AC 2007-373: THE USE OF FACULTY COURSE ASSESSMENT REPORTS IN BME: LESSONS LEARNED IN THREE YEARS

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The Use of Faculty Course Assessment Reports in BME: Lessons Learned Over Three Years

Abstract

The assessment of program outcomes for ABET accreditation has become a challenge for engineering programs nationwide. It is especially difficult for biomedical engineering programs that rely heavily on core engineering courses offered in non-biomedical engineering departments. Thus, the Department of Biomedical Engineering at The University of Akron has developed Course Objectives and Faculty Course Assessment Reports (FCARs) to support the assessment process using only courses taught in the Department. The first step of this process begins with the development of Course Objectives, or stated directly "Upon successful completion of this course, students will …". These course objectives are then evaluated at the end of each semester using the FCARs which provide a format to track changes made to course, quantitative assessment of the course objectives, grade distributions, student feedback, instructor reflection and proposed changes for the next offering. The quantitative and qualitative details generated in the FCARs may then be mapped directly to the Program Outcomes (ABET Criterion 3). The department began using this process at the beginning of the 2004-2005 academic year and has developed course objectives and FCARs for all of the undergraduate courses taught by the Department of Biomedical Engineering, thus removing the dependency upon other engineering departments for assessment of their Program Outcomes.

The Development of Faculty Course Assessment Reports

The first step of this process begins with the development of Course Objectives and Course Outcomes. Course Objectives are general statements about the content of the course. Course Outcomes are statements relating to what the students should know at the end of the course, or stated directly "Upon successful completion of this course, students will …". Course Outcomes should be developed with a metric, or metrics, in mind for measuring the level of success or failure, such as examination or homework questions, or project requirements. Course Objectives and Outcomes should then be included in the course syllabus distributed to each student on the first day of class (Figure 1).

At the completion of the course, each instructor completes an assessment report for each BME course they taught. The report includes the following sections; Heading, Catalog Description, Grade Distribution, Modifications Made to Course, Course Outcomes Assessment, Student Feedback, Reflection, Proposed Actions for Course Improvement. Other sections may be included as each instructor or the Department wishes. These extra sections may be used to assess the "soft" skills required by ABET such as written and oral communications, engineering ethics, etc. and should reflect your institution's Program Outcomes and Objectives. The Course Outcomes Assessment is the main section of the report and should include a quantitative evaluation of each stated course outcome. These evaluations should include examples of how the outcome was taught and evaluated. Finally, the extent to which the class satisfied the outcome should be stated numerically (Figure 2).

Lessons Learned in the Past Three Years

It has been our experience to date that this process requires at least one year to develop and at least two years for the faculty to become somewhat comfortable with it. The optimum procedure to follow is to have one or two faculty meetings dedicated to training prior to the beginning of each semester to ensure that each program faculty member has well thought out Course Outcomes. It is then imperative to ensure that these Course Outcomes are listed on the class syllabus and discussed with the students during the initial meeting of that class. Once the Course Outcomes are determined and presented to the students, it is necessary to occasionally remind the faculty to review these Outcomes and to ensure that they are providing homework problems, exam questions and/or project requirements that will allow them to quantitatively assess the Outcomes at the end of the course. Program faculty found this process of developing Course Outcomes to be confusing at first, expecting that they should take on the form of the Program Outcomes. Several repetitions of the process were required to develop appropriate outcomes, with the understanding that this would be a dynamic process to be considered prior to handing out their syllabus each semester.

At the completion of each semester, it is necessary to have each program faculty complete the FCAR for their courses in a timely manner. All faculty are extremely busy and need a gentle reminder to complete their part of the process. A reminder two weeks prior to the end of the class is useful so that faculty are beginning to fill out the FCAR and it also reminds them to check and determine if each Course Outcome has been "tested". It has also been our experience that the process is typically not completed until the beginning of the next term. This is not a problem and typically necessary due to the need to review teaching evaluations which are not returned to the faculty until early the following semester. The first time, the development of FCARs also generated much confusion for the faculty, as does any new process. Several repetitions of this process were required after each semester (fall and spring) to develop the desired result and the faculty all agreed that the process truly made them consider what they were teaching, what they wanted the students to learn and whether the student were actually learning the material sufficiently. In addition, faculty used a variety of "grades" to assess their success in achieving their proposed Course Outcomes, such as percentages or letter grades. It was determined that percentages would be the most useful in comparing Outcomes across courses. It is also necessary for ALL program faculty to participate in the process.

The Final Step – Mapping Course Outcomes to Program Outcomes.

The final step required to "close the loop" for ABET assessment of Program Outcomes, is to map the Course Outcomes for each class to the Program Outcomes for the BME Program. Ideally, this process should be completed by the entire program faculty. However, it is typically easier for a single, knowledgeable individual to complete a first-pass at this process and then ask for input from the program faculty. A visual chart or "map" helps considerably in this process and may be completed initially for each course then for the entire curriculum. An example is presented in Figure 3 for the course presented in Figure 1. The Program Outcomes a-k closely match the prescribed a-k in the ABET requirements with minor variations that make them more specific to the Biomedical Engineering Program. It may be noted that this course only maps to

Program Outcomes a, b, c, f, and k. It is obvious that not every course will address or assess every Program Outcome. The "Measured Score" column reflects the information presented in the FCAR report and the "NM" indicates that this outcome was not measured quantitatively, but a qualitative measure may exist and is discussed in the FCAR report.

Once the individual Course Outcomes are mapped to the Program Outcomes, the results may be combined to determine an overall assessment of the Program outcomes from the entire BME curriculum. It is not the intent of the FCARs to be the sole assessment tool for the Program Outcomes. As stated in our Interim ABET report, "The extent to which each Program Outcome is being satisfied may be determined by analyzing the FCARs assessment of Course Outcomes (Measured Score), but must also incorporate the non-curriculum related tools, such as Co-op employment via Employer Surveys, participation in undergraduate research activities, participation in student organizations and associated leadership positions, participation in the University Honors Program, and Senior Exit Interviews." However, this process easily identifies Program Outcomes that are not being assessed in the curriculum and thus must be addressed in other ways.

Conclusions

The use of FCARs has facilitated the process of ABET assessment by providing quantitative measures (Course Outcomes) that may be directly related to BME Program Outcomes. The ability to track changes in courses over time as a result of the assessment of Course Outcomes allows the program to "close the loop" and provides the opportunity for continuous improvement. However, as noted by the ABET evaluators, every course and every instructor must participate for the FCARs to be valid. In addition, a consistent format for the quantitative measures is mandatory to allow the Course Outcomes to be mapped to the Program Outcomes. Over the period of three years, the majority of the faculty have become acclimated to the process and value its worth. The ability to track changes made to specific courses, and hence the program as a whole, has been found to be the greatest benefit.

4800:305-001
Biophysical Measurements

Instructor: Dr. ______________________

Course Objective:
The objective of this course is to provide the biomedical engineering students with the skills necessary to perform proper physical and physiological measurements of devices and phenomena likely to be encountered in their engineering careers. A major concept used in this course is hands-on training which allows the student to physically participate in device construction, data collection and data analysis.

Course Outcomes:
Upon successful completion of this course, the students will:

- **Understand equipment calibration, accuracy and error**
- **Understand error analysis and how to report uncertainties**
- **Understand numerical methodologies used to determine accuracy and uncertainty**
- **Understand simple statistical analysis and least-squares fitting of data**
- **Understand statistical criteria for the rejection of data**
- **Understand AC and DC electrical measurements**
- **Understand and be able to design and build biomedical amplifiers including safety considerations**
- **Understand and use Laplace and Fourier Transforms and system transfer function**
- **Understand and use data acquisition hardware and software**

Figure 1. Syllabus for Biophysical Measurements, including Course Objectives and Outcomes.

Faculty Course Assessment Report
BME 4800:305 – Introduction to Biophysical Measurements – 4 Credits
Fall 2004

Catalog Description:
Biomedical Engineering involves measurement of Physiological processes in living organisms. An understanding of the variety of instruments used and the limitations are introduced.

Grade Distribution:

A	B	C	D	F	WD	Total
2	1	0	0	0	0	3

Modifications Made to Course:
Modifications to the course involve in increase in hands-on procedures. The students learned to use distance measuring equipment including LASER Rangefinder, GPS and Surveyor's Theodolite. The students also built a Photoplethysmograph and ECG amplifier and learned to use the Dataq® data acquisition system to record and analyze physiological data. Several types of measurement were also introduced this current semester including estimating the diameter of a ball by measuring it's displacement, in water. I also added oscilloscope measurements of analog filter circuits.

Course Outcomes Assessment:
CO-1: Understand equipment calibration, accuracy and error
This outcome was introduced by having the students calibrate a D'Arsonval-type voltmeter which they built themselves. The original design was structured so that the result was non-linear and not particularly accurate. Repeated measurements of known DC voltages demonstrated errors in reproducibility. The concept of a least-squares linear fit and a study of residuals demonstrated deviations from ideal conditions. This outcome was assessed through the assignment of homework problems using Excel® Spreadsheets and exam questions. Exam results on this subject, for the three students, were as follws: 1-20/20, 1-18/20 and 1-8/20%.

CO-2: Understand error analysis and how to report uncertainties
This course outcome is implemented through the building of a DC voltmeter, then calibrating it, and writing a specification sheet that includes error and uncertainty analysis. The experimental design intentionally introduced reproducibility, linearity and accuracy errors. The results of this error analysis was evaluated through a homework and laboratory assignments. Laboratory exercises included measuring the speed of sound in the field (1-18/25, 2-24/25), measuring the speed of sound in the laboratory, (1-25/25, 2-22/25) and estimating the diameter of a steel ball by measuring it's displacement in water(1-25/25, 1-20/25, 24/25). Quantitative assessment was done through exam questions involving voltmeters having high input resistance versus low input resistance. The exam results were as follows: 2-20/20 and 1-10/20 for error analysis and 2-20/20, 1-18/20 for the display of uncertainties.

CO–3: Understand numerical methodologies used to determine accuracy and uncertainty
The Biomedical Engineering students learn some numerical methods, primarily via MathCad®, during their freshman year (Tools, 4800:101) however they do not choose to rely on these newly-learned numerical methods to solve current problems. To force the students to use numerical tools available to them several assignments are implemented. The students are required to derive solutions for linear regression, rather than "packaged" methods. Numerical differentiation and integration are used in the solution of 2^{nd}-order, and higher, differential equations which are necessary to evaluate Transfer Functions and to evaluate statistical results. Quantitative assessment through examination provided the following results: 2-20/20 and 1-18/20 for using numerical differentiation to estimate error propagation, 3-20/20 for deriving and plotting transfer functions.

CO-4: Understand simple statistical analysis and least-squares fitting of data and understand statistical criteria for the rejection of data
The student learns how to fit data to (primarily)linear data in order to calibrate linear instrumentation such as voltmeters. Statistical methods (mean, standard deviation, confidence limits)are used to explain the uncertainties in measured results. Analyses of normal distributions are used to examine the rejection of "outliers" in any normally distributed dataset. The students' understanding of these concepts are evaluated through examination questions that include the following: Linear Regression Analysis (1-20/20, 2-/20) and the use of *Chauvenet's Criterion* for the rejection of data (2-20/20 and 1-18/20)

CO-5: Understand AC and DC electrical measurements
AC and DC electrical measurements are made in the laboratory through building electrical circuits and then using modern laboratory equipment (Oscilloscope) to measure the result. The is done with simple resistive circuits and more complex analog filter circuits. The actual measurements take place in the laboratory and are evaluated by performing laboratory exercises. The measurements involve the measurement of transfer functions where the input and output of various circuits are compared. Determining the Transfer Function (2-25/25, 1-20/25), Determining Common Mode Rejection Ratio(CMRR), (1-25/25,1-24/25, 1-18/25), and measuring the gains of various standard Op-Amp Configurations (1-25/25,1-24/25,1-22/25).

CO-6: Understand and be able to design and build biomedical amplifiers including safety considerations
The biomedical engineering student, in this course, learns to design and build basic Op-Amp circuits including high-impedance input stages for electrical safety and subject protection. The students were required to build and evaluate the amplifiers then submit a laboratory report explaining the results. Grading Results (1-25/25, 1-22/25, 1-0/25). In a separate laboratory exercise, the students were required to build and test a Differential Amplifier (one of the most commonly used configurations in Biomedical Engineering) and measure the Common Mode Rejection Ratio (CMRR). The students were required to prepare and submit a lab report on their results. Grading Results(1-25/25, 1-24/25, 1-18/25)The first practical device is a Photoelectric Plethysmograph which permits the student to observe his/her own blood flow in the extremtites. The device is fabricated in the laboratory and a laboratory report is required. Grading Results(2-25/25, 1-0/25) Quantitative assessment of this outcome was accomplished through exam questions. Exam Results (1-20/20,1-16/20,1-0/20) and (2-20/20, 1-10/20)

CO-7: Understand and use Laplace and Fourier Transforms and system transfer functions
Knowledge of Laplace and Fourier Transforms is necessary for the understanding of filtering technidques. The students are required to analyze and build several types of analog filter, then build and test each of the filters in the laboratory. Laboratory Results (2-25/25, 1-24/25), (1-25/25, 1-21/25, 1-20/25), (1-25/25, 1-22/25, 1-21/25). Quantitative assessment was accomplished through an examination. Three exam questions evaluated several

aspects of Laplace and Fourier Transforms. Exam results (2-60/60, 1-54/60)

CO-8: Understand and use data acquisition hardware and software
The use of Dataq® data acquisition or similar devices was required to make permanent recordings if the laboratory experimental data. There was no specific quantitative evaluation method required.

Ethics Component:
The primary ethical component encountered in this class is to note that calibration statistics must represent the true behavior of the device, even if it points out some shortcomings in the design. Calibration statistics must represent the actual results of calibration and the results should not be hidden by manipulating the numbers.

Student Feedback:
In general, the students seem to appreciate the course and what it is trying to teach. The hands-on nature of the course is well appreciated. This is the first opportunity that some of the students have gotten to use some of the equipment, such as an oscilloscope.
One of the students felt that the text book(s) could be used more. I suspect that they do not see the value in using the texts as a reference and they therefore resent having to purchase the book and then not having homework problems assigned out of it.

Reflection:
The course seems to be well received by the students. I still feel that they learn the material in the class, for the class and do not see the universal application of what they learn.

Proposed Actions for Course Improvement:
There are only a few changes anticipated for next semester. I expect to increase the hands-on aspect of the course. Although the students were required to build and test an ECG Amplifier, I did not evaluate their understanding of the device. I expect to include an additional laboratory report and exam question on this device.

In general, the students' attitude does not seem to grasp the generally applied nature of what they are studying. They learn the material in order to obtain a good grade in the class but outside of the class environment they do not apply what they have learned. I will try to get the student to realize that the material they learn is to be universally applied. I will increase the number of mechanical measurements so that the students do not associate the measurements with only electrical concepts.

In teaching this course, I tend not to give assignments out of the textbooks. I feel that the students can use the books for reference. This is particularly true with the medical instrument portion. I will continue to give assignments from this book however I will also evaluate, through testing, the students' comprehension of this material.

Figure 2. FCAR for Biophysical Measurements, including assessment of Course Outcomes.

Course Number	**Course Outcomes -** Upon successful completion of this course, students will:	Program Outcomes	Measured Score
305	(1) Understand equipment calibration, accuracy and error	(1) k	77%
	(2) Understand error analysis and how to report uncertainties	(2) b	83%, 97%
	(3) Understand numerical methodologies used to determine accuracy and uncertainty	(3) a	98%
	(4) Understand simple statistical analysis and least-squares fitting of data	(4) b	98%
	(5) Understand statistical criteria for the rejection of data	(5) b	NM
	(6) Understand AC and DC electrical measurements	(6) a, b, c	92%
	(7) Understand and be able to design and build biomedical amplifiers including safety considerations	(7) a, b, c, f, k	72%
	(8) Understand and use Laplace and Fourier transforms and system transfer functions	(8) k	97%
	(9) Understand and use data acquisition hardware and software	(9) b, k	NM

Figure 3. Mapping Course Outcome to Program Outcomes