Portrayal of a Signals and Systems Course for Biomedical Engineering Program at King Abdulaziz University

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***Abstract* — Biomedical engineering (BME) program is interdisciplinary necessitating a strong foundation built by courses taken from several disciplines. EE 470 - Biomedical Signals and Systems is one of the capstone courses developed to bridge the engineering sciences and math with terminal BME courses. Students' scholastic levels, capabilities and learning abilities are determined at the beginning as they take the courses. Then, the course runs dynamically with students' involvements in carrying out teaching and course assessments. It contributes a lot to the maturity of students and achievement of the program outcomes to satisfy the ABET EC2000 requirements.**

***Index Terms* — Biomedical engineering education, Educational technology, Knowledge acquisition, Signals, System analysis and design.**

I. Introduction

Biomedical engineering (BME) is a discipline that serves as a metaphorical "bridge" between engineering and medicine by providing the foundation and structural integrity for the passage of engineering knowledge to the medical field [1]. In this field, there is continual change and establishment of new areas due to rapid advancement in technology. The program at KAU is one of the four programs in the Department of Electrical and Computer Engineering (ECE). It mainly deals with bioinstrumentation, clinical engineering and medical imaging. **Bioinstrumentation** is the application of electronics and measurement techniques to develop devices used in diagnosis and treatment of disease. Computers are an essential part of bioinstrumentation, from the microprocessor in a single-purpose instrument used to do a variety of small tasks to the microcomputer needed to process the large amount of information in a medical imaging system. **Clinical engineering** is the application of technology to health care in hospitals. **Medical imaging** combines knowledge of a unique physical phenomenon (sound, radiation, magnetism, etc.) with high speed electronic data processing, analysis and display to generate an image [2].

Capstone courses are recommended to bridge the gaps in interdisciplinary programs, or interdepartmental majors. The Biomedical Signals and Systems – EE 470 is one of the capstone courses in the BME program [3].

II. BIOMEDICAL ENGINEERING AT KAU

A. Description of the Program

The program requires 48 courses that add up to 153 credit-hours and are distributed into five years. 6 courses (14 credits) are university requirements and 19 courses (61 credits) are the faculty requirements. 10 courses (35 credits) are taken as the electrical engineering requirements. On top of these, 10 compulsory (34 credits) and 3 elective (9 credits) courses are taken as biomedical engineering requirements. Fig. 1 illustrates pictorially the design of the program.

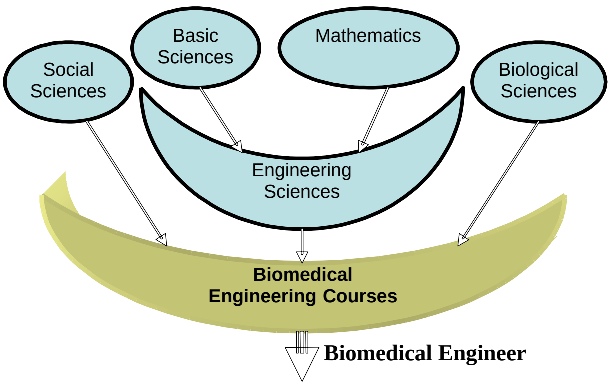

Fig. 1 Pictorial presentation of the BME program [3]

B. Accreditation from ABET

The BME Program received substantial equivalency (SE) from the Accreditation Board of Engineering and Technology (ABET) Inc. in September 2003 according to the conventional criteria [4]. The administration and staff in the Faculty of Engineering at KAU appreciated the strength of EC2000 and preparations started soon after the recognition for SE. The Program objectives were rephrased as perceived by the staff in cooperation with some feedback from alumni. They will be revised after the extensive undergoing constituencies' surveys. Abilities and skills gained by students at the graduation are stated as program outcomes (POs). POs contain statements to satisfy the EC2000 engineering criteria (***A-K***), program criteria for electrical engineering (***L, M,*** and ***N***) and BME (***O, P,*** and ***Q***) program requirements. The BME program shares courses with other three programs in the Department. Hence, a verbatim copy of ABET ***3a-3k*** is adopted as ***A-K*** for all programs to unify the approaches department-wise. Information on program objectives, program outcomes, their elements and attributes is available on the web [5].

Foundations of program outcomes in courses are specified as course learning objectives (CLOs). Since the work of equipping students with attributes specified in program outcomes (POs) must be done at the individual course level, all faculty members involved in teaching required courses must now understand and be involved in the accreditation process on a continuing basis.

C. Capstone Courses

Each course is a primary ingredient of the curriculum. All attempts have been made to have a staggered curriculum in which all courses are designed and conducted to support each other to achieve optimum learning successes by students. However, this is not always possible since the courses are offered from several disciplines and from different faculties beside the faculty of engineering. Hence, there is a problem in control of ingredients and it is not always possible to assemble a reasonably acceptable result.

A **capstone course** is offered normally in the final semester of a student's major. It ties together the key learning objectives that faculty expect the student to have learned during the major. It helps students focus on what they have accomplished academically and professionally while at the university. Hopefully, the realization of the skills and capabilities they have developed assists in bridging the gap between life as a student and the graduate's first job. Ultimately it shall lead to a successful career. So, the capstone is a summation experience for students where they may use all the information they have been gathering and obtaining [6, 7].

Three courses are designed as capstone courses to fuse diverse approaches and techniques to achieve the ultimate aim: to graduate engineers who can think scientifically, communicate effectively and work in a team.

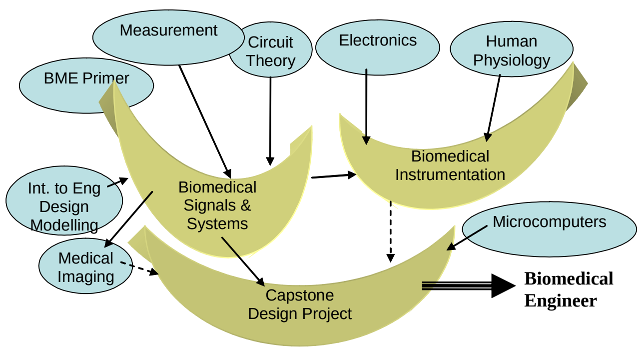

Fig. 2 Capstone courses with prerequisites and co-requisites [3]

The courses are EE 470 - Biomedical Signals and Systems, EE 471 - Biomedical Instrumentation and EE 499 - Senior (Capstone Design) Project. Fig. 2 presents relationships between courses in preparing the biomedical engineer. EE 499 is the capstone design project that is a terminal course. Students work one full year for it. This course is compulsory for all engineering students. EE 470 and EE 471 are offered in the second terms of the fourth year and the fifth year respectively. They are for biomedical engineering students only [3]. EE 470 is the subject matter of the current paper.

III. Design of the Course

A Microsoft EXCEL® based utility software has been developed to assist the course design, assessment and evaluation. It is widely used in the Department of Electrical and Computer Engineering [8]. Graphs in this paper are prepared using the software.

A. Objective of the Course

This course is designed to develop the ability of biomedical engineering (BME) students to recognize signals, systems and their interactions, and to train them on essential mathematical and engineering tools for analysis of biomedical signals and systems. It provides a bridge between core courses in engineering sciences, mathematics and engineering design, and terminal courses medical imaging, biomedical instrumentation and senior (capstone design) project. The objectives of the course can be stated as:

1. Familiarization of BME students with basic signals, their derivations and transformations;
2. Familiarization with system identification tools, expressing complex systems as combinations of simpler components, and performance test criteria;
3. Practices on operations on signals and systems in time and transform domains;
4. Preparing the BME students as life-long learners so that they can easily follow changes in the biomedical equipment technology.

After finishing the course successfully, the BME student shall

1. Express signals in terms of basic signal components in time domain;
2. Identify characteristics of 1st and 2nd order systems using test signals;
3. Switch between several models developed for system analysis and identify the best approach for a given application;
4. Obtain transfer function model for a given system and asses the time and frequency behavior of the system;
5. Understand affects of sampling rate in generating the discrete-time signals and estimate the proper sampling frequency;

6. Estimate the number samples needed to study a continuous-time signal and choose a proper window function;
7. Identify the dynamic range, accuracy and precision requirement for biomedical equipment.

B. Courses Learning Objectives

A capstone course is designed like any other course: a course file is prepared containing necessary course information and course learning objectives (CLOs). CLOs are laid out for every core course in the curriculum and assessed carefully so that corresponding program outcomes (POs) are satisfied at the end. An articulation matrix that relates the POs to CLOs is planned for each course. However, a capstone course (even though "capstone" may not appear in the name of the course) requires many courses to be taken as prerequisites or corequisites. At the same time, the course addresses several POs. EE 470 requires 4 prerequisites and supports 12 of 17 POs as illustrated in Fig.3. 7 of the 12 POs have been addressed substantially in fall 2006/2007 academic year. Some program outcomes rely more on the student's background and out-class activities, hence they have larger effects on the grades. List of CLOs is available on the web [9].

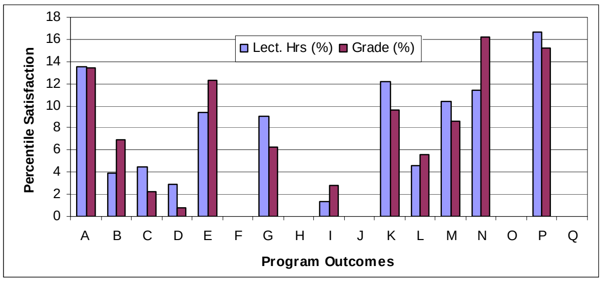

Fig. 3 BME program outcomes addressed by EE 470

IV. Administration of the Course

The administration of the course takes place in four stages as

- familiarization,
- rectification,
- teaching and
- reinforcing.

A. Familiarization and Rectification

Students go through extensive entry surveys and pretests to establish the level of the class and learning styles of students. The entry survey contains verbal questions to verify students' performances before the course. The pretest has 40 multiple-choice questions to determine the level of students in prerequisites. There are tables in the pretest to be filled by students related to difficulty levels of questions and self assessments of their performances. Several conceptual problems are encountered at this stage.

Students were afraid of the level of the course being raised due to high scores in the pretest. Hence, they were reluctant to answer the questions correctly as the pretest applied for the first time. In successive semesters, the test has been carried out in the first week of the term while add/drop still continues. They have been asked either to drop the course or reduce their semester loads by dropping some other courses if they scored low in the test. Then, the results have become more trustworthy.

Extra tutorials are provided to rectify the deficiencies and correct the misconceptions. Students are asked to prepare a journal within the first month for the questions they have missed in the pretests. Correction of a misconception is a difficult task and it generally runs throughout the whole semester.

B. Teaching and Reinforcing

Teaching is carried out in classroom in several forms:

- power point presentations using a data show,
- problem solving and detailed explanations on white board,
- individually and group assigned homework problems, and
- discussions as active learning sessions in study groups.

The education is supported by experiential learning practices as demonstrations, lab works (experiments and projects), computer simulations, hardware simulations and workshops. Projects are indispensable elements of education for capstone courses and they are realized as interim projects with textbook style problems and term projects with semi-real life problems.

A detailed teaching time-table is prepared soon after the entry survey and pretest. The progress of every student is monitored closely throughout the term. Students learning skills and abilities are analyzed. Students are encouraged to identify the learning method they can cope with best and use it to learn the subject matter, and share it with the class.

In addition to the textbook, a workbook is prepared and made available for students in the photocopy centre and on the web. It contains the course content, tentative timetable, supplementary course material, solved examples, active learning exercises, extra exercise problems, laboratory guides and notes, and experiment sheets. All lecture notes and supplementary material including power point slides, solved examples and MATLAB® files are also available on the web [9].

Every student presents at the end a portfolio of all his work throughout the semester. The course instructor picks up materials to support the program outcomes from the portfolios and returns the rest to students.

IV. ASSESSMENT OF THE COURSE

Assessment is a process to identify, collect, use, and prepare data that can be used to evaluate achievements. It involves analysis of data to inform changes that will improve an outcome. Assessment of the course and assigning grades to the students is a challenge for the instructor. Various assessment methods are currently dwelled upon [10]. Traditional assessment tools such as homework, quizzes, major and final exams, interim and term projects are still the key elements. In addition, performance appraisals such as lab performance, lab reports, lab project reports, written and oral presentations, self and peer assessments, reflective journals and portfolios are important contributors. Performance surveys (i.e. cross/delta checks) and opinion polls are used to monitor the progress. Rubrics are prepared for assessment tools that can't be graded directly.

Weights of course learning objectives (CLOs) are modified according to the overall performance measures and questions in the exams are devised accordingly. Naturally, the articulation matrices are modified with such biases and distribution of course grade into program outcomes are expected to change (Fig.3).

Self and peer evaluations are carried out for most exams, assignments and projects. Students are given chances to improve their grades by making corrections for all exams, assignments and projects. In some main exams (major and final), they are allowed to discuss the questions among themselves (without taking notes for about 15 minutes) at the beginning. In these exams, they are allowed to use their laptop computers.

A comprehensive exit survey is carried out as an indirect assessment tool at the end of the term. Students complete the surveys at home and include them in their portfolios. Hence, they are not pressed in time and are totally free of any psychological influence. It reflects students' perceptions of achievements of CLOs, satisfaction with teaching and assessment methods, and their appreciation of the course in contributing to their career. Students' comments are welcomed and few have commented mainly to express their satisfactions and appreciations.

IV. RESULTS AND DISCUSSIONS

Evaluation is a process of reviewing the result of data collection and analysis, and eventually making a determination of the value of findings and action to be taken. Specific, measurable statements identifying the performances required to meet the outcome are called the performance criteria. Surely, they must be confirmable through evidences. A course binder is prepared for every course containing the course design information, indirect and direct assessment tools and students' samples. The course is evaluated via the data collected using the assessment tools and predetermined performance criteria to find out:

- Achievements of Course Learning Objectives
- Achievements of Program Outcomes addressed, and
- Achievements of Program Outcomes addressed by individual students.

A. Achievements of Course Learning Objectives (CLOs)

Course learning objectives are contracts between the instructor and students. They were defined in fall 2005-

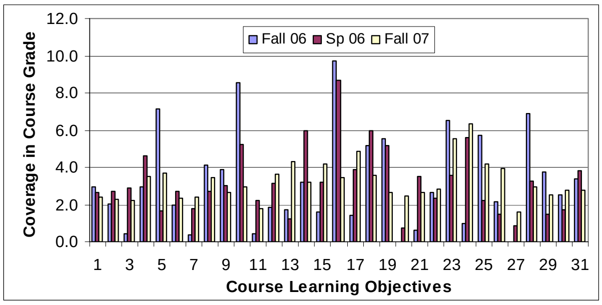

Fig. 4 Coverage (%) of CLOs as indicated in the course grade

2006 (Fall 06) for the first time and carried out since then with small modifications. Fig.4 shows coverage of CLOs in course grades for three successive terms. Some CLOs were not addressed at all in Fall 07 while some others were over-emphasized. The situation has been improved in Sp 06 but still a balanced distribution was not achieved. In Fall 07, a much more balanced distribution has been obtained.

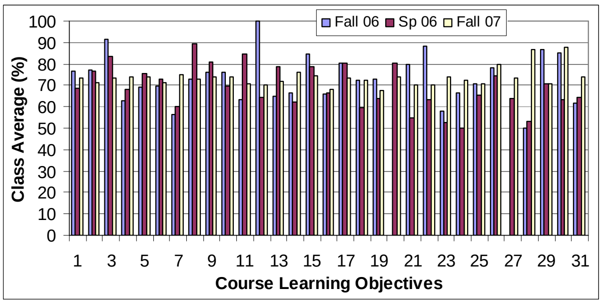

Fig. 5 Class averages (%) in three successive terms

Satisfaction and class averages achieved are summarized in Fig.5. Performance criteria for the CLO averages have been set as 65%. A much more balanced class average is realized in all CLOs that led achievement of the performance criteria in the last term.

Average scores in grades of students who have passed the course reflect the teacher's evaluation of the satisfaction of CLOs. Scores achieved using direct (grades) and indirect assessment tools (exit survey) are compared and generally they come very close to each other as displayed in Fig.6 for Fall 07. Discrepancies are analyzed and used for objective assessment of the course.

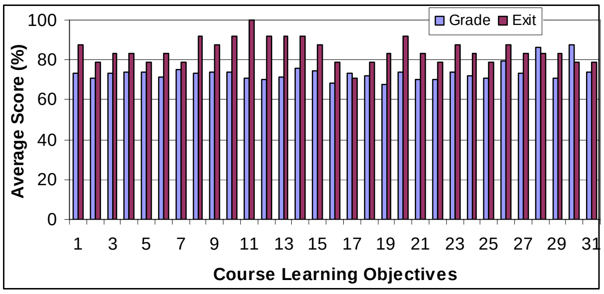

Fig. 6 Average scores from course grade and exit survey

B. Achievements of Program Outcomes (POs)

Fig. 7 briefs the distribution of course activities (as reflected into grades) into program outcomes in three successive terms. There are inevitable variations in the distribution imposed by the state of students in the class. For example, more engineering math has been included in the last term due to deficiencies of students in this area at a cost of jeopardizing the engineering design.

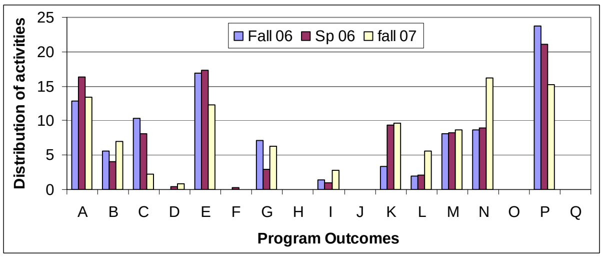

Fig. 7 Distribution of course grade into program outcomes

Fig. 8 shows the class averages obtained (for students who passed the course) in three successive terms. Performance criteria for the program outcomes have been set to have 70% on average for all POs addressed by the course and this has been achieved in Fall 07.

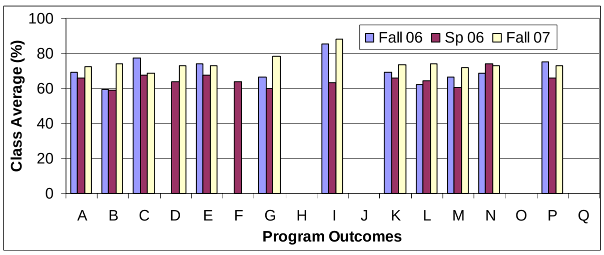

Fig. 8 Class averages for program outcomes

C. Achievements of POs by Students

Importance of students' learning can be stipulated as: they (students) didn't learn it, we (teachers) didn't teach it. Each student must satisfy all program outcomes at minimum level before graduation. The software utility tool provides the level of satisfaction of program outcomes by each student. It also yields assessment tools used to measure each outcome. Eventually, a student who misses a major outcome shall be asked to compensate either in that specific course (i.e. by giving additional assignments) or in another course that will be taken at a later stage.

VII. Conclusion

EE 470 – Biomedical Signals and Systems course is a backbone to the BME program. It especially contributes a lot to the satisfaction of professional engineering criteria such as identifying problems, designing solutions and using modern design tools as well as to most elements of the electrical and biomedical engineering program criteria. Students get chance of unifying diverse background of BME curriculum in a common ground.

Achievement of objectives is verified by

1. Assessment during the progression of the course and immediately after taking the course. Students' work in the course file demonstrates several examples of this assessment in terms of homework/exam questions, lab experiments and projects.
2. Assessment of students in courses that utilize the course materials (EE 471 – Biomedical Instrumentation, EE 472 – Biomedical Imaging and other senior-level BME courses).
3. Assessment of students in the field after graduation (alumni surveys).

The course is difficult to mentor; bothersome for the instructor; and it needs a lot of effort and time to run. Yet, it pays back by contributing a great deal to the maturity of students and achievement of the program outcomes. Many recent graduates called the course instructor to express their appreciation especially as they attend courses in technical training or graduate study.

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