Improvement in Teaching Quality Concepts to Engineers: Measurement, Data Analysis, Experiments and Modeling

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ABSTRACT

A pair of courses has been developed to teach engineering students about measurement, data analysis, and statistical modeling concepts used in quality control and quality systems in technical environments. Engineering students take two complementary courses, typically during the first year of the engineering curriculum: Statistical Modeling for Engineers (STA 220) and Engineering Measurement and Data Analysis (EGR 220). The new course pair is designed to provide an introduction to probability and statistical concepts. STA 220 introduces students to statistical tools that can be used to aid in the design of engineering experiments and in the analysis of data generated from these studies. The EGR 220 course provides hands-on, lab experiences which reinforce the material discussed in STA 220, and introduces students to many of the physical tools used in the engineering sciences. Effectively the new STA 220 and EGR 220 courses are a cross-college team teaching effort to teach a highly interdisciplinary topic more effectively than either department could teach these topics alone. This paper discusses how these two courses were developed, the content of the courses, how concepts and methods are interwoven between the two courses for engineering students, and learning outcomes realized.

KEYWORDS: STEM, Conference Proceedings, Engineering, Higher Education

INTRODUCTION

The Engineering Accreditation Commission (EAC) of ABET, the accrediting body for over 3,100 applied science, computing, engineering, and technology programs at over 660 institutions in 23 countries, clearly identifies criteria for accrediting engineering programs (ABET, n.d.). Student learning outcome (b) under the General Criteria 3. Student Outcomes of the 2013-2014 Criteria for Accrediting Engineering Programs states, “The program must have documented student outcomes that prepare graduates… (b) an ability to design and conduct experiments, as well as to analyze and interpret data” (ABET, n.d.). The second part of this criterion suggests, but does not specifically require, that engineering students have some knowledge of appropriate means of analyzing and interpreting data. This can be construed to include knowledge of appropriate statistical concepts and analytical technics. However, it does mandate that an engineering program have dedicated courses or content in statistical analysis.

It is difficult to estimate the number of current engineering undergraduate degree programs that contain a required statistics course. Prior to the evolution of the ABET accreditation processes that were part of the EC 2000 changes (ABET, n.d.), there was specific language that indicated components of engineering curricula, including the types of courses that should be a part of an accredited engineering program curriculum. The pre-EC 2000 criteria included references to courses in statistics and probability being ‘encouraged’ in the 1999-2000 ABET EAC criteria

(ABET Criteria, n.d.) to requiring that "students must demonstrate knowledge of the application of statistics to engineering problems" in the 1992-1993 ABET EAC criteria (Barton, 1994). It is probably safe to assume that, pre-EC 2000 criteria, the majority of ABET-accredited engineering programs contained a required statistics course in the curriculum. Post-EC 200 criteria, however, it is not as safe an assumption to make that ABET-accredited programs contain a dedicated probability and statistics course. A quick review of the curricula for various types of engineering programs across the United States (searching online university catalogs) results in many examples of programs that do not include a required, dedicated probability and statics course.

ABET also provides program-specific criteria, in addition to the General Criteria, that are developed through the associated professional organizations of an engineering discipline (e.g. American Society of Mechanical Engineers for mechanical engineering, American Society of Civil Engineers for civil engineering, etc.). Several of the accreditable program areas (12 out of 28 engineering program areas) do identify statistical analysis or quality systems as an important part of the curriculum-specific criteria, including those identified in Table 1:

Table 1: Engineering Curricula Requiring Statistics as part of ABET Program-Specific Accreditation Criteria (ABET, n.d.)

Program name (and any similarly named programs)	**Language used specifying statistics content ("Graduates must be able to…)**
Bioengineering, Biomedical	…apply advanced mathematics (including differential equations and statistics)…"
Ceramic	to utilize experimental, statistical, and computational methods…"
Construction	apply knowledge of mathematics through differential and integral calculus, probability and statistics…"
Electrical, Computer	…include probability and statistics…"
Environmental	…be proficient in mathematics through differential equations, probability and statistics…"
Industrial	…accomplish the integration of systems using appropriate analytical, computational, and experimental practices…"
Manufacturing	…create competitive advantage through manufacturing planning, strategy, quality, and control; analyze, synthesize, and control manufacturing operations using statistical methods…"
Mining	…apply probability and statistics…"
Naval Architectural, Marine	…apply probability and statistical methods…"
Ocean	...apply the principles of probability and applied statistics…"
Petroleum	…be proficient in mathematics through differential equations, probability and statistics…"
Software	…appropriately apply discrete mathematics, probability and statistics…"

Engineering, by nature, deals with uncertainty – not only in the quality of the products, but also, in the characteristics of any designed system. It has long been argued that the traditional engineering curriculum have underemphasized teaching of foundational statistical knowledge required by the engineers to tackle this dilemma (Hazelrigg, 1994). Many scholars suggested methods of teaching engineering statistics with new approaches (Gigerenzer & Hoffrage, 1995). Those observations led to the ABET criteria of teaching probability and statistics in the undergraduate curriculum (ABET Criteria, n.d.). The focus of this paper are two required, co-requisite statistics-based, first-year courses in the Bachelor of Science in Engineering programs at Grand Valley State University (GVSU), a large Master's granting university in Grand Rapids, Michigan. The unique set of features of these two courses, and the approach taken by GVSU's engineering programs include:

- Co-requisite courses including a lecture course taught by Statistics Department faculty and a lab taught by School of Engineering faculty;
- Requiring the courses for students in all undergraduate engineering degree programs;
- Hands-on, interactive labs that focus on application of engineering measurement techniques, data collection, and data analysis (including statistical analysis); and,
- Assessment of ABET student learning outcomes in the laboratory course, not only for outcome (b) – design of experiments and data analysis, but also for student learning outcome (g) – verbal and written communication, and student learning outcome (i) – ability to engage in lifelong learning.

The development and integration of these two courses, including overview of their current content, along with results from recent assessment of student learning outcomes will be shared in the next sections.

BACKGROUND AND HISTORY

The GVSU School of Engineering (SOE) offers degrees in five engineering programs, including computer, electrical, interdisciplinary, mechanical, and product design and manufacturing engineering. The engineering degree programs (approximately 650 total undergraduate engineering students) share a relatively common curriculum for the first two years, with students taking six engineering courses that are common to all programs. All engineering programs require secondary admission after completing the first two years of the curriculum, and require both a cooperative education experience incorporated throughout the upper-division of the degree program and an interdisciplinary senior capstone design project.

The ABET requirement and recognition of the need for statistics content directed GVSU's engineering curriculum to incorporate junior level statistics courses as mandatory for the engineering students. However, the cooperative education based curriculum of the GVSU SOE forced the issue of introducing probability and statistics earlier in the curriculum. Some authors suggested that early introduction to probability and statistics will directly enhance the core ability of engineers (Wood, 2004). It was also recognized that the other courses in the sophomore year required some basic knowledge of probability and statistics.

ABET requirements, cooperative education, and prerequisites for the follow up courses led to the introduction of an Engineering Measurement and Data Analysis course (EGR 103) into the freshmen curriculum for all disciplines of engineering students (Standridge & Marvel, 2002).

However, the development of the new course was influenced by the findings of retention literature (Kvam, 2000) and the hands-on, project based learning pedagogy (Dym, Agogino, Eris, Frey, & Leifer, 2005). The newly designed course incorporated two hours of weekly lecture and a 3-hour lab session. The lecture sessions were aimed to teach the fundamental knowledge of statistics in the context of engineering. The laboratory sessions were intended to apply the theoretical knowledge through designed experiments. The major topics were – concepts of uncertainty, direct and indirect measurements, data summarization, probability, regression analysis, hypothesis testing, confidence interval development, statistical process control, and measurement system analysis. Some of the laboratory experiments required substantial background knowledge of the relevant engineering fields, e.g. stress-strain, circuit analysis, heat transfer, and material properties. Moreover, the course also aimed at introducing different branches of engineering to the students. These goals of introducing the unrelated subject from week to week and forced introduction of topics from various branches of engineering muddled the principal objective of teaching engineering statistics through laboratory exercises. Semester end evaluations from the instructors consistently showed the pedagogical challenges. The dissatisfaction resulted in four major revisions of the course material in five years. Yet, the fundamental problems remained and led to eventual abandonment of the course.

NEW COURSE DEVELOPMENT

Assessment of the curriculum, and the EGR 103 course, including achievement of student learning outcomes, in 2008-2009 led to discussions with the GVSU Department of Statistics regarding curriculum change. The EGR 103 course had developed into a course that was trying to be an introduction to engineering for first-year engineering students, and it was not succeeding. Students consistently rated the course as the least-favorite and least-useful course in the foundation courses, and there was limited evidence that student learning outcomes were being achieved. It was determined, from course delivery and operational perspectives, that students needed a better, more focused foundation in probability and statistics, and that would be best accomplished through instruction by Department of Statistics faculty. Likewise, students needed a strong foundation in engineering measurement and applied data analysis. The solution was to develop two new complementary courses: Statistical Modeling for Engineers (STA 220) taught by the Department of Statistics faculty; and, Engineering Measurement and Data Analysis (EGR 220) taught by SOE faculty.

The STA 220 and EGR 220 courses were jointly developed between the Department of Statistics and the SOE. EGR 103 was subsequently dropped from the curriculum. The current curriculum for all of GVSU's undergraduate engineering degree programs includes STA 220 and EGR 220 as required first-year courses. The EGR 220 course is a 1-credit, laboratory-based course. It complements STA 220 - a co-required, 2-credit, lecture-based course. Statistical concepts and theory are introduced and assessed in the lecture-based modeling course. The measurement and data analysis lab introduces basic engineering and science concepts, and conducts associated tests and experiments for the purposes of taking measurements for data collection. Students demonstrate understanding of statistical concepts and theory by applying that knowledge to make meaning of the data obtained from the tests and experiments.

The course pair provides a new perspective which is a more focused and complete introduction to statistical modeling and data analysis than EGR103. The STA 220 and EGR 220 courses are required to be successfully completed prior to the secondary admission process to each of the engineering majors. Therefore, most students take these co-requisite courses within the first two years of the engineering curriculum (considered pre-engineering). EGR 220 was designed to mesh tightly with STA 220 and provide engineering specific data collection and skills related to the collection and manipulation of data used in statistical modeling work. Labs in EGR 220 are coordinated to topically match with material covered earlier in the week in STA 220. Therefore, it is essential that the planning and coordination of the STA220 and EGR220 courses are done jointly and collaboratively. The student receives a separate grade in each course.

STA 220 CONTENT

STA 220 is a course in statistics using modeling as the unifying framework upon which to build understanding of applied statistical analysis. The focus is on hands-on work with real and simulated data. Topics include descriptive statistics, probability, data management and statistical modeling and inference. The objectives of STA 220 are that the student should be able to:

- manage and describe data with appropriate graphical and numerical summaries;
- demonstrate a basic understanding of probability theory;
- utilize standard probability distributions to compute likelihoods;
- develop an appropriate statistical model for data;
- interpret/statistically analyze data obtained in scientific and engineering contexts;
- utilize statistical software to aid in the analysis of data; and,
- convey statistical results in writing.

Calculus I is a necessary prerequisite for this course to assure students have the quantitative literacy required for understanding relationships fundamental to statistical models. In addition, the basic calculus concepts of differentiation and integration are utilized when covering basic probability theory associated with continuous random variables. The statistical freeware *R* (The R Project, n.d.), a language and environment for statistical computing and graphics, is used for data analysis. An overview of the topics covered in the STA 220 course is provided in Table 2.

A variety of methods are used to assess the performance of the students in STA 220. More specifically, throughout the semester evaluation methods include:

- Homework: Students have a homework assignment each week.
- Quizzes: Periodically, a quiz is given in lieu of collecting homework.
- Exams: Two exams and a cumulative final are given.

EGR 220 CONTENT

The goals and objectives of the EGR 220 are that the student should be able to:

- demonstrate a basic understanding and skills in using concepts, methods, and techniques for making common measurements needed in engineering;
- demonstrate a basic understanding of conducting engineering experiments;
- manage and describe graphically, and with appropriate summary statistics, data obtained in scientific and engineering contexts;
- develop appropriate statistical models for data obtained in scientific/engineering contexts;

Table 2: Overview of Contents of STA 220 Lecture Course

Week	Handout Title	Content / Topics
1	Data Displays	Samples vs. Populations Types of Variables/Data Graphical Summaries for Quantitative Data (histograms, box and whisker plots, runs charts)
2	Descriptive Statistics & Scatterplots for Quantitative Data	Descriptive Statistics (measures of center and variation) Accuracy and Precision Propagation of Uncertainty
3	Scientific/Engineering Method and Data Collection	The Scientific/Engineering Method Methods for Collecting Data Six-Sigma Approach (DMAIC) to Problem Solving Principles of Experimental Design and Randomization
4	Linear Regression Analysis	Principles of Least-Squares Interpretation of Slope and Coefficient of Determination Examination of Residuals for Model Adequacy
5	Modeling Random Behavior (Part I)	Random Variables (RVs) Probability Density Functions for Continuous RVs Cumulative Distribution Function for Continuous RVs Expected Value (Mean), Variance, and Standard Deviation of a Continuous RV
6	Modeling Random Behavior (Part II)	The Normal (Gaussian) Distribution Probabilities for the Normal Distribution The Exponential Distribution and Probabilities The Weibull Distribution and Probabilities
7	Random Behavior of Means	The Central Limit Theorem Probabilities for the Sampling Distribution of the Mean
8	Estimation and Confidence Intervals	Confidence interval for μ (population mean) Confidence interval for μ_d (paired differences) Confidence interval for μ_1-μ_2 (difference of two means)
9	Inference for Population Means (Part I)	Steps for Hypothesis Testing Hypothesis testing for μ (population mean)
10	Inference for Means Two Samples	Hypothesis testing for μ_d (paired differences) Hypothesis testing for μ_1 and μ_2 (two population means)
11		Extra week in the schedule for catch-up
12	Inference for Means Three or More Samples	One-Way Analysis of Variance (ANOVA) The ANOVA table and F test
13	Control Charts	Shewhart Control Charts, Estimating Control Charts for X-bar and R Processes “in-control” and determining if there is an indication that the process is “out-of-control”
14	Discrete Random Variables	Probability Density Functions for Discrete RVs Cumulative Distribution Function for Discrete RVs Binomial Distribution and Probabilities, Geometric Distribution and Probabilities Poisson Distribution and Probabilities

- interpret statistical analysis for data obtained in scientific and engineering contexts;
- write technical reports of various forms to communicate information obtained from scientific and engineering experiments; and,
- prepare and give technical oral presentations.

The statistical and data analysis content of EGR 220 includes descriptive statistics, graphical representation of the data and data summarization, introduction to probability, distributions, inferential statistics including creation of confidence intervals and use of hypothesis tests, introduction to statistical process control, gage reproducibility and repeatability analysis, and propagation of uncertainty in calculations using measurements. Engineering concepts that are introduced, to apply the statistical and data analysis concepts, range from analyzing basic circuits to investigating engineering stress. Tests and experiments are conducted that introduce the student to instruments and tools such as calipers, micrometers, digital multi-meters, mass balances, and tensile testers. As with the other foundation courses in the first two years of the curriculum, pre-engineering students from all five degree programs are co-mingled in the course.

The EGR 220 course has some challenges because a number of foundational concepts are introduced in this course including data analysis/statistics applied to engineering concepts, engineering measurements and proper data reporting, conducting engineering tests and developing testing procedures, technical writing, and formal presentations. This is presented within the constraints of a 1-credit, laboratory-based course that meets once per week. Depth of coverage of all topics is sacrificed for the goal of using introductory experiences to provide a foundation for subsequent courses in the curriculum.

Calculus I is a prerequisite for EGR 220 to assure that students have the necessary background to work with introductory engineering concepts that require the knowledge of differentiation, such as propagation of uncertainty in calculations made with measured variables. A university-wide, required, introductory writing course is also a prerequisite for the course; the writing course may be taken concurrently with EGR 220.

The EGR 220 lab provides engineering applications that allow students to measure and analyze parts/assemblies/signals/etc. using the statistical concepts/tools discussed in lecture (STA 220). This provides context for the statistical concepts and helps students connect the importance of statistics to the engineering process. Students are taught to use various computer tools, with a concentration in the lab on use of Excel as a data storage and summarization tool. The statistical freeware *R* (The R Project, n.d.), a language and environment for statistical computing and graphics, is used for data analysis and is taught in the STA 220 lecture course.

An overview of the topics covered in the EGR 220 course is provided in Table 3. These topics are reinforced through the introduction of various introductory engineering concepts and topics, using tests and experimentation to collect data with the use of various types of measurement tools. The first five weeks of the course are focused on creating projectiles using a mold-process, and then performing various tests with the projectiles including shooting them out of an air-powered launcher both at a target to test for accuracy and precision, and to maximum flight distance.

EGR 220 is structured as a three hour lab that meets one time per week. There is no separate text book for the course – students use the text from the STA 220 course. The Blackboard

Table 3: Overview of Contents of EGR 220 Lab Course

Week	Lab Title	Content / Topics
1	Product and Process Variability: Production of Projectiles	Summary statistics (centrality and spread of data) and graphical representation of data (run charts, scatterplots) Formal report writing
2	Product and Process Variability: Shooting Projectile at a Target	Accuracy and precision Graphical representation of data (histograms, box and whisker plots) Formal report writing
3	Product and Process Variability: Projectile Design Analysis and Re-design	Experiment/test design Product design analysis Formal report writing
4	Shooting Projectile for Distance with Cost Analysis	Experiment/test design Cost analysis
5	Propagation of Uncertainty: Calculation of Volume of a Projectile	Propagation of uncertainty Memo report writing
6	Gage R&R	Measurement system analysis (reproducibility, repeatability)
7	Resistor Resistance Measurement	Normal distributions Probability concepts
8	Presentation on project topics	Formal technical presentations Application of course content to personal interests for course projects
9	Electrical Circuit Design and Analysis	Comparison of theoretical values to measured data
10	Obtaining Stress Data using Instron	Data collection with Instron
11	Stress Data Analysis using Confidence Intervals and Hypothesis Tests	Confidence intervals Hypothesis testing
12	Project Work	Project work time Independent research and proper documentation of sources
13	Control Charts	Statistical process control
14	Final Project Presentations	Culminating assessment of course objectives based on individual or team projects

(Blackboard, n.d.) online course management system is used extensively for posting engineering-related materials and readings, weekly lab procedures, and reference materials for technical writing and presentations. Evaluation methods consist of graded laboratory reports (formal and memo reports) – 65% of the course grade, presentation (including the final project) – 25% of the course grade, and weekly quizzes – 10% of the course grade.

The final project and presentation is intended to provide students with an opportunity to demonstrate understanding and mastery of the course objectives by applying knowledge obtained to a topic of interest to each student. Students are expected to deliver presentations on the topics from a perspective of teaching the topic to classmates. Students are asked to select a topic that makes the assignment personally interesting to investigate. Ultimately, the assignment should advance the student's understanding of the topic, along with the understanding of those who are hearing the presentation. The scope of topics that can be proposed is purposely open-ended to allow freedom in selection of what to present. Students must conduct their own tests and generate their own data. Students are expected to research background information for their topics and provide documentation in the presentation (in the form of a References slide at the end of their presentation slides) to support the content. Finally, students are required to use inferential statistics as part of the data analysis during the presentation. Broad topic areas for the projects have included arms and ammunition, automotive, aviation, electronics, energy, environment, manufacturing, modeling, physiology, robotics, sports, and testing and materials. Examples of presentation titles include:

- Feasibility of photovoltaic panel installation;
- True randomness: An analysis of potential biases in random number generators;
- Ionizing blow-off fan cleaning schedule analysis;
- Analysis of methods for counting brass forgings and fittings for customer shipping;
- Internet speed data analysis;
- Analysis of temperature effects on capacitance; and,
- Photo-electric distance sensors: Fluctuation due to differing surface colors

Assessment of ABET Outcomes

The EGR 220 course is designated as a key course for assessing three ABET student learning outcomes:

outcome (b) – design of experiments and data analysis
outcome (g) – verbal and written communication,
outcome (i) – ability to engage in lifelong learning.

Following are summaries of the winter 2012 semester assessment for each of the outcomes. In all cases, rubrics were used for assessment, which are available from the authors if interested. For each assessment, the number of presentations, projects and papers assessed was based on the amount of complete information available from instructors after the course. Some instructors did not retain final submissions from students. Future assessment activities will require that instructors from all sections retain student work for assessment purposes.

ABET Student Learning Outcome (b)

Student learning outcome (b) states that graduates have an ability to design and conduct experiments. To assess this outcome, the EGR 220 final project, consisting of topic selection, development of a test procedure, collection of data, appropriate analysis of data, and conclusions, was used as the measure. There were 33 out of 120 total student projects assessed, including students from three of the eight lab sections. The mean score on the projects using a grading rubric was 85.4 out of 100.0. The target score was 75.0 out of 100.0. The scores on the final project related to the test procedure development, data collection, data analysis and conclusions were good for a first-year course. Students were able to demonstrate the ability to develop an appropriate test procedure that generated good data. Students were also able to analyze the data appropriately to make sense of it. After evaluation of the assessment results, no further action was warranted related to the course project or this outcome.

The second part of student learning outcome (b) states that graduates have an ability to analyze and interpret data. To assess this outcome, the final, comprehensive quiz for the semester was used as the measure. There were 114 total quizzes assessed, including students from all eight lab sections. The mean score on the quizzes was 6.64 out of 10.0, with a target score of 7.00 out of 10.0. The scores on the final comprehensive quiz were lower than the target. In particular students performed below target-level on the probability and inferential statistics questions. After evaluation of the assessment results, it was proposed that more attention be given to probability and inferential statistics components in both the STA 220 course and the EGR 220 course. Additional instruction should be included in these areas and additional assessment of students' knowledge should be conducted in the fall 2013 course offerings.

ABET Student Learning Outcome (g)

Student learning outcome (g) states that graduates have an ability to communicate effectively. This was assessed for both verbal communication and written communication. To assess verbal communication, the presentation given on the end-of-semester project was used as the measure. The project was a self-motivated activity that involved developing a test plan for collecting measurement data, conducting the test, and analyzing the data to make appropriate conclusions. The presentation was to review all components of the project. Assessment consisted of both content, format and speaking style/mechanics. There were 34 out of 120 total student presentations assessed, originating from three of the eight lab sections. The mean score for the final project presentation using a scoring rubric was 88.4 out of 100.0, with a target of 75.0 out of 100.0. The scores on the presentation for the final project were good for first-year students. Students were able to incorporate all of the essential components of a good presentation, and the presentation style was good (voice, eye contact, posture, etc.). This was the second presentation students conducted in the semester and there was noticeable improvement from the first to the second presentation. After evaluation of the assessment results, no further action was warranted related to this outcome.

To assess written communication, the full formal laboratory report written as the final report for the course was used as the measure. The laboratory was an analysis of data from a study on ultimate tensile strength of several metal specimens. The formal report consisted of an executive summary, introduction, apparatus, procedure, results and discussion, conclusion, and appendices. Assessment consisted of both content and format/writing mechanics using a scoring rubric. There were 68 out of 120 total student reports assessed, representing enrollment from five of the eight lab sections. The mean score of the reports, using a scoring rubric, was 82.6 out of 100.0, with a target of 75.0 out of 100.0. The scores on the final report were adequate for first-year students, and on average met the target. Students were able to develop appropriate content for each of the expected sections of the report. The style, structure, and mechanics of the writing and presentation within the report were improved from the start of the course and were adequate for freshman by the end of the semester. After evaluation of the assessment results, no further action was warranted related to the course project or this outcome.

ABET Student Learning Outcome (i)
Student learning outcome (i) states that graduates have recognition of the need for, and an ability to engage in life-long learning. The measure used for this outcome was assessment of the presentation slides for the final course project. The specific focus of the assessment was students' use of appropriate outside resources, properly documented, to support the student-initiated project. The ability to use outside resources to supplement and/or corroborate the student's tests is a skill consistent with demonstration of lifelong learning activities. There were 110 total student presentation slides assessed for this outcome (all that were submitted), including samples from all eight lab sections. The mean score, using a scoring rubric, was 4.66 out of 9.00, with a target of 6.50 out of 9.00.

The scores on this component of the final course project were below target level. It was possible that this component of the project was not emphasized appropriately in all lab sections by all instructors because in a couple of lab sections several students scored zero points and did not attempt to include any outside resources. Looking more closely at the sub-scores of the assessment, scores were lowest in the area of identifying good, appropriate resources, followed by using the resources to effectively support the presentation. Between 30 and 60 minutes of one lab meeting was dedicated to discussing appropriate use of outside resources to support students' tests/studies. In one half of the lab sections, these discussions were led by the lab instructor, and in the other half of the lab sections, the discussions were led by the university library liaison. There was no significant difference between scores by students in sections in which the instructor or librarian led the discussion. Students were also provided in advance with the rubric used for scoring this assessment, so students were aware of what would be assessed. However, only about 10% of the final grade for the project presentation was awarded to this component.

After review of the assessment materials, it was proposed that more instruction and focus be given to identifying and effectively using outside resources. Additional instruction should be included in these areas and additional assessment of students' knowledge should be conducted. Also, more weight could be given to this component in the final presentation grade in order to convince students to focus on it more. These actions should be taken in the fall 2013 offering of the courses.

Conclusions and Future Directions

Two co-requisite courses, one lecture and one laboratory, focused on introductory probability and statistics, and engineering measurement, were developed as required courses for the first year in the engineering degree programs at GVSU. Having dedicated, required statistics courses in an engineering curriculum is becoming less common for programs, particularly those not required to have a statistics course by ABET criteria. One unique feature of the courses is that they were jointly developed between faculty of the Statistics Department and the SOE. The lecture course, taught by statistics faculty, and the laboratory, taught by engineering faculty, are jointly planned and coordinated each semester. Also, unlike many programs that do offer a statistics course for engineers, the EGR 220 course provides hands-on, interactive labs that focus on application of engineering measurement techniques, data collection, and data analysis (including statistical analysis). Finally, assessments of student learning outcomes (b), (g), and (i) in the EGR 220 course have been largely positive and indicate that students, at an introductory level, are achieving outcomes at or near target levels.

In the future, the EGR 220 course could have students gradually build and assemble a multi-component electro-mechanical device over the full semester. The functionality of the product should invigorate self-motivation in the students, and require significant measurements in the intermediate stages thus providing opportunity for statistical analysis. This will provide even deeper context for the statistical concepts and help students connect the importance of statistics to engineering processes. The culmination of the lab will be student-identified tests/analyses of the products that incorporate concepts learned throughout the course. The student will write a formal culminating lab report, and make a formal presentation summarizing the tests/analyses and results.

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