QUANTITATIVELY ASSESSING AN OUTCOME ON DESIGNING AND CONDUCTING EXPERIMENTS AND ANALYZING DATA FOR ABET 2000

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Abstract *¾ The Mercer University School of Engineering (MUSE) identified eight outcomes to assess for the accreditation process. MUSE Outcome #4 stipulates that students should be able to design and conduct experiments and analyze data.*

The committee charged with assessment of Outcome #4 identified four separate skills associated with this outcome; conducting experiments, analyzing experimental data, interpreting experimental data, and designing experiments. The committee determined that assessment of this outcome required documentation of the number of student experiences with each of the four skills and the overall student performance level on each of these skills. A skill assessment worksheet was developed for use in the grading of any activity related to Outcome #4. The worksheet quickly identifies which of the four skills the activity incorporates as well as the performance of the students on each of the individual skills. This worksheet was distributed to instructors teaching courses that contain a significant content related to this outcome.

Data collected from courses in Industrial Engineering, Biomedical Engineering, and Electrical Engineering taught during the Fall of Semester of 2000 suggests that MUSE has been successful at meeting Outcome #4. The data also indicates that the skill assessment worksheet was an efficient and accurate method for collecting quantitative data and identifying weakness in the assessment process. Modifications made to the worksheet by professors to accommodate their personal grading scheme demonstrates that the tool has enough flexibility to be used across multiple disciplines and grading styles while still providing the data required for assessment of Outcome #4.

This paper presents the skill assessment worksheet, data collected using the worksheet, and instructor comments on use of the worksheet.

Index Terms ¾ ABET, EC 2000, assessment, competency measurement, quantitative data

INTRODUCTION

Once an engineering program has developed a set of outcomes under ABET's EC 2000, it must develop a methodology for assessing its performance on these outcomes [1]. A variety of assessment tools and methodologies are available and have been documented [2, 3]. Ideally, the assessment methodology chosen will demonstrate the performance of the students as well as the ability of the program, school or college, and ultimately the instructors to deliver the content associated with a specific outcome. Reference [4] states that faculty should be aware and understand the learning outcomes of other courses. It is then obviously critical that sequenced courses (and possibly pre/co-requisite courses) have similar and compatible learning outcomes. The assessment methodology employed should then demonstrate the compatibility of the learning outcomes for these courses and, more importantly, provide data on the performance of students on these outcomes from one course to the next. Sub-standard performance in an upper level course may be directly attributable to a lack of preparation in a previous course. Finally, the assessment methodology should provide quantitative data that can be used to identify strengths and weaknesses and track the impact of changes within the program on the specific outcome. The Mercer University School of Engineering (MUSE) identified eight outcomes to assess for the accreditation process. MUSE Outcome #4 stipulates that students should be able to design and conduct experiments and analyze data.

MUSE was visited by an outside Assessment Process Review Team (APRT) on May 9 - 10, 2000. The APRT consisted of three professors from universities with program's similar to MUSE's and provided an outside and objective view of the outcomes chosen by MUSE and the assessment processes employed. The APRT made a variety of observations that greatly aided the MUSE assessment teams in directing future efforts. In particular, the APRT noted that qualitative assessment tools had been well defined but that the development of quantitative measurements required more attention and that there was an over reliance on surveys in the assessment process. With respect to MUSE Outcome #4, the APRT commented that the use of student grades was an insufficient means of assessing the design and use of experimental techniques.

After reviewing the APRT"s comments, the committee charged with assessment of Outcome #4 identified four separate skills associated with this outcome:

- Conducting experiments,
- Analyzing experimental data,
- Interpreting experimental data, and
- Designing experiments.

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The committee recognized that there was a hierarchy to these skills (i.e. before a student can design an experiment they must be familiar with how to conduct an experiment and anticipate the data analysis process). Furthermore, the committee acknowledged that not all laboratory projects will include all four skills and some courses that do not contain a lab component have assignments that address some of these skills.

The committee subsequently determined that two pieces of data were required to determine how the students, school, and instructors were performing on this outcome. These data were the number of student experiences with each of the four skills and the overall student performance level on each of these skills. In order to quickly and quantitatively collect the required data, the committee chose to use a competency measurement methodology [2, 3] and developed a skill assessment worksheet. This worksheet can be used to grade any activity related to Outcome #4 and quickly identifies which of the four skills the activity incorporates as well as the performance of the students on each of the individual skills. This worksheet was distributed to instructors teaching courses that have a significant content related to this outcome.

This paper presents the skill assessment worksheet, data collected using the worksheet, and instructor comments on the use of the worksheet.

METHODOLOGY

Assessment of MUSE Outcome #4 required the committee to quantify the ability of the students to conduct experiments, analyze data, interpret data, and design experiments. The specific proficiencies associated with each of these four skills are presented in Table 1.

Table 1. MUSE Outcome #4 skills and associated proficiencies.

Skill	Proficiencies
Conducting experiments	Operate laboratory equipment appropriate to the course or discipline, demonstrate appropriate laboratory technique and etiquette, collect data
Analysis of data	Organize data, perform appropriate data manipulations and calculations, present final data in an appropriate format,
Interpretation of data	Draw appropriate conclusions from data, use good engineering judgement to determine if data is reasonable
Design of experiments	Develop a methodology which will produce high quality data that can be used to evaluate a specific process or parameter

The committee recognizing that there was a hierarchy to these four skills with experiment design demonstrating the highest level of competency. Discussions with faculty members indicated that many lab experiences did not incorporate all four skills and that many courses that did not contain a laboratory component contained assignments that incorporated some of these skills. The committee also acknowledged that comprehensive and objective assessment of this outcome required data to be produced on the program (curriculum) and instructor as well as the student. To this end a skill assessment worksheet (Table 2) was developed. This worksheet can be used to compile data on the number of experiences a student in a given program (industrial engineering, environmental engineering, etc.) will have with a specific skill and the overall performance on each of the skills.

Table 2. Skills assessment worksheet for MUSE Outcome #4.[1]

Item	Value[2]	Score[3]
Experiment Design	_____	
Conduct Experiment	_____	
Analyze Data.	_____	
Interpret Data	_____	
Additional grading criteria 1 (optional)		
Additional grading criteria 2 (optional)		
Additional grading criteria cont'd (optional)		
RAW SCORE		

[1]Data in gray rows required for assessment of Outcome #4.
[2]Number of points assigned by the instructor to a specific item on a specific assignment.
[3]Points awarded by the instructor to a specific item on individual student submittals.

Instructors teaching courses with a significant content related to Outcome #4 were requested to utilize this worksheet as part of the grading process for each assignment related to this outcome. Some professors have adopted this worksheet as the primary grading mechanism and have incorporated additional grading criteria into the worksheet as appropriate to the specific assignment. Other professors have simply filled out the worksheet after conducting their normal grading routine. Either method provides the assessment committee with the data required for the assessment process. This data can be used to determine if the curriculum provides a sufficient number of experiences with each skill relative to the specific program and the overall student performance level on each skill. The student performance levels can then be used to evaluate the quality of instruction and/or curriculum. For instance, if students in course X consistently demonstrate sub-standard performance

on a specific skill or set of skills then the appropriate action would be to scrutinize both the instructional techniques employed in course X and the content of the pre-requisites for course X.

RESULTS

The skills assessment worksheet was implemented in the Fall Semester of 2000. Three courses taught during the Fall of 2000 provided significant data for the committee. These courses were Human Factors Engineering (ISE 412, Industrial Engineering), Electrical Engineering Senior Capstone Lab (ECE 405L), and Senior Biomedical Engineering Laboratory (BME 445L).

The Human Factors Engineering course provided one laboratory experience containing all four of the Outcome #4 skills. There were six students in the course and no failing grades were assigned. Ratings of good, marginal, and poor were provided for each skill via the skills assessment worksheet. Three of the six students scored a rating of "good" in all four categories. The other three students received a "marginal" rating in the categories of designing and conducting the experiment and were rated as "poor" on analyzing and interpreting data.

The Electrical Engineering Senior Capstone Lab provided students with four experiences with designing and conducting experiments and five experiences with analyzing and interpreting laboratory data. The instructor indicated that the students performed very well on the open-ended design problems and that more difficult problem should be presented in the future. The instructor also commented that the students were well-prepared for this course and ready to handle these type of problems. Skill assessment work sheets and example laboratory work were available for the high, middle, and low scoring reports. The skill sheet data suggest that the majority of the students did well in the course, however score sheets were not available for all of the students.

The Senior Biomedical Engineering Laboratory included 10 laboratory experiences. Fifteen students were enrolled in the course during the Fall of 2000. Eight of the laboratory experiences were documented using the skills assessment worksheet, Table 3. Course grades were assigned to the individual laboratory reports and then the professor completed the skills assessment work sheet for each laboratory report. Each of these eight labs required the students to conduct an experiment and analyze the data. Students were required to interpret data in seven of the eight experiences. Students were responsible for the experiment design in five of the eight experiences. The data collected indicates that the required score of 70% for each skill was met or exceeded by the majority of the students, thus suggesting both student and instructor success in satisfying Outcome #4.

In the Spring Semester of 2001, the Senior Environmental Engineering Laboratory (EVE 445L) implemented the skills assessment worksheet. The course coordinator required the students to participate in seven 'cookbook' laboratories and conduct a lab project. The cookbook laboratories required student lab groups to operate lab equipment, collect data, analyze data, and interpret results and produce an abbreviated laboratory report. The laboratory project contained experiment design as well as the operation of lab equipment, collection of data, data analysis, and interpretation of results and the production of a detailed report. The course coordinator brought in professors to conduct the 'cookbook' laboratories in their area of expertise and to provide technical assistance with the projects. The outside professors were responsible for grading both the 'cookbook' laboratories and projects done in their area of expertise.

Modifications were made to the skills assessment worksheet to accommodate both the abbreviated and detailed reports produced by the students (Tables 4 and 5). The instructor's intent was to create a uniform standard for all of the professors to grade against and to provide students with concise feedback as to where they lost points. The course coordinator also wanted to break down the evaluation of data analysis and date interpretation into four and two sub-tasks, respectively. These sub-tasks were evaluated by the grader and then summed to provide the assessment team with the required data.

DISCUSSION

Results from courses taught during the Fall of 2000 indicate that the skills assessment worksheet can be an effective tool for collecting data for the assessment on MUSE Outcome #4. The Senior Biomedical Engineering Laboratory made the most effective use of the tool and generated the most quantitative information for the assessment process. The professor teaching this course commented that the worksheet was obviously an effective tool for collecting assessment data but that it took some getting used to. In the Fall of 2000, the skills assessment worksheet was completed after assigning the course grades to each report. This course was also taught during the Spring of 2001. The professor added additional criteria to the skills assessment worksheet and used the worksheet to produce both the course grade and assessment data for the individual laboratory assignments. The professor indicated that this was a much more efficient process than the methodology used in the Fall of 2000.

The Human Factors Engineering course used ratings of good, marginal, and poor for each of the skill rather than numeric grades. While not as easy to track as numeric data, these qualitative rankings may be used to produce quantitative trend information for the course and program. It is difficult to draw any conclusions regarding

Table 3. Summary results from the skills assessment worksheet for the Senior Biomedical Engineering Laboratory

Skill	# of labs containing specific skill	# of Total Experiences[1]	# Scoring > 70%	Percentage (%)
Design	5	75	74	98.7
Conducting	8	120	115	95.8
Analyzing	8	120	116	96.7
Interpreting	7	105	101	96.2

[1]# of Total Experiences = (Number of labs with skill) × (number of students)

Table 4. Criteria for evaluation of abbreviated reports in the Senior Environmental Engineering Laboratory

Item	Value	Score
Experiment Design	N/A	----------
Conduct Experiment	N/A	----------
Analyze Data. (g + h + i + j)	25	✲
Interpret Data (k + l)	15	✲
a. Neatness; coherent, professional document	5	
b. Writing: grammar and spelling.	10	
c. Adherence to format	10	
d. Equipment: thorough; clear; suitable figures	10	
e. Procedure explained in students' own words and organization	5	
f. Complete description of procedure with clear steps	5	
g. Description of steps for data analysis	5	
h. Data: complete and clear reporting of results	5	
i. Clear presentation of calculations.	5	
j. Appropriate graphs and tables	10	
k. Results: clear identification of key results	5	
l. Explanation significance of results	10	
m. Discussion of difficulties and their effects.	5	
n. Answers to any questions posed.	10	
RAW NET SCORE[1]		

✲ This cell not added to Raw Net Score
N/A – not applicable
[1]Total possible score is 100 points

Table 5. Criteria for evaluation of detailed project reports in the Senior Environmental Engineering Laboratory

Item	Value	Score
Experiment Design	200	
Conduct Experiment	50	
Analyze Data. (g + h + i + j)	100	✲
Interpret Data (k + l)	50	✲
a. Neatness; coherent, professional document	15	
b. Writing: grammar and spelling.	15	
c. Adherence to format	20	
d. Equipment: thorough; clear; suitable figures	10	
e. Procedure explained in students' own words and organization	10	
f. Complete description of procedure with clear steps	10	
g. Description of steps for data analysis	25	
h. Data: complete and clear reporting of results	25	
i. Clear presentation of calculations.	25	
j. Appropriate graphs and tables	25	
k. Results: clear identification of key results	25	
l. Explanation significance of results	25	
m. Discussion of difficulties and their effects.	20	
RAW NET SCORE[1]		

✲ This cell not added to Raw Net Score
[1]Total possible score is 500 points

the curriculum, instructor, or students from the data produced, three high and three marginal to poor ratings, in this one course. As a larger data set develops, it will be easier to draw conclusions as to whether the responsibility for low scores should be placed on the curriculum, current instructor, previous instructors, or students.

The Electrical Engineering Senior Capstone Lab produced the least quantifiable information for the assessment of Outcome #4. The fact that data was only provided for the high, middle, and low scoring reports suggests that the professors did not understand the assessment committee's intent but rather produced data similar to what would have been produced under the old ABET criteria. The quantitative data produced was insufficient to derive any concrete conclusion as to the success of the students, professors, or program at meeting Outcome #4.

The use of multiple permutations of the skills worksheet in the Senior Environmental Engineering Laboratory demonstrates that the worksheet can be used very flexibly and still produce data for the assessment process. Thus, professors should be able to easily adapt the worksheet to whatever grading format they have been using in the past. The modifications made to the Spring 2001 offering of the Senior Biomedical Engineering Laboratory also support this hypothesis.

CONCLUSIONS AND RECOMMENDATIONS

The MUSE Outcome #4 committee was charged with assessing the ability of the students to design and conduct experiments and analyze data as well as the performance of both the faculty and curriculum in supporting the development of these abilities. A skills assessment worksheet was developed and distributed for use in the grading of assignments which included conducting an experiment, analyzing experimental data, interpreting experimental data, and/or designing an experiment. Data was compiled from three courses that utilized the form during the Fall Semester of 2000. The data gathered suggested that the worksheet was an effective tool for gathering the required data and identifying weaknesses in the assessment process.

The worksheet has been adopted for continued use in the assessment of MUSE Outcome #4. The primary difficulty encountered with the use of the worksheet has been professor interpretation of the instructions. Representatives from the Outcome #4 assessment committee have been assigned to each program within MUSE to aid professors in utilizing the worksheet correctly and thereby producing useful data for the assessment process.

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