TEACHING A SENIOR DESIGN COURSE IN INDUSTRIAL ENGINEERING

Mehmet Savsar

Department of Industrial & Management Systems Engineering, College of Engineering & Petroleum, Kuwait University, Kuwait, msavsar@gmail.com

Abstract

Industrial Engineering is one of the engineering disciplines that deals with analysis, design and improvement of systems, which include manufacturing, supply chain, healthcare, communication, and general service systems. Industrial engineers involve with comprehensive study of a given system, analysis of its interacting units, determination of problem areas, application of various optimization and operations research tools, and recommendation of solutions resulting in significant improvements. The Senior Design course in Industrial Engineering is the culmination of the Industrial Engineering Curriculum in a Capstone Design course which fundamentally deals with systems analysis and design. The course in Kuwait University has been carefully designed with various course objectives and course outcomes in mind in order to achieve several program outcomes by practices and learning experiences, which are explicitly gained by systems analysis and design.

The Senior Design Course is carried out in a selected industrial or service organization, with possible support from its engineering personnel, during a full semester by a team of students, who are usually in the last semester of their academic programs. Senior design course is constantly administered by a senior faculty member to ensure that the students accomplish the prescribed objectives. Students work in teams to formulate issues and propose solutions, and communicate results in formal written and oral presentations. The students, who work on the senior design course during a full semester and complete it, emerge at the end as engineers that can be clearly identified as more mature, able to communicate better, able to participate in team work, able to see systems perspective in analysis and design, and more importantly, able to assume responsibility at entry level as engineers. The accomplishments are mainly due to real life experiences gained during the design course.

This paper presents methods, procedures, and experiences in teaching a Senior Design Course in Industrial Engineering Curriculum. A detailed description of the course, its role, its objectives, outcomes, learning practices, and assessments are explained in relation to other courses in the Industrial Engineering Curriculum. The administration of the course, selected organizations where the course project is carried out, problems and solution tools utilized, student accomplishments and obstacles faced are presented. Issues discussed in this paper could help instructors in teaching the course as well as in clarifying contribution of a design course to the Industrial Engineering education in general. Also, the methods and teaching procedures presented could facilitate future improvements in Industrial Engineering Curriculum.

Keywords: Senior Design, Engineering Education, Industrial Engineering

1. INTRODUCTION

Engineering profession is concerned with design, which has been defined by Accreditation Board for Engineering and Technology (ABET, 2001) as "the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative) in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective". ABET indicates that the followings are the fundamental elements of design process:

Establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. ABET also signifies that the engineering design component of a curriculum must include at least some of the following features: Development of student creativity, use of open ended problems, development and use of design methodology, formulation of design problem statements and specifications, consideration of alternative solutions, feasibility consideration, and detailed system description. It is essential also to include a variety of realistic constraints in the design, such as economic factors, safety, reliability, aesthetics, ethics, and social impact. One of the requirements for an engineering program to be accredited and recognized is the integration of the design in its curriculum. In order to be meaningful, the design element should be introduced early in the program and in most of the courses. However, all design experiences gained should be culminated in a major design course, designated as a capstone design, in which the student participates in an actual design process in detail.

Many researchers have addressed the issue of design in engineering education including Kimmel et al. (2003), Bailey and Szabo (2006), Dym (2006), Davis et al. (2006), Lemancusa (2006), Sheppard et al. (2006), Turns et al. (2006), Walker et al. (2006). Healy (2006) discussed the issue of preparing engineering students through core courses for effective design experience. Mehalik and Schunn (2006) presented a review of empirical studies on design process in engineering education. The creativity is an important factor in engineering problem solution and design as indicated by Chen et al. (2005). Andreas et al. (2003) discussed the improvement issues of engineering education at Kuwait University. Furthermore, Odora (2015), Katz (2015), Storbel et al. (2013), and Mahmud et al. (2012) have also addressed the engineering design education in detail. In order to prepare the engineering graduates for a job in real life, especially at entry level, teaching design courses has become an important component in engineering curriculums worldwide. It is reported that engineering graduates are increasingly expected to work in team-based projects, and hence, employers are looking for graduates with strong teamwork capabilities, Natishan et al., (2000) and Willey and Freeman (2006). As a result, “an ability to function on multidisciplinary teams” is included as a student outcome in ABET Engineering Criteria.

One of main concern the senior design course students have is the amount of time, work, and stress it has on their academic performances. Nobes et al. (2010) investigated the effect of senior design project workload on student performance and reported that students have typical workloads of 15 hours/person/week, on average, and it may be as high as 25-40 hours/person/week. Furthermore, Gruenther et al. (2009) investigated the influence of prior industry experience and multidisciplinary teamwork on student design learning in a capstone design course. Moreover, Zou and Ko (2012) assessed the teamwork development process for capstone design course. They assessed the intended learning outcomes of teamwork skills by both qualitative and quantitative methods. On the other hand, Cooper et al. (2015) proposed a method of evaluating different senior design projects against common outcomes. Shin et al. (2013) discussed the benefits of developing capstone design course and internship in combination with industry. They also stated that it is not easy to check the progress and status of students periodically during the period of internship. However, they stated during the capstone design course, it is easier to check each student progress. They further stated that the students have the opportunity to deal with real world problems and to prepare their future profession during capstone design course.

Industrial Engineering is one of the engineering disciplines that concentrate on systems analysis and design, which involves a comprehensive study of a given system, analysis of its interacting units, determination of problem areas, application of various optimization and operations research tools, and recommendation of solutions resulting in significant improvements. The senior design course in Industrial Engineering at Kuwait University, which has been discussed in this paper, is the culmination of the Industrial Engineering curriculum in a capstone design course which fundamentally deals with systems analysis and design. The course has been carefully designed with various course objectives and course outcomes in mind in order to achieve several program outcomes by practices and learning experiences, which are explicitly gained by systems analysis and design. The course is carried out in a selected industrial or service organization, with possible support from its engineering personnel, during a full semester by a team of students, who are usually in the last semester of their academic programs. A senior faculty member to ensure that the students accomplish the prescribed objectives constantly administers senior design course. Students work in teams to formulate problems and propose solutions, and communicate results in formal written and oral presentations. The students work on the senior design course during a full semester. When the course is completed, the students emerge at the end as engineers that can be clearly identified as more mature, able to communicate better, able to participate in team work, able to do systems analysis and design, and more importantly, able to assume responsibility at entry level as engineers. The accomplishments are mainly due to real life experiences gained during the design course.

In this study, the senior design course in Industrial Engineering curriculum at Kuwait University is presented. A detailed description of the course, its role, its objectives, outcomes, learning practices, and assessments are explained in relation to other courses in the curriculum. The administration of the course, several case studies, selected organizations where the course project is carried out, actual student accomplishments, and the obstacles faced are presented. Issues discussed in this paper could help to clarify the contribution of the senior design course to the Industrial Engineering education, and facilitate future improvements in Industrial Engineering curriculum at Kuwait University and elsewhere.

2. SENIOR DESIGN IN ENGINEERING

Senior design is a basic requirement in all engineering disciplines. It is a required 3-credit course generally taken during the last year of the engineering curriculum. The senior design course in Industrial & Management Systems Engineering (IMSE) at Kuwait University (KU) is developed based on the IMSE department mission and objectives, which are consistent with the mission of College of Engineering and Petroleum. The Senior Design Course is titled as Industrial Engineering Design with the code number IMSE 496. It has the following course catalog description, prerequisites, and course objectives:

Course Description: This is a capstone design course in which students are exposed to creative design and synthesis in various areas of industrial and systems engineering. All knowledge acquired in mathematical modeling and economic techniques are utilized in conducting the design analysis.

Course Prerequisites: IMSE 457 Statistical Quality Control, IMSE 434 Facilities Planning & Design, IMSE 454 Production & Inventory Control, IMSE 461 Operations Research II, IMSE 481 Simulation of Engineering Systems, and Consent of the Department

Course Objectives: This course aims at developing certain skills that are both essential and helpful to industrial engineering graduates in their career. These skills include to followings:

1. Identification of problems to be studied and systems design issues
2. Application of various Industrial Engineering tools to solve identified real life problems
3. Gaining effective communication skills
4. Gaining presentation and documentation skills
5. Ability to work in multi-disciplinary teams
6. Developing professional and ethical responsibility

In order to achieve these objectives and help the students gain the above skills, a faculty member carefully administers the course during a full semester. The students consult other faculty members in different areas of study while working on their projects. The evolution of the project selection, problem identification, selection of solution approaches and use of IE techniques, final submission of comprehensive report, and project presentation is a long process. The basic process is outlined in a flow chart as shown in Figure 1. It should be noted that almost all of the required 11 ABET outcomes (a-k) and the program outcomes are covered in detail in this course. The detailed descriptions of these outcomes and how they are met are not integrated into this paper due to the space limitation.

3. SELECTION OF DESIGN PROJECTS

Selection of the design topic is the most important and the difficult step during design course study. If the topic is not selected appropriately, the students may end up in a loop trying endlessly between problem definition and topic selection. Also, a wrong selection may end up with no problems to study or with problems with no clear solutions that could be achieved by the students. Therefore, the design course coordinator has to be careful and helpful in the selection of the topic and identification of the problem areas. In real life, engineers or other related personnel do not see the problems or do not consider a problem as a problem.

It should be noted that the time is another constraint on the topic to be selected and studied. The students have to complete their projects in a 15 weeks semester. However, they have only about 10-12 weeks to work on the topic since first few weeks of the semester are spent in selecting an organization. The design topic selection at the organization also takes some time due to the difficulty in identifying problem areas. Therefore, it happens that students identify some promising areas to work on, but do not have enough time to finish it. It is responsibility of the supervising faculty member to help students select a topic that they can finish within 10-12 weeks period.

Yet another constraint on the topic to be selected is the lack of related data. Some of the data can be obtained by observing the system or asking employees in the organization to collect the required data for the students. However, the time is not enough to observe and collect some other data, such as monthly or yearly demands or sales, frequency of equipment breakdowns, etc. Students should make sure that the data required for the selected topic are available or can be obtained by observing the system for relatively short period of time, up to a couple of weeks. It is also important to note that some of the organizations are not willing to provide the required data even when they have the data as the organizations consider the data confidential.

Finally, one more difficulty faced during the execution of the senior design is related to the willingness and cooperation of the employees in the company where the design project is carried out. This is due to the lack of the willingness and ability of the employees. As a result, students have difficulty to obtain the required data and information. This difficulty may be in part due to students' inability to identify problems and the required data during the topic selection. The coordinator plays an important role in helping the students to select an appropriate topic so that they are able to collect the data and finish the design work in a reasonable time.

4. DESIGN WORK DURING THE SEMESTER

The senior design course is administered and carried out carefully by a faculty member during the semester to achieve the stated objectives. The first step after selection of the company is to identify the design problem areas to study. This is not an easy task for several reasons. First, employees at the organization do not recognize that they have any problems. This may be due to the fact that many non-IE personnel perform IE tasks. The second reason is that the students themselves may not be able to detect any problems while making their initial visits to the organization. Our experience with the students indicates that in all cases the students initially have hard time to identify specific problems. Students always have reported that there are no problems in the selected organizations to study. Most of the selected organizations are usually well-established companies and therefore, the students are misled that there are no problems in those companies. With the help of their advisor, several more visits, and careful observation of the systems, they finally identify the problem areas to study. At this stage, the students learn that problem identification is an important step in the analysis and design process.

After identifying problem areas, the students form groups according to their abilities and interests. The size of groups may be from two to four students. Each group works on a different problem area in a section of the company. However, the groups usually interact with each other in data collection, systems analysis, and problem solving. The next step is the identification of the necessary IE tools to be utilized in solving the specified problems. At this stage, the students consult with their supervisor and other faculty members in the department. Once they specify the necessary tools, the students collect more related data and try to improve the system.

Three important objectives in the senior design course are to develop effective communication, presentation, and report writing skills. These skills are gained through the course of the project design work. Each group makes a presentation on the progress of their work once a week. Moreover, they submit a written report at the end of each week. Each student within a group participates in the written report as well as the presentation. The course supervisor administers and attends all presentations in order to improve the students' presentation and communication skills. The supervisor also corrects their weekly written reports in order to improve their writing skills. The students present their selected areas and possible solution approaches along with initial results to the faculty members in the departments to get their feedback. This presentation usually takes place in about the fifth week of the semester. The final design results are presented to the faculty member during the last week of the semester. The faculty members evaluate the students' performance during this presentation. In order to further improve their abilities in communication, the students are required to present their work in an exhibition at the college and in the company to company representatives. Finally, they make a public presentation where their families and other people are also invited. The students learn how to work in a team during the course of the senior design project since all the work is carried out in teams. Students are informed at the beginning of the semester that they will be evaluated by each other. This forces each member of the group to work on the assigned tasks and be responsible. In addition to team work in each group, all the groups have to work together since they work in the same organization and all their work should be integrated into one presentation and one report. Each semester a team leader and a vice team leader are selected by the students and the instructor to coordinate the work among the different teams.

Finally, one important ability that the students gain during this course is to learn ethical responsibility. First, they learn to behave ethically towards their team members by performing the assigned tasks in the approved

time and manner. They also learn to keep the information about the companies confidential and not to release the information. Moreover, the ethical issues are always discussed throughout the semester.

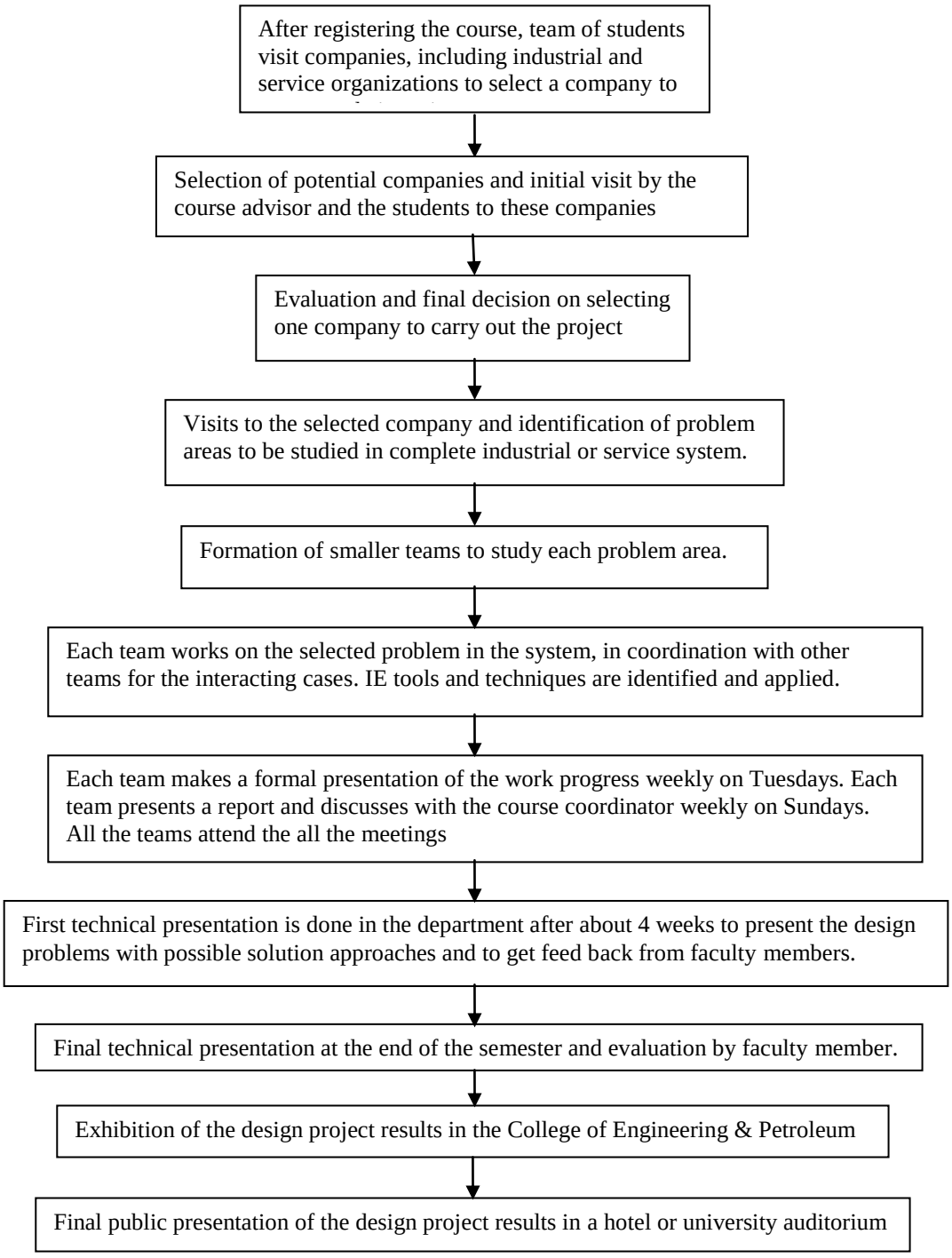

Figure 1. Process flow chart for the evolution of the senior design project from start to the e

5. ASSESSMENT OF SENIOR DESIGN PROJECTS

The assessment and evaluation process is designed to assure that the required ABET as well as the program outcomes are met. The design project is evaluated based on the following factors.

1. Participation and performance of the students in weekly meetings

2. Written weekly progress reports
3. Weekly oral presentations
4. First technical presentation to the faculty members
5. Final technical presentation to the faculty members (to be graded)
6. Final report (graded by three faculty members)
7. Final technical presentation to the public
8. Team member evaluation
9. Meeting deadlines

The factors, presentation style, use of audio-visual aids, content of presentation, audience level consideration, and quality of technical information presented are considered in evaluation of oral presentations. The faculty member may assign different weights to each of these factors. In evaluating the written reports, ease of understanding, appropriate use of visual tools, logical presentation of ideas, quality of technical information presented, quality of the outcomes presented, and overall report quality are taken into consideration with different weights assigned to each of these factors by each faculty member. A team work scoring rubric is used in self-evaluation and the evaluation of team members by taking into account the factors, quality of work, quantity of work, creativity, reliability, teamwork, team norms, and others. The final grade is calculated based on the scores from all the above evaluations. Table 1 shows a typical evaluation and grading for senior design course.

Table 1. Evaluation aof senior design course and breakdown of assessment components

Assessment Factors	Presentations During Semester	Discussions During Semester	Mid-Semester Reports	First Technical Present.	Final Technical Present.	Final Report	Self-Evaluation	Total Grade
% of Grade	20%	10%	10%	10%	20%	25%	5%	100%
……	……	……	…… …	…… …	…… …	…… …	……	…….

6. STATISTICS OF PAST PROJECTS AND TOOLS UTILIZED

Since the IMSE department started graduating students in spring 1997, the senior design project course has been compulsory and has been offered during the fall and spring semesters of each academic year. Statistics related to the design project over the past years have been collected and analyzed to identify some significant points and issues. Table 2 summarizes the past organizations, design topics carried out, and IE tools used. Table 3 indicates the percentage of the times different tools have been used in the course throughout the years since the senior design course was first offered in 1997. As can be seen from the table, the most widely used tools are Simulation, Inventory Management, Facility Planning, and Quality Control. This is expected since the design concepts are best applied when these two tools are utilized. These are followed by Forecasting, Statistics and Linear Programming Tools. As can be seen from the table, almost all IE tools have been used in the course. It should be also noted that the senior design projects have been conducted in both manufacturing and service organizations with majority of them being in the manufacturing organizations.

7. CONCLUSIONS

The senior design project in Industrial and Management Systems Department at Kuwait University is a capstone design course that includes important design concepts in IE, and taken by students who have completed almost all of their course work. In this paper, we have described the course in detail, the way the course is administered and taught, the obstacles faced by students during the semester, and the ways these obstacles are overcome. A list of the organizations where the course was carried out is presented along with the IE tools that were utilized in the design project.

It has been observed that one important factor in the success of the project is the selection of an appropriate organization. This is important particularly in terms of the cooperation and willingness of the staff in the organization to help the students. However, the IE tools can always be applied in any organization, regardless of the type and size, to improve the system performance. The second crucial issue is the identification of the problem areas since students (including the company staff members) do not usually

notice the existence of the problem as long as the system works. In other words, in the majority of the cases, the effectiveness of the system is not investigated. Therefore, the problem identification is difficult. However, it is crucial to identify the right problem so that an appropriate design can be accomplished. Data collection is another difficult task since most of the organizations do not like to provide confidential data and some other organizations do not keep historical data. On the other hand, data is very important component of the system analysis and design. Finally, another difficulty is the limited time during which the project has to be finished. All these issues must be considered during the selection of the company, the design topics, and the techniques to be applied.

Considering all the difficulties mentioned above, it is extremely important that the course is carefully supervised so that a successful project is completed. The supervising faculty member should be experienced and should have enough background in almost all IE areas in order to be able to help the students in problem identification and in the design process. The college or the IMSE department should establish cooperation with organizations so that they accept the team of students to work on a project in a selected company.

Table 2. Recent companies in which Senior Design Course was carried out and tools utilized

Organization	**Design Topics**	**IE Tools Utilized**
Abraaj Water Co.	1. Facility layout and warehouse location analysis	Facility layout tools and SW, location analysis, simulation modeling
	2. Manufacturing feasibility analysis	Economic analysis, sensitivity, simulation
	3. Product distribution	Minimum spanning tree, minisum location analysis
	4. Production planning, quality control	Inventory control, forecasting, control charts
Kuwait Lube Oil Co. (KLOC)	1. Waste oil collection system design and optimum storage tank location	Facility location analysis
	2. Forecasting of waste oil produced in Kuwait and the demand for oil products	Forecasting methods
	3. Product selection & profit optimization	Linear programming
	4. Production line analysis and facility layout	Simulation, Design of experiments, Facility layout
	5. Safety analysis at KLOC	Safety and Fault Tree Analysis
Refrigeration Industries and Storage Co.(RISCO)	1. Facility planning and re-design	Facility Planning
	2. Optimum machine location for a newly purchased machine	Machine location
	3. Assembly line balancing for AC units	Line balancing method, Simulation, Design of experiment
	4. Production planning and inventory control	Forecasting, Aggregate production planning by LP, EOQ and EPQ analysis
	5. Quality control	Acceptance sampling, Control charts
	6. Safety and Ergonomics analysis	Safety checklist, Risk assessment
MTC Vodafone	1. Modeling, analysis, and improving help desk operations	Simulation
	2. Car selection for the employees	Decision Analysis
	3. Operator requirement analysis	Forecasting and Simulation
	4. Introduction of a new service	Statistical Analysis
	5. Analyzing and forecasting of main services	Forecasting
	6. Selection of location for branches	Integer Programming
KNPC	1. Improving queuing system at a depot	Queuing, Simulation
	2. Improving gas station layout	Facility Layout, Stat. Analysis, Simulation
	3. Selecting the location of a new depot	Linear programming
	4. Forecasting and inventory for selected items	Forecasting, ABC Analysis, Inventory Control (EOQ Model)
	5. Expert system to spot hazardous gases	Expert Systems, Decision Analysis
NIC (Al-Abyad Factory)	1. Facility planning and design	Facility planning, layout software
	2. Maintenance operations and spare part analysis	Maintenance management, cost analysis, scheduling, statistical analyses

	3. Occupational safety and health analysis	Safety, statistical analysis
Al-Ahli Bank of Kuwait (ABK)	1. Credit risk management	Regression analysis, Decision analysis
	2. Service quality and branches	Queuing analysis, cause and effect diagram, productivity analysis, Facility layout, Simulation, Market survey
	3. Branch location	Location analysis
	4. Internet banking service	Cost benefit analysis
Industrial Build. &Const. Co.(IBC)	1. Ready mix analysis	Forecasting, Quality, Inventory control, Productivity
	2. Project evaluation	Project management
Industrial Bank of Kuwait (IBK)	1. Small business	Feasibility study, Project management,
	2. Decision support system	Feasibility study, Quality control, Inventory control
National Bank of Kuwait (NBK)	1. Asset Management	Forecasting , Risk analysis, productivity analysis
	2. NBK channels (banking type, e.g. tele-banking)	Productivity analysis
	3. Credit card process analysis	Cost analysis, Productivity, Quality
	4. Activity cost estimation	Break-even analysis, activity based costing
	5. Management information system	MIS, DSS
	6. Branch layout	Facility layout
Analysis and Improvement of Operations at Kuwait Airline Company (KAC	1. Maintenance management	Reliability and maintenance Analysis
	2. Business Process management	Business Process reengineering
	3. Manpower Planning	Planning for manpower
	4. Safety and Ergonomics	Safety analysis at the hangars
	5. Materials Inventory Management	Spare part management
	6. Simulation of Inventory Systems	Simulation of work flow
Analysis and Improvements of Production & Distribution Systems at Americana	1. Assembly Line balancing	Using balancing methods for efficiency
	3. Distribution system	GIS in Distribution system
	4. Analysis of Inventory System	Inventory models applications
	7. Integer Programming and TSP	Linear Integer Programming
	8. ABC Analysis for food inventory	Inventory ABC Analysis
Analysis and Improvement of Operations at IKEA	Distribution System Analysis	Applications of Simulation and LP
	Sales Analysis	Analysis of sales operations
	Customer flow	Analysis of customer flow in the shop
Analysis of Food Distribution at Lazurd	Fresh Food Distribution System	Heuristics in designing a distribution system using GIS
	Dry Food Inventory	Inventory Models
	Analysis of Food Production Line	Assembly line analysis
Analysis of Hospital Management Operations	Operations Room Scheduling	Integer Programming
	Hospital Quality management	Quality Control
	Hospital material management	Inventory Control
Analysis of an Aquarium in Kuwait Scientific center	Reliability of water circulation and life cycle system	Reliability Analysis
	Safety Analysis for the exhibits	Safety systems
Analysis of Operations in a Tile Manufacturing System	Production Line Analysis	Production rate analysis
	Demand forecasting	Demand forecasting methods
	Inventory control for raw material and finished products	Inventory analysis methods
	Quality analysis of raw material and finished products	Quality Control methods

Table 3. Statistics of the IE tools utilized in the Senior Design Course

Tools Utilized	Number of Times	Percentage
Inventory Control, ABC Analysis, EOQ and EPQ analysis	13	10.83
Quality Control, Control Charts, Acceptance sampling	10	8.33
Cost analysis and Activity Based Costing	6	5.00
Decision Analysis and DSS	5	4.17
Design of experiments	3	2.50
Facility Planning & Layout , Facility Location	11	9.17
Feasibility study	4	3.33
Forecasting	9	7.50
Linear and Integer programming	8	6.67
Productivity analysis	5	4.17
Project management	3	2.50
Queuing analysis	4	3.33
Safety	5	4.17
Simulation	18	15.00
Statistical Analysis	8	6.67
Others	7	5.83

REFERENCE LIST

1. ABET, Accreditation Board for Engineering and Technology, www.abet.org
2. Andreas, P.C., Yigit, A.S., Al-Ansary, M.D., Ali, F., Aly, A.A., Lababidi, H., Nashawi, I.S., Tayfun, A., Zribi, M., (2003). Improving engineering education at Kuwait University through continuous assessment. International Journal of Engineering Education 19, 818-827.
3. Bailey, R., Szabo, Z., (2006). Assessing Engineering Design Process Knowledge. International Journal of Engineering Education 22, 508-518.
4. Chen, C.K., Jiang, B.C. and Hsu, K.Y., (2005). An empirical study of industrial engineering and management curriculum reform in fostering students' creativity. *European Journal of Engineering Education* 30, 191–202.
5. Cooper, C.A., Fulton, J.M., Homan, J.J., (2015). A Multi-spectrum Framework for Characterizing Interdisciplinary Capstone Design Experiences. *Procedia Computer Science* 44, 699-707.
6. Davis, D.C., Beyerlein, S.W. and Davis, I.T., (2006). Deriving design course outcomes from a professional profile. *International Journal of Engineering Education* 22, 439–446.
7. Dutson, A.J., Todd, R.H., Mahleby, S.P., Sorensen, C.D., (1997). A review of literature on teaching engineering design through project-oriented capstone courses. *Journal of Engineering Education* 86 , 17-28.
8. Dym, C.L., (2006). Engineering Design: So Much to Learn. Int. Journal of Engineering Education 22, 422-28.
9. Fornaro, R.J., Heil, M.R., Tharp, A.L., (2007). Reflections on 10 years of sponsored senior design projects: Students win–clients win! *Journal of Systems and Software* 80, 1209-1216.
10. Gruenther, K., Bailey, R., Wilson, J., Plucker, C., Hashmi, H., (2009). The influence of prior industry experience and multidisciplinary teamwork on student design learning in a capstone design course. *Design Studies* 30, 721-736.

11. Healy, T., (2006). Restructuring an Engineering Core Course to Prepare Students for Design Experiences. International Journal of Engineering Education 22, 584-590.

12. Katz, R., (2015). Integrating Analysis and Design in Mech.l Engineerng Education. *Procedia CIRP* 36, 23-28.

13. Kimmel, S.I., Kimmel, H.S. and Deek, F.P., (2003). The common skills of problem solving: from

program development to engineering design. *International Journal of Engineering Education* 19, 810–817.

14. Kornecki, A.J., Khajenoori, S., Gluch, D., Kameli, N., (2003). On a partnership between software industry and academia. *Proceedings of 16th Conference on Software Engineering Education and Training*, 60–69.

15. Lamancusa, J.S., (2006). Design as the Bridge Between Theory and Practice. International Journal of Engineering Education 22, 652-658.

16. Mahmud, J.O., Mohd, M.S., Mohd Taib, J., (2012). Engineering Education and Product Design: Nigeria's Challenge. *Procedia - Social and Behavioral Sciences* 56, 679-684.

17. Mehalik, M.M., Schunn, C., (2006). What Constitutes Good Design? A Review of Empirical Studies of Design Processes. International Journal of Engineering Education 22, 519-532.

18. Natishan, M.E., Schmidt, L.C., Mead, P., (2000). Student focus group results on student team performance issues. *Journal of Engineering Education* 89, 269–272.

19. Nobes, D.S., Stout, C., Ackerman, M., (2010). The impact of senior design project workload on student performance. *Proceedings of the 3rd International Symposium for Engineering Education*, 1-8.

20. Odora, R.J., (2015). Integrating Product Design and Entrepreneurship Education: A Stimulant for Enterprising Design and Engineering Students in South Africa. *Procedia Technology* 20, 276-283.

21. Shin, Y.S., Lee, K.W., Ahn, J.S., Jung, J.W., (2013). Development of Internship & Capstone Design Integrated Program for University-Industry Collaboration. *Procedia-Social and Behavioral Sciences* 102, 386-391.

22. Sheppard, S.D., Sullivan, W., Colby, A., Macatangay, K., (2006). What is Engineering Practice? International Journal of Engineering Education 22, 429-438.

23. Storbel, J., Wang, J., Weber, N.R., Dyehouse, M., (2013). The role of authenticity in design-based learning environments: The case of engineering education. *Computers & Education* 64, 143-152.

24. Todd, R.H., Magleby, S.P., Sorensen, C.D., Swan, B., Anthony, D.K., (1995). A survey of capstone engineering courses in North America. *Journal of Engineering Education* 84, 165-174.

25. Willey, K., Freeman, M., (2006). Improving teamwork and engagement: the case for self and peer assessment. *Australasian Journal of Engineering Education* 2, 1–19.

26. Turns, J., Cardella M., Atman, C.J., Martin, J., Newman, J., Adams, R.S., (2006). Tackling the Research-to-Teaching Challenge in Engineering Design Education: Making the Invisible Visible. International Journal of Engineering Education 22, 598-608.

27. Walker, J.M.T., Cordray, D.S., King, P.H., Brophy S.P., (2006). Design Scenarios as an Assessment of Adaptive Expertise. International Journal of Engineering Education 22, 645-651.

28. Zou, T.X.P., Ko, E.I., (2012). Teamwork development across the curriculum for chemical engineering students in Hong Kong: Processes, outcomes and lessons learned. *Education for Chemical Engineers* 7, e105-e117.