental, manufacturing, sustainability, safety and social. Detailed descriptions of the two design courses together with typical design projects are given in Appendix A.

The Senior Projects Program coordinates the completion of a two-semester project sequence required of all Mechanical Engineering seniors. Students work individually. Each student is required to provide a detailed final report and a formal presentation to his peers (examiners). Unfortunately, the contents of most of these projects are analysis rather than design.

The authors strive to make the senior project to be a senior design project as a "capstone design experience", in which the students apply engineering design methodology, using both analysis and synthesis, to solve open-ended problems. And in which the faculty member will monitor the student's progress by means of informal meetings, oral presentations, and notebook checks. In addition, general design issues and professional responsibility will be addressed in the lectures. The other two "cornerstone" design courses will set the foundation for this senior design course.

These design-project courses aim to provide students with the understanding of the profession, a creative learning environment and positive attitude, skills for team-based problem solving, and an appreciation of the need to be communicators. These courses generally take a "holistic" approach to design education by having students experience that design is more than a project, more than a teamwork, more than an oral presentation, more than analysis, and more than creativity—it is a comprehensive and professional endeavor.

The design courses are developed to help engineering students see themselves as emerging professionals by challenging them to develop leadership skills, attitudes and confidence.

Objectives

The overall objective of these design courses is to provide the student with an integrative experience which ties the skills and knowledge obtained from the curriculum to the business world.

The specific objectives of these design courses are: (1) to instill the philosophy that real engineering problems are open-ended; (2) to provide students with good technical capabilities; (3) to teach a design methodology; (4) to enable the students to identify and solve the ill-structured and open-ended problems; (5) to sharpen skills in critical thinking, problem solving, planning, scheduling, and decision making; (6) to generate a set of distinct and creative design concepts; (7) to develop the experience and ability for tackling problems individually and cooperatively; (8) to acquire the ability to function on a design team; (9) to be able to perform integrated design tasks utilizing basic engineering sciences and technology knowledge; (10) to make students familiar with legal issues such as liability and intellectual property; (11) to guide students to deliver professional quality presentations; and (12) to acquire important basic skills such as communication and leadership.

Expected student outcomes from design courses

a. Be able to use the fundamental steps in the design process mode—recognize the need, define the problem, plan the project, gather information, conceptualize alternative approaches, evaluate alternatives, select preferred alternative, and implement the preferred design.
b. Learn to work and communicate effectively both as individual and in teams.
c. Be able to perform and communicate the results of a multi-disciplinary system design.
d. Be able to make decisions based on societal need and implications, contemporary issues and ethical considerations.
e. Be able, as a member of a team, to complete a design project to a finished, functioning system.
f. Use appropriate software for design, modeling, analysis, wordprocessing, presentations, e-mail, and Internet.

Class structure and management

Each class is divided into 3 to 5 teams, and each team is composed of 4 to 5 students, depending on the design projects and participants available. Since engineering design education places large emphasis on developing independent thinking and leadership, the members of each team assign the different responsibilities within themselves. These responsibilities include team leader, presenter, report writer, information digger, public communicator, etc.

The engineering design classes are divided into three lectures and two hours studio each. Student participation is an integral component of the classes. A lecture, a class exercise and a discussion can take place all in one period. The questions asked and issues raised by the class may guide the course of discussion in a class. Each team has to select a project from a set of projects proposed by the professor. There are more topics to select from, than there will be design projects, so that there is a considerable flexibility in the student selection of projects. The students are given the freedom to select from the menu of problems that is provided. The main objective is to stimulate student motivation. In some cases, the students are allowed to propose their own topics for a project, provided it is sufficiently well developed and does not violate the theme for all of the projects in the course in a particular semester. The students are required to identify, clarify and analyze problems and relevant solutions on their own, both independently and as teams. All relevant information such as design goals and objectives, design project characterization, design constraints, design requirements, design specifications, possible design concepts generation, evaluation, and selection are determined by the students. The role of the professor is to provide the students with tools and guidance in order to help them analyze and utilize the information that they gather more effectively and efficiently. The professors encourage creativity and assure that the students reach an acceptable end point. It has been found that the professor's sincere enthusiasm for students' work can be one of the best approaches to get the most out of the students.

All teams are required to meet with their professor once a week during studio hours to discuss the problems they faced, the results they obtained, and the progress they accomplished. They are required to submit a biweekly report detailing their activities. At the end of the semester, all teams are required to submit a final report and to give a final oral presentation together with a prototype if any. Public presentation using a poster is required from each team.

Every student is expected to maintain a bound design notebook for the design project in this course. All student work concerning the design project should be recorded in this notebook, including meeting participants and minutes, sketches, notes, gathered information, ideas and calculations. The student should keep the design notebook with him at all team meetings and bring it to every class and studio period. This design notebook must be submitted for evaluation at the end of the semester.

In order to enhance the design courses, the authors team up with other teachers to give the project an interdisciplinary scope that is typical of more real-world engineering projects. They also used to bring experts into the classroom as mentors and/or guest speakers.

Project development

Since there is no set of rules governing the development of a project from the start to the final report, the following suggestions are offered to the students:

- New (or improved) systems should be designed to fulfill a given requirement in the most satisfactory manner at the least cost.
- All avenues of achieving the desired results should be investigated to insure that one has not overlooked a better or more economical way.
- Flexibility of thought, that is the ability to choose and investigate a number of approaches without losing the sight of the overall goal, is of the utmost importance.
- Make use of the experience of others as a check on your own work, not as a substitute.
- Naturally, no problem can be solved unless the problem is defined. Statement of problem must be clear and precise. This means researching the project in the library and Internet.
- With the problem precisely defined one must gather all the facts. The ability to gather and understand a large number of facts concerning the problem may result in the ability to see a large number of new possibilities or to perceive new relationships.
- When a solution begins to take form, it is usually best to work for long periods of time without interruption. On the other hand, ideas seem to come best when the mind is relaxed. Sometimes when a solution is not seen, it is wise to leave the problem for awhile and then return to it.
- Sometimes benefits can be obtained by reviewing your problem with others and listening to their comments. Brainstorming a problem with other competent engineers or technicians is often helpful.
- Custom, habit or tradition are road blocks. Adherence to the old methods often prevents the new ideas. The desire to conform or to be practical often limits the search for something new. Do not automatically eliminate new and different approaches or you will end up with something already in existence.

Design Courses Assessment

On an annual basis, the Engineering Design Committee reviews the design courses outcomes. Small groups of faculty members who teach design courses will meet to update the courses learning goals, objectives, strategies and actions. Specific data are gathered and used to determine progress towards design courses outcomes. The Engineering Design Committee is responsible for determining how well the design courses outcomes have been met and makes the necessary adjustments to them based on the information gathered.

To assure that graduates have achieved the design courses outcomes, several strategies and actions are employed for each design course outcome. Typical strategies and actions are given in Tables 1 to 4. The results are the consequences of implementing the strategies and action. Each strategy, action and result is related to one or more of the outcomes suggested by ABET. The use of the strategies and actions below assures that all of the expected design courses outcomes are addressed. The assessment methods and metrics listed identify the processes and procedures used to determine the achievement of the outcomes. These processes and procedures assure that students achieve the design courses outcomes upon graduation.

Student outcome A

Be able to use the fundamental steps in the design process mode- recognize the need, define the problem, plan the project, gather information, conceptualize alternative approaches, evaluate alternatives, select preferred alternative, and implement the preferred design.

Table 1. Student outcome A

Strategies and Actions	Results	ABET (a-k)	Assessment Methods/Metrics
Students will identify design problem and constraints	Students will be able to present clear and complete identification of the design goal and the constraints	c, e	• Oral discussions • Course binder • Written report
Students will set goals and create action plan for the execution of the project	Students will be able to create action plan and timetables to complete assigned work, seek clarification of task requirements and take corrective action	c	• Design reports • Faculty team review (instructor assessment)
Students will generate and explore alternative designs	Students will be able to generate and explore reasonable alternatives to arrive at final design	c, e	• Design reports • Course binder • Faculty team review
Students will use analytic tools to aid in design process, select preferred alternative and support final design	Students will be able to select appropriate tools and use them effectively in developing final design	a, c	• Reports • Peer review • Exit interviews

Student outcome B

Student will learn to work and communicate effectively both as individuals and in teams.

Table 2. Student outcome B

Strategies and Actions	Results	ABET (a-k)	Assessment Methods/Metrics
Students will give presentations in design courses	Students will be able to present designs for review to their peers	d, g	• Oral presentation • Written reports • Peer evaluation
Students will write complete design reports	Students will be able to gather information and report to a group	f, g, h, i, j, k	• Design reports
Students will work on group assignments in the design courses	Students will have interpersonal skills to produce a given result	d, g	• Reports • Peer review • Exit interviews
Participation in local and regional conferences and technical shows will be encouraged	Students will have experience giving presentations about independent or group projects to professional audiences	a, b, c, d, f, g, h, i, k	• Technical evaluations from audience and judges • Prize order

Student outcome C

Students will demonstrate an ability to perform and communicate the results of a multi-disciplinary systems design.

Table 3. Student outcome C

Strategies and Actions	Results	ABET Outcomes (a-k)	Assessment Methods/Metrics
Students will participate in teams in the design courses	Students will be able to apply basic concepts to design	a, c, d, e, k	• Instructor assessment of design project • Peer review of individual contributions to group design
Required design courses will include multi-disciplinary and systems analysis concepts	Students will be able to identify the components and the requirements of a complex system, and to recognize and identify the various trade-offs	c, d, e, g, k	• Instructor assessment • Peer review
Contemporary design problems will be selected for capstone design	Students will be familiar with the use of current technology in design	a, c, h, i, j, k	• Instructor assessment • Peer review • Exit interview
Design courses will include aspects of ethical, social and environmental issues	Students will have the awareness of the social and environmental issues	f, g, h	• Exit interview
Design course will require oral and written presentations	Students will have the ability to communicate technical ideas	g	• Written reports • Oral presentations

Student outcome D

Students will show that they can make decisions based on societal need and implications, contemporary issues and ethical considerations.

Table 4. Student outcome D

Strategies and Actions	Results	ABET Outcomes (a-k)	Assessment Methods/Metrics
Students will attend seminars given by researchers, industry and government	Students will understand contemporary issues and the connection between their work and the needs of society	f, h, j	• Seminar attendance • Exit interviews
Students will be introduced to ethical conduct in all classes	Students will be able to make decisions involving ethical dilemmas	f	• Ability to solve ethical problems • Exit interviews
Students will be given a statement on plagiarism	Students will not plagiarize.	f	• Students sign statement

Quantitative Data

In order to assess the student overall development as a professional through the design courses, a form has been designed and the students are asked to fill it. This includes the student opinions about the course, and his assessment of his own skills and professional preparation. Table 5 is designed to collect student feedback on skills, abilities and attributes generally expected of a student passed the design courses.

Table 6 gives faculty team review—final report. The purpose of this survey is to afford the instructor an opportunity to review and evaluate the acquisition and demonstration of specific knowledge and skills.

Table 5. Assessment of specific skills, abilities and attributes

Use a scale of one (1) to five (5) with 1 = Not At All; 2 = Somewhat; 3 = Adequate; 4 = Moderate; 5 = High; and NA = Not Applicable

Item	1	2	3	4	5	NA
a. Rate your ability to apply:	**1**	**2**	**3**	**4**	**5**	**NA**
• mathematics in your coursework	☐	☐	☐	☐	☐	☐
• physics in your coursework	☐	☐	☐	☐	☐	☐
• chemistry in your coursework	☐	☐	☐	☐	☐	☐
• engineering principles in coursework	☐	☐	☐	☐	☐	☐
b. Rate your ability to:	**1**	**2**	**3**	**4**	**5**	**NA**
• design experiments	☐	☐	☐	☐	☐	☐
• conduct experiments	☐	☐	☐	☐	☐	☐
• analyze data	☐	☐	☐	☐	☐	☐
• interpret data	☐	☐	☐	☐	☐	☐
c. Rate your ability to design:	**1**	**2**	**3**	**4**	**5**	**NA**
• systems to meet desired needs	☐	☐	☐	☐	☐	☐
• components to meet desired needs	☐	☐	☐	☐	☐	☐
• processes to meet desired needs	☐	☐	☐	☐	☐	☐
d. Rate your ability to:	**1**	**2**	**3**	**4**	**5**	**NA**
• function on multi-disciplinary teams	☐	☐	☐	☐	☐	☐
e. Rate your ability to:	**1**	**2**	**3**	**4**	**5**	**NA**
• identify engineering problems	☐	☐	☐	☐	☐	☐
• formulate engineering problems	☐	☐	☐	☐	☐	☐
• solve engineering problems	☐	☐	☐	☐	☐	☐
f. Rate your understanding of:	**1**	**2**	**3**	**4**	**5**	**NA**
• professional responsibility	☐	☐	☐	☐	☐	☐
• ethical responsibility	☐	☐	☐	☐	☐	☐
g. Rate your ability to use:	**1**	**2**	**3**	**4**	**5**	**NA**
• professional speaking skills	☐	☐	☐	☐	☐	☐
• media presentation skills	☐	☐	☐	☐	☐	☐
• professional writing skills	☐	☐	☐	☐	☐	☐
h. Rate your understanding of the impact of:	**1**	**2**	**3**	**4**	**5**	**NA**
• engineering solutions in a global context	☐	☐	☐	☐	☐	☐
• engineering solutions in a societal	☐	☐	☐	☐	☐	☐
i. Rate the following statements:	**1**	**2**	**3**	**4**	**5**	**NA**
• I recognize the need for life-long learning	☐	☐	☐	☐	☐	☐
• I have the ability to engage in life-long learning	☐	☐	☐	☐	☐	☐
j. Rate your knowledge of:	**1**	**2**	**3**	**4**	**5**	**NA**
• contemporary issues as they relate to my profession	☐	☐	☐	☐	☐	☐
• contemporary issues as they relate to society	☐	☐	☐	☐	☐	☐
k Rate your ability to use necessary:	**1**	**2**	**3**	**4**	**5**	**NA**
• techniques for engineering practice	☐	☐	☐	☐	☐	☐
• skills for engineering practice	☐	☐	☐	☐	☐	☐
• modern engineering tools for engineering practice	☐	☐	☐	☐	☐	☐
l. Rate your ability to apply advanced mathematics through:	**1**	**2**	**3**	**4**	**5**	**NA**
• multivariate calculus	☐	☐	☐	☐	☐	☐
• differential equations	☐	☐	☐	☐	☐	☐
m. Rate your ability to apply:	**1**	**2**	**3**	**4**	**5**	**NA**
• statistics to problem in mechanical engineering	☐	☐	☐	☐	☐	☐
• linear algebra to problems in mechanical engineering	☐	☐	☐	☐	☐	☐
n. Rate your ability to demonstrate knowledge of:	**1**	**2**	**3**	**4**	**5**	**NA**
• chemistry	☐	☐	☐	☐	☐	☐
• physics	☐	☐	☐	☐	☐	☐
o. Rate your ability to work professionally in:	**1**	**2**	**3**	**4**	**5**	**NA**
• thermal systems	☐	☐	☐	☐	☐	☐
• mechanical systems	☐	☐	☐	☐	☐	☐

Table 6. Faculty team review-final report

Throughout the phase of the project, the team demonstrated the following CORE knowledge, skills, and abilities:	Not At All **1**	Somewhat **2**	Somewhat **3**	Moderate **4**	High **5**	Not Applicable
Analytical Skills Applies logic in solving problems and analyzes problems from different points of view. Translates academic theory into practical applications using appropriate technical techniques, processes, and tools.						
Creative Problem-solving Suggests new approaches and challenges the way things are normally done. Develops many potential solutions to problems.						
Systems Thinking Understands how events interrelate and demonstrates an ability to take new information and integrate it with past knowledge. Integrates and uses knowledge from various courses, including engineering, physics, mathematics, and social sciences, to solve technical problems.						
Communication Skills Articulates ideas in a clear and concise fashion and uses facts to reinforce points. Written materials flow logically and are grammatically correct. Plans and delivers oral presentations effectively. Uses technology and graphics to support ideas and decisions.						
Teamwork Each member contributes a fair share to the completion of the project. Everyone participates, listens and cooperates with other members. Members share information and help reconcile differences of opinions when they occur.						
Research Skills Uses computer based and other resources effectively, thus acquiring information from multiple sources. Organizes and interprets data appropriately. Designs and conducts experiments to validate theories.						
Life-long Learning Learns independently and continuously seeks to acquire new knowledge. Exceeds basic requirements of an assignment and brings in relevant outside experiences to provide advanced solutions to the problems at hand.						
Project Management Sets goals, prioritizes tasks and meets project milestones. Seeks clarification of task requirements and takes corrective action based upon feedback from others. Creates action plans and timetables to complete assigned work.						

This review will take place at the conclusion of the final report phase of the Design of Mechanical Systems II. The faculty member's assessment will be recorded on this review form. A copy of the completed evaluation will be given to the student team as additional feedback on their performance.

Table 7. Analysis of design courses' outcomes based on the students data in the last ten years

a	Ability to apply knowledge of math, engineering, and science	3
b	Ability to design and conduct experiments, ability to analyze and interpret data	NA
c	Ability to design system, component or process to meet needs	4
d	Ability to function on multi-disciplinary teams	2
e	Ability to identify, formulate, and solve engineering problems	4
f	Understanding of professional and ethical responsibility	3
g	Ability to communicate effectively	3
h	Broad education	3
i	Recognition of need and ability to engage in life-long learning	2
j	Knowledge of contemporary issues	3
k	Ability to use techniques, skills, and tools in engineering practice	4

Table 7 presents the analysis of design courses' outcomes (ME 301 and 401) based on the average of students' data over the last 10 years. The data are collected at the end of the semester by distributing and asking the students to fill out forms containing Table 5. Statistical analysis is being performed on the collected data each semester, but the results are not included here due to the restriction on the length of the paper. Nevertheless, Table 7 shows the majority of the elements which students have gained in dealing with these kinds of design courses that call for extensive skills. For example, students have shown low abilities in applying simple basic information in math, science and engineering. Moreover, elements such as in (k) showed that students have had considerable amount of knowledge gaining. This means that students could work with technical tools and be creative in dealing with them in order to perform certain programs. The table also indicates that elements such as (c) and (e) showed that students have had an extensive availing of knowledge and skills. For instance, throughout the study, students showed their creativity in designing systems as well as the skill in identifying, formulating and solving engineering problems. Finally, the results have shown also that element (d) had the lowest rank among the rest of the others. This means that, unfortunately, our students have shown a bad cooperation in team work. This result indicates that the students prefere to work individually and the sharing of project loads is not done equally. In order to overcome this, we suggest to introduce teamwork in the early years of engineering educations and continue impelementing it across the curriculum.

Concluding Remarks

In this paper, an assessment of the student outcomes from the design courses has been presented and some related results have been highlighted and discussed.

Teaching critical knowledge, skills and attitudes as demonstrated in the design courses must be student-centered, where the teaching faculty members are viewed as learning coaches, facilitators and guides in the learning process. Learning activities that reflect real-world situations must engage students in individual and collaborative problem-solving, analysis, synthesis, critical thinking and reasoning.

The students should understand how to generate design specifications, and how to proceed from design specifications to a final product. This would emphasize that engineering design is the crucial component of the product realization process, the means by which new products are conceived, developed, and brought to market. New teaching and learning approaches must be put to use that heighten practical learning and allow students to demonstrate the application of their studies to real-world situations.

It is recognized that strong improvements in engineering design teaching can be accomplished through strong, knowledgeable, enthusiastic faculty who interact with a broad base of colleagues in industry as well as academe.

The problems relating to project design management issue include: (a) student's time scallop (the tendency to increase effort exponentially as the final deadline approaches); (b) potential laggards in a group (students doing little work and getting credit for the group's results); and (c) students lacking appropriate work documentation habit. We still work on solving these problems.

References

ABET Engineering Criteria. http://www.abet.ba.md.us/EAC/eac2000.html, 2000.

Aldridge, M.D. and Lewis, P.M. "Multi-disciplinary Teams: How to Assess and Satisfy ABET Criteria." *Symposium on Best Assessment Processes in Engineering Education*. Rose-Hulman Institute of Technology, Terre Haute, Indiana, (1997).

Dahir, M. "Educating Engineers for the Real World." *Technology Review*, (1993), 14-16.

Dixson, J.R. "Engineering Design Science: The State of Education." *Mechanical Engineering*, Vol. 113, No. 2, (1991), 64-67.

ElMadany, M.M. "Establishing Engineering Design Competencies: An Approach." *Third Forum, Engineering Education*, University of Sharja, (2003).

Faste, R.A.; Roth, B. and Wilde, D.J. "Integrating Creativity into the Mechanical Engineering Curriculum." *Innovation in Engineering Education, ASME*, (1993), 93-98.

McCreanor, P.T. "Quantitatively Assessing an Outcome on Designing and Conducting Experiments and Analyzing Data for ABET 2000." *Proceedings, Frontiers in Education Conference*, (2001).

Mourtos, N.J. "The Nuts and Bolts Cooperative Learning in Engineering." *Journal of Engineering Education*, Vol. 86, No. (1), (1997), 35-37.

Pimmel, R. "Cooperative Learning Instructional Activities in a Capstone Design Course." *Journal of Engineering Education*, Vol. 90, No. 3, (2001), 413-421.

Oakes, W.C.; Coyle, E.J. and Jamieson, L.H. "EPICS: A Model of Service-learning in an Engineering Curriculum." *ASEE 2000 Annual Conference*, Session 3630, (2000).

Seat, E. and Lord, S. "Enabling Effective Engineering Teams: A Program for Teaching Interaction Skills." *Journal of Engineering Education*, Vol. 88, No. 4, (1999), 385-390.

Seat, E.; Parson, J.R. and Poppen, W.A. "Enabling Engineering Performance Skills: A Program to Teach Communication, Leadership, and Teamwork." *Journal of Engineering Education*, Vol. 90, No. 1, (2001), 7-12.

Valenti, M. "Teaching Tomorrow's Engineers." *Mechanical Engineering Magazine*, Vol. 118, No. 7, (1996), 64-69.

Woods, D., *et al.* "Developing Problem Solving Skills: The McMaster Problem Solving Program." *Journal of Engineering Education*, Vol. 86, No. 2, (1997), 75-91.

APPENDIX A

A.1. Course Description

ME 301 Design of Mechanical Systems I
4(3,1,2)

Introduction to design process. Review of static failure theories. Designing against fatigue failures. Elements design: shafts, power screws, bolted, riveted and welded joints. Design of Elements: bearings (journal and anti-friction); springs.
Prerequisites by Course:
ME 354 (Mechanics of Materials-II)
ME 361 (Mechanics of Machinery)
ME 355 (Processing of Engineering Materials-I)

ME 401 Design of Mechanical Systems II
3(2,1,2)

Design process, origin and identification of engineering design problems; creativity in engineering design; technical analysis; human and legal factors; problem and decision making; design of spur and helical gears; design of clutches and brakes; miscellaneous power transmission components; communicating the design; term design project.
Prerequisites by Course:
ME 301 (Design of Mechanical Systems I)

A.2. Typical Term Projects

1. Design a device to help blind people to walk and cross streets. The device should detect objects and stairs.
2. Design an automatic delivery machine to move products to selected locations in warehouses.
3. Design an improved bicycle rack for cars.
4. Design a wheeled, multi-articulated robot, which is able to operate autonomously in sewerage systems. To manage the robot in the hazardous environment of sewers, the robot has to be designed very carefully.
5. Design a solar bicycle hybrid.
6. Design and manufacture an exhaust heat utilizer.
7. Design a deep freezer with 4 to 6 baskets so that is easy to access the back and bottom of the freezer.
8. Design an innovative internal combustion engine.
9. You, the information technology (IT) generation, have grown up with technology filling every aspect of your lives. You have become accustomed to voice and text communication with cell phones. However, the current standard of text messaging is not compatible with the existing car environment. Typing text on the small cell phone keypad using the tiny display for feedback requires a great deal of attention, endangering both the driver and those they share the road with. You are asked to develop a new text entry system that adapts and integrates the cell phone keypad to the unique challenges of the driving environment.

التصميم ا ندسي ا يكانيكي جامعة ا لك سعود: تقييم ا خرجات

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ملخص البحث. في الماضي، كانت الأهداف الأساسية لعلم التصميم الهندسي تدور حول جعل الأشياء المصنعة تعمل فقط، ولكن في الوقت الحاضر ازدادت تعقيدًا بشكل كبير. أصبح مهندسوا ومعلموا التصميم مطالبين ببذل جهود ووضع اعتبارات كثيرة تجاه موضوعات بيئية وقانونية وصناعية وتجارية وفكرية وثقافية وعالمية، بالإضافة إلى مشاكل الصيانة والعمر الافتراضي للمنتجات المصنعة. وبالتالي فإن طلاب التصميم الميكانيكي يحتاجون إلى أكثر من مجرد معلومات تقنية. هؤلاء الطلاب يحتاجون إلى تجارب تعليمية مكثفة تساعدهم على تطويرمهارات فعَّالة للتعامل مع أناس آخرين في جميع المجالات الاجتماعية والثقافية. وتعطي هذه التجارب التعليمية أيضًا هؤلاء الطلاب القدرة على العمل في الجمعيات العلمية كفريق واحد يحتوي على أعضاء متفوقين لهم القدرة على القيادة وإدارة المشاريع العلمية،.وهذا هو المفتاح الأساسي في أي عملية لحل المشاكل التقنية لخلق بيئة جيدة للاتصالات وللتواصل، وأيضًا لتشجيع الناس وتوعيتهم للقضايا المهنية الأخلاقية التي تخص هذه المجالات العلمية.

إن هدف معلموا التصميم الهندسي في جامعة الملك سعود هو: (أ) تعزيز التوعية تجاه علم التصميم الميكانيكي كعامل وعنصر أساسي في التعليم الهندسي والمجالات العلمية التطبيقية، و(ب) تشجيع تطوير المناهج الدراسية الهندسية لتشمل المفاهيم الحديثة التي تخص المبادئ الأساسية لعلم التصميم الميكانيكي والرقي بالمنهج العلمي لها، و(ج) إنشاء وتأسيس تعليم مفهوم التصميم الهندسي في مناهج دراسة التعليم الهندسي.

إن الموضوع الرئيسي في هذا البحث هو تسليط الضوء على تطوير التصميم الهندسي الميكانيكي في جامعة الملك سعود بشكل مكثف بحيث يحتوي على إيضاحات لمختلف المجالات والمقرارات، ولقد تم تطبيق طريقة علمية لقياس أداء ما تعلمه الطلاب في البرنامج، وكذلك مقارنة مقررات التصميم بالبرنامج العالمي أبيت (ABET EC 2000)، وفي الأخير تم عرض النتائج التي حققها الطلاب في هذا البرنامج.