AC 2007-1134: USE OF A SUPPLEMENTAL ABET ASSESSMENT DOCUMENT TO IMPROVE CAPSTONE DESIGN COURSES

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Use of a Supplemental ABET Assessment Document to Improve Capstone Design Courses

Abstract

In an effort to demonstrate attainment of ABET Criteria 3a – 3k[1] in a 2000 ABET accreditation review, the Colorado School of Mines' Petroleum Engineering (PE) Department developed a supplemental assessment document that provided a "road map" for assessment preparation and demonstration. This supplemental document was not intended to replace the departmental self-study in any way but rather provided the ABET reviewers with a very detailed outline of how the department met the various assessment criteria associated with the specific program objectives. The development of this document was the subject of a 2006 ASEE Annual Conference paper.[2] The conclusions from that 2006 paper are:

> "In an effort to demonstrate attainment of the Criterion 3 assessment criteria outlined in the departmental self-study, the CSM Petroleum Engineering Department has developed a supplemental assessment document that provides a "road map" for the assessment preparation and demonstration. This supplemental document is not intended to replace the self-study in any way but rather provides the ABET reviewers with a very detailed outline of how the department meets the various assessment criteria associated with the specific program objectives. The department's capstone design class is a critical component that aids in showing the interaction between the program objectives, the various data sources, and the associated outcomes. The supplemental document was well received by the ABET reviewers during the last ABET review in 2000, which has encouraged the PE Department to continue with this practice in future review cycles."

This current paper describes a second iteration of the supplemental document prepared for a 2006 ABET accreditation review and provides a description of improvements to the assessment process between the 2000 and 2006 iterations. A demonstration of how the "loop was closed" between document iterations is provided, such as a better understanding of the statistical significance of various data sources. Specific strengths and weaknesses of the program were identified in the assessment document. These strengths and weaknesses had been noted in the capstone design course, but until this supplemental assessment document, it had been unclear where the gaps were occurring in pre-requisite courses.

In addition to documenting the fulfillment of ABET Criteria 3a – 3k, the second document provided some unintended consequences and benefits to the overall PE program. It actually helped to identify disconnects in the current curriculum and was very beneficial in helping the faculty document and correct these gaps, as well as, understand how their courses fed into the senior capstone design. It also generated considerable faculty involvement in the overall assessment process and has become a developmental tool for new faculty. Finally, these

supplemental documents have aided in assuring that the pre-requisite courses are meeting the needs of the capstone design course and that all program faculty are involved.

Introduction

In 2000, when the Colorado School of Mines (CSM) underwent its first accreditation cycle under the ABET 2000 Criteria, there was serious concern by both the school in general and the Petroleum Engineering (PE) Program specifically regarding the ability to demonstrate fulfillment of the Criterion 3 Program Outcomes and Assessment Criteria 3a through 3k.[1] At that time, the ABET 2000 Criteria was very new and few institutions had undergone accreditation under those circumstances. In an effort to successfully obtain accreditation and to demonstrate the successful fulfillment of these criteria, a supplement to the ABET Self-Study Report was created and entitled "Petroleum Engineering Program Assessment Report Supplement to ABET Self-Study Report, Colorado School of Mines." The main purpose of this supplemental document was to provide a "road map" to the documentation process.

In 2006, the development of this document and its impact on capstone design and the overall accreditation process was presented at the American Society for Engineering Education (ASEE) Annual Conference and Exhibition in Chicago, Illinois.[2] This current paper is a follow-up to that initial publication after a second ABET accreditation cycle was incorporated. This paper presents an overview of the document itself, shows how the assessment process was improved between the 2000 and 2006 iterations, demonstrates how the "loop was closed" between the 2000 and 2006 assessment, and finally provides a discussion of how the document has enhanced the program's overall self-study and ABET visits and reviews.

ABET Criterion 3

Although most readers are likely familiar with the ABET Criterion 3 components, it would be prudent to provide a brief overview of them at this time for reference purposes.

The Criterion 3 components are:[1]

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Initial Supplemental Document Development

In 2000, the initial supplemental document had four main components including: 1) program assessment results with a section for each of the Criteria 3a – 3k that included the data sources, the methods used to analyze the data, and the results of the analysis; 2) various cross-referenced tables that listed the program assessment objectives and outcomes and the available data evidence; 3) documentation of faculty meetings regarding ABET preparedness; and 4) assessment rubrics and questionnaires. For each of the eleven individual 3a – 3k criteria sections, the specific interview and survey questions developed for that particular criteria were provided along with verbatim answers and summaries of the answers. Additionally graphs, which showed the rubric assessment results, were provided. Figure 1 shows an example of the provided graphs. In general, the supplemental document was intended to show how the raw data was gathered, organized, and pulled together to verify what was claimed in the self study report.

Several concerns with the first iteration of the document arose at the time of development in 2000, including statistically significant data had been generated to verify the claims of Criterion 3 fulfillment. Also, there were some concerns about the acceptance of the document by the ABET reviewers. This second concern was alleviated during the 2000 ABET review when the document was very well-received by both the departmental and the school reviewers. The first concern about statistically verification was not completely addressed until the document's second iteration in 2006. This issue is discussed in the following section.

Although it was developed to address all eleven Criterion 3 criteria, the first document iteration definitely had a focus on the multidisciplinary senior capstone design class and the criteria that it specifically was responsible for meeting. It was (and is) felt that this course was the main component that links the curriculum together, and, therefore, it was also the linchpin of verifying fulfillment of the various criteria.

The first document also focused on certain curriculum issues that were present at the time in 2000. Several of the survey and interview questions used for all data sources (students, alumni, industry recruiters, etc.) reflected concerns about certain classes, course sequences, and overall curriculum flow. Although not intended as such, this document provided a history of these issues for new faculty to review and become familiar with history of curriculum development and relation of course sequencing and connectivity.

Second Generation Supplemental Document Development

Based on the success of the first document, a second iteration was prepared for the 2006 ABET accreditation review. The second iteration was developed to fill any holes that were discovered in the 2000 assessment and build on the insight that was provided in that initial document. Also, since the first document was so helpful (inadvertently so) in showing gaps in the curriculum and issues between curriculum continuation, the second document and its associated interview questions and surveys were developed to help in identifying these problems. Data sources include rubric assessments, student interviews by an independent professional, peer evaluations, and end-of-course surveys.

The development of the case for Criterion 3a shows one of the modifications to the second iteration which was the inclusion of significantly more data for statistical verification of results. This additional data was made possible by faculty involvement from the entire PE staff and senior graduate students. Additionally, a more detailed breakout of the rubric analysis was generated to determine specific strengths and weaknesses that needed improvement. Table 1 shows the rubric used to review the homework and laboratory assignments reviewed for Criterion 3a. Figure 1 shows the results from 2000, and Figure 2 shows the results from 2006. In 2000, only 23 data points (rubric analyses) were used, but in 2006, that number was increased to 182 data points. There is also a noticeable shift in the results between Figures 1 and 2. Figure 1 indicated that several of the results fell into the "Needs Improvement" category, whereas, there is a noticeable shift of the 2006 results in Figure 2 to the categories of "Meets or Exceeds Expectations". The shift into these more desirable categories in 2006 may be due to a conscientious focus on enhancing the Criterion 3a by the departmental and school faculty or it may simply be the inclusion of a more statistically significant number of results. Either way, there is now a trend developed which can be tracked and modified as needed.

Improvements Made

One concern about including additional data analysis in the second document iteration was the necessary manpower to provide the numerous rubric reviews of homework, laboratory, etc, assignments. In the case of the 2006 assessment, all faculty in the department participated in various rubric reviews. Each assignment that was assessed with a rubric received three independent faculty reviews. Although this additional duty is obviously a concern to all faculty, which already have tremendous draws on their time, it was in actually not a large time consumer for the majority of the faculty members in this particular situation. In fact, this assessment practice had some unintended, but very beneficial, consequences. The assignments reviewed by each faculty member were either from courses that were pre-requisites for their own current courses or were for courses that their current courses would feed into. This allowed the entire faculty to get an idea of what was being taught in other courses, where gaps or overlaps between curriculums were present, and how the overall flow of the undergraduate curriculum was progressing. This process has lead to some changes in various courses, which in turn have led to major curricular improvements.

A second improvement with the second iteration was the breakdown and analysis of individual rubric categories for review. Table 2 shows the rubric used for oral communication portion of ABET Criterion 3g. Figure 3 shows the results of the overall analysis of 1353 data points. As can be seen in Figure 3, a large percentage of the reviewed oral presentations met expectations. Figure 4 then presents a breakdown of the individual categories measured with the rubric (bulleted in rubric, Table 2). As can be seen in Figure 4, the focus of the presentation (second category) and the eye contact by the presenter (sixth category) are the weaker components of the reviewed oral presentations.

A third improvement showed that experience with the interview questions from the first document allowed improved design of questions for the second document. Specifically, these questions were capable of focusing in on student-perceived, but unproven, gaps in the overall

departmental curriculum. The questions that were modified and added were mainly focused on the senior capstone design course and are addressed in the following section.

Overall, the second 2006 document iteration allowed for "closing the loop" on areas identified for improvement from the 2000 document. These improvements included: 1) inclusion of significantly more data for statistical verification; 2) breakdown and analysis of individual rubric categories; and 3) improved design of interview questions. It also helped to identify areas for improvement of the overall program, which will be addressed in the third iteration in 2012. Even without the need for satisfaction of ABET review criteria, the document provides a powerful overview of departmental curriculum and its flow and interaction.

Integration of Results Into Senior Capstone Design Courses

In the CSM Petroleum Engineering Department, the senior capstone design course (PE 439) is a one-semester multidisciplinary course taught in conjunction with CSM's Geophysical Engineering and Geology and Geological Engineering Departments.[3-5] Data for this course and associated ABET criteria, specifically 3d and 3g, is collected from four sources including rubric assessments for oral and written communication (Tables 2 and 3), student interviews by an independent professional, peer evaluations, and end-of-course surveys. The peer evaluations demonstrate statistically significant increases in team skills over semester-long periods.[6-8]

An example concern regarding the senior capstone course was the flow of an economical pre-requisite course into the capstone course. Therefore, one interview question was designed to address this concern as follows:

> *From your perspective, were you prepared to handle the economics and statistics required in PE 439? If not, why not and what could be improved? Did you have all the prerequisites for taking PE 439?*

The resulting answers to this question did show a disconnect between these critical pre-requisite topics and the senior capstone design course, which was damaging the effectiveness of the capstone course. Due to the documentation in this assessment documents, the involved faculty was made aware of the problem, and it has since been corrected. These corrections included discussions between all involved faculty, which led to mini-tutorials provided by the capstone course faculty to the economics class to develop and show connections between the courses.

Another benefit of the document was the summation of alumni surveys. Figures 5 and 6 show the results of alumni surveys when asked how much time they spend working in team settings (Figure 5) and how much time they spend working in multidisciplinary team settings (Figure 6). These results are shown to the students in the class to help demonstrate the importance of team skills and the ability to work with a team. In the assessment document, these alumni results are coupled together with student interviews questions such as *"What do you feel are some of the benefits of working on a multidisciplinary team?"* and *"What do you feel are some of the challenges of working on a multidisciplinary team?"* to help demonstrate fulfillment of such criteria as 3g and 3i.

Results from the summation of different data sources in the assessment document showed a large missing link in the area of communication (Criteria 3g), specifically in team presentations. A combination of the results from assessment rubrics and interviews indicated that the students were not receiving appropriate instruction in team presentations, which are a large part of the senior capstone curriculum. Through the assessment document, all pertinent faculty members were made aware of this gap, and it is now being addressed across the Petroleum Engineering Program curriculum. It should be noted that these gaps were not due to individual faculty gaps or intentional errors, but rather due to lack of communication of the faculty as a whole in discussing how their courses relate and interlink to the capstone course and overall program objectives. None of the faculty members took offense at this, as it helped with overall course sequencing and connections that benefited their individual courses.

Similarly, some gaps in the technical report writing of Criterion 3g were also identified including insufficient support for conclusions, lack of documentation and referencing, and failure to link figures and tables to text. The rubric for this criterion is shown in Table 3 and the results of the analysis in Figure 7 (based on 2766 data points). Once again, these discrepancies were made known to the entire faculty through the assessment document. The department faculty discussed this issue and arrived at the idea of developing a universal technical writing guide that will put emphasis on these weak areas, as well as, address team writing components. This guide will be distributed in all PE writing intensive courses which will result in emphasizing these issues in the sophomore, junior, and senior years. How well this guide works will be a focus of the 2012 version of the assessment document. Additionally, group writing, which is a focus in the capstone course, will be specifically discussed in future classes and references distributed.[9]

Conclusions

This paper describes a second iteration of a supplemental document that aids in the assessment and documentation of ABET Criteria 3a – 3k. The preparation of this document provided several benefits to the PE Program including:

- Involvement of faculty in evaluating assessment rubrics aided in their individual understanding of how their courses feed into the senior capstone design course.
- Involvement of faculty in evaluating rubrics aided in an overall assessment of the flow and connections of the PE curriculum which led to improvements.
- Faculty feedback improved the rubrics and made them more relevant to our assessment criteria.
- Student interviews identified perceived weaknesses in certain classes which led to improvements to those classes, including mini-tutorials for subjects critical to the senior capstone design course.
- A better understanding of statistical needs (number of data points) between the 2000 and 2006 document iterations was developed.
- The assessment document showed weaknesses in team presentation and writing skills, which are critical to the senior capstone design, therefore, steps will be taken to remediate this issue.
- As with the first iteration in 2000, the 2006 ABET review team appreciated the supplemental assessment document and the “road map” it provided.

Overall, the supplemental assessment documents have generated considerable faculty involvement in the overall assessment process and have become a helpful developmental tool for new faculty. The PE Program will continue this assessment practice in preparation for the next ABET review in 2012.

Acknowledgements

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Table 1
Problem Solving/Design Skills Scoring Rubric

Problem Solving/Design Skills: Scoring Rubric for Petroleum Engineering Program

Objective	N/A	Needs improvement	Meets Expectations	Exceeds Expectations	Comments	ABET
3.3/3.4 and 5.1: Students will be able to demonstrate **problem solving skills** in engineering practice and working real world problems in written work and oral presentations:						
Apply Math, Engineering, and Science ▪ Use of equations, concepts, and theories	___	__ Does not effectively apply equations, concepts, or theories available to solve problem	__ Adequately applies equations, concepts, or theories available to solve problem	__ Effectively applies equations, concepts, or theories available to solve problem		**3(a)**
Identify Problem ▪ Identify problem and main objective, based on stated requirements	___	__ Inadequately identifies problem and objective	__ Adequately identifies problem and objective	__ Very clear identification of problem and objective		
Identify Information ▪ Identify basic information needed to solve the problem	___	__ Does not identify basic information needed to solve the problem	__ Adequately identifies basic information needed to solve the problem	__ Clearly identifies information needed to solve the problem		
Analyze Alternatives ▪ Analyze alternative interpretations or solutions	___	__ Does not analyze alternative interpretations or solutions	__ Adequately analyzes alternative interpretations or solutions	__ Analyzes multiple alternative interpretations or solutions		
Integration of Data ▪ Integration of data from multiple sources	___	__ Low level of integration of data and information from multiple sources	__ Moderate level of integration of data and information from multiple sources	__ High level of integration of data and information from multiple sources		**3(c) & 3(e)**
Interpretation ▪ Make interpretation of system based on information gathered ▪ Strong supporting arguments	___ ___	__ Uses very little of the information gathered to make an interpretation of system __ Lacks supporting arguments for interpretation	__ Uses some of the information gathered to make an interpretation of system __ Adequate supporting arguments for interpretation	__ Effectively uses the information gathered to make an interpretation of system __ Strong supporting arguments for interpretation		
Recommendations ▪ Recommendations/ conclusions based on interpretation of the system	___	__ Little evidence that the recommendations/ conclusions are based on interpretation of the system	__ Some evidence that the recommendations/ conclusions are based on interpretation of the system	__ Strong evidence that the recommendations/ conclusions are based on interpretation of the system		
Ability to Use Techniques ▪ Use of techniques, skills, and tools in engineering practice	___	__ Does not effectively use techniques, skills, or tools available to solve problem	__ Adequately uses techniques, skills, and tools available to solve problem	__ Effectively uses techniques, skills, and tools available to solve problem		**3(k)**

Table 2
Oral Presentations Scoring Rubric

Oral Presentations: Scoring Rubric for Petroleum Engineering Program

Objective	N/.A	Needs improvement	Meets Expectations	Exceeds Expectations	Comments	ABET
1.2a: Students will be able to demonstrate **effective communication skills** in oral presentations						
Quality of Content ♦ Audience awareness (interacts with audience: e.g., stepping toward audience and speaking to them, not at them) ♦ Focus: goal, evidence, conclusion (gives audience a road map and follows it) ♦ Transitions (phrases smoothly link one part to next) ♦ Use of visual aids (to tell the story and enhance the quality of the presentation)	___ ___ ___ ___	__ Does not interact with audience __ Does not give audience an adequate road map of goal, evidence and conclusion __ Abruptly transitions from one phase to the next __ Does not use visual aids effectively to tell the story; too much dependency on visual aids	__ Some interaction with audience __ Gives audience an adequate road map of goal, evidence, and conclusion __ Transitions are generally smooth __ Overall, uses visual aids effectively to tell the story; visual aids add to presentation	__ Interacts with audience throughout presentation __ Gives audience very clear road map of goal, evidence, and conclusion __ Very smooth transitions __ Uses visual aids very effectively to tell the story; visual aids enhance presentation		3(g)
Mechanics ♦ Body Position (e.g., facing audience or screen) ♦ Eye Contact (e.g., scanning entire audience) ♦ Body Movement (e.g., hand gestures, stepping back) ♦ Visual aids e.g., (clear, not too busy, readable size font) ♦ Delivery (e.g., fluency, pace, voice projection, um's, uh's)	___ ___ ___ ___ ___	Does not effectively use (e.g.'s): __ Body position (faces screen) __ Eye contact (not enough, looking down a lot) __ Body movement (lack of gestures, glued to overhead) __ Visual aids (too busy, blurry) __ Delivery (too fast, too many um's, not projecting voice, lack of enthusiasm)	Adequately uses (e.g.'s): __ Body position (faces audience most of the time) __ Eye contact (some scanning of audience, looking at people) __ Body movement (some hand gestures, steps back f/ OH) __ Visual aids (can read clearly, usually not too much material) __ Delivery (good pace, usually projects voice, some enthusiasm)	Very effectively uses (e.g.'s): __ Body position (always facing audience) __ Eye contact (excellent scanning, looking at people) __ Body movement (good use of hand gestures, steps back) __ Visual aids (clear, right amount on each slide) __ Delivery (excellent pace, projects voice, great enthusiasm)		
Questions ♦ Asks audience for questions ♦ Answers questions effectively and smoothly	___ ___	__ Does not ask for questions __ Does not answer questions adequately	__ Asks for questions __ Answers questions adequately	__ Effectively opens ("I'd be happy to answer questions") __ Answers questions effectively and smoothly		

Table 3
Writing Technical Reports Scoring Rubric

Writing Technical Reports: Scoring Rubric for Petroleum Engineering Program

Objective	N/.A	Needs improvement	Meets Expectations	Exceeds Expectations	Comments	ABET
1.2b: Students will be able to demonstrate **effective communication** skills in writing technical reports						
Purpose ▪ Focus (clearly states the objective, has a central focus, idea) ▪ Significance (shows an awareness of main ideas)	____ ____	__ Objective not clearly stated, paper lacks central focus __ Lack of awareness of main ideas	__ Objective adequately stated paper has central focus __ Some awareness of main ideas	__ Objective very clearly stated, paper has strong central focus __ Strong awareness of main ideas		
Organization ▪ Structure (structure or pattern of whole report is clear) ▪ Coherence (whole report is clear, tells coherent story) ▪ Paragraphing (transitions f/one idea to next) ▪ Tables/Figures (link to text)	____ ____ ____ ____	Loses reader: __ No clear structure or pattern __ Whole report lacks clarity; story lacks coherence overall __ Lack of or too many paragraph transitions __ Tables/Figures do not link to text	Guides reader: __ Adequate structure or pattern __ Whole report is clear; story is coherent overall __ Adequate paragraph transitions __ Most Tables/Figures link to text	Engages reader: __ Clear structure or pattern __ Whole report is very clear; story is very coherent __ Excellent paragraph transitions __ All Tables/Figures link to text		3(g)
Evidence ▪ Accuracy (statements) ▪ Support (opinions are adequately supported) ▪ Documentation (sources are identified and referenced appropriately in the body)	____ ____ ____	__ Inaccurate statements __ Lack of support for statements/opinions __ Sources are not identified and referenced appropriately in the body	__ Most statements are accurate __ Adequate support for statements/opinions __ Most sources are identified and referenced appropriately in the body	__ Statements are very accurate __ Strong support for statements/opinions __ All sources are identified and referenced appropriately in the body		
Mechanics ▪ Sentence structure (grammar, sentence structure, spelling, punctuation) ▪ Appearance (Report, Figures/Tables/ References)	____ ____	__ Many errors in grammar, spelling, and/or punctuation __ Poor appearance of Report, Figures/Tables/ References	__ Few errors in grammar, spelling, and/or punctuation __ Acceptable appearance of Report, Figures/Tables/ References	__ Excellent grammar, spelling, and punctuation __ Excellent appearance of Report, Figures/Tables/ References		

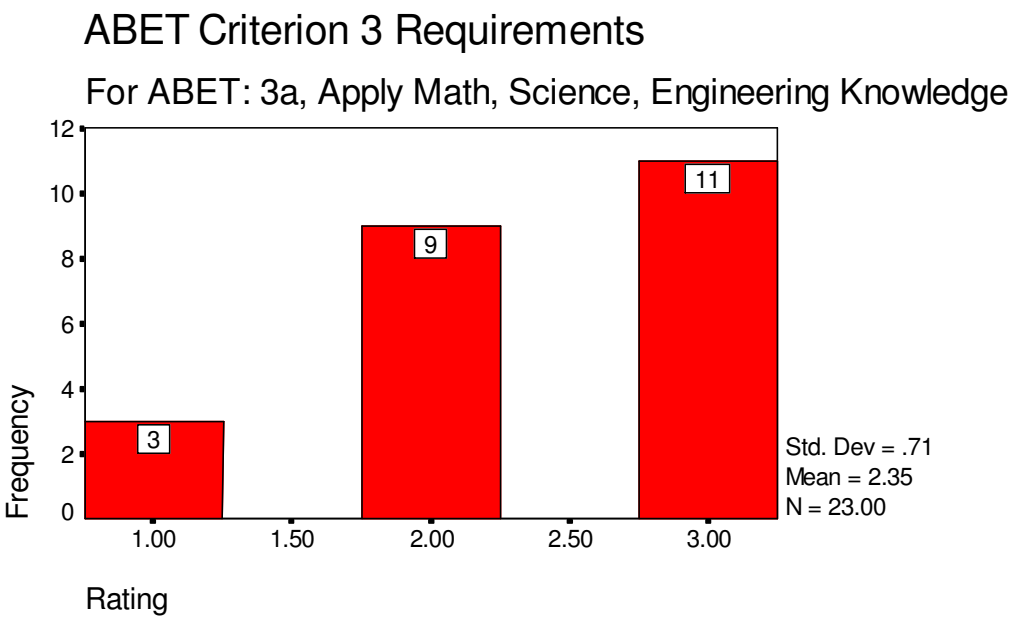

Figure 1: The results of rubric analysis (Table 1) for ABET Criteria 3a from the 2000 document. The rating categories equate to 1.00 = Needs Improvement, 2.00 = Meets Expectations, 3.00 = Exceeds Expectations. Note that 23 data points were used in this analysis.

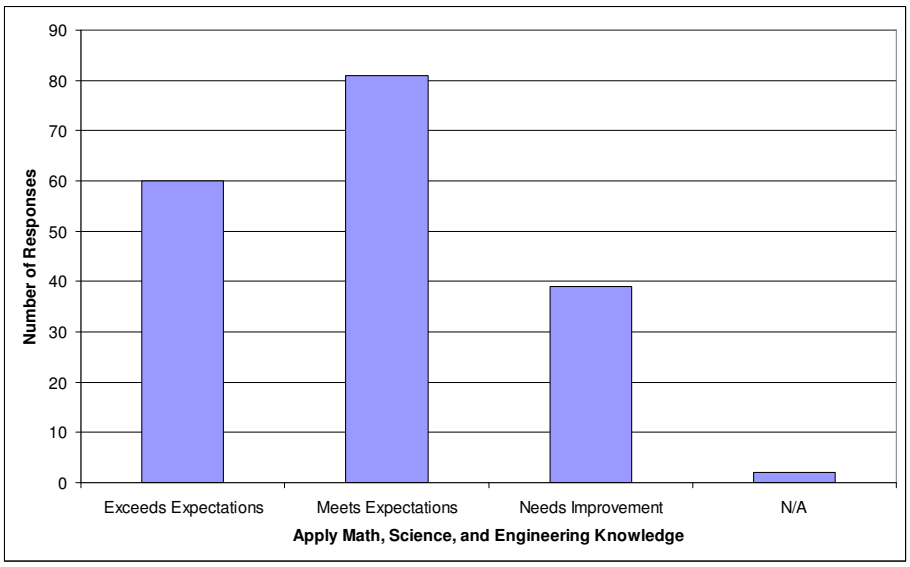

Figure 2: The results of rubric analysis (Table 1) for ABET Criteria 3a from the 2006 document. Note that 182 data points were used in this analysis.

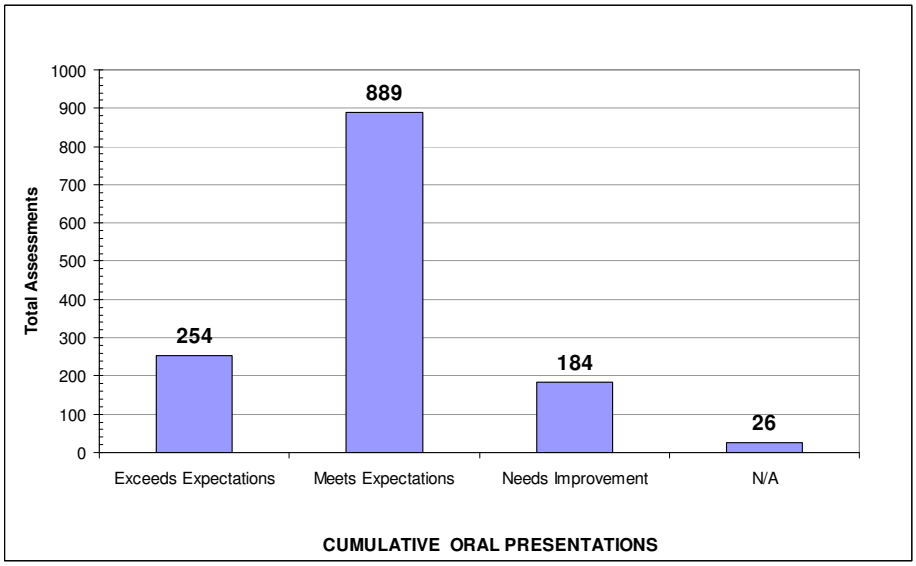

Figure 3: The results of overall rubric analysis (Table 2) for ABET Criteria 3g oral presentations.

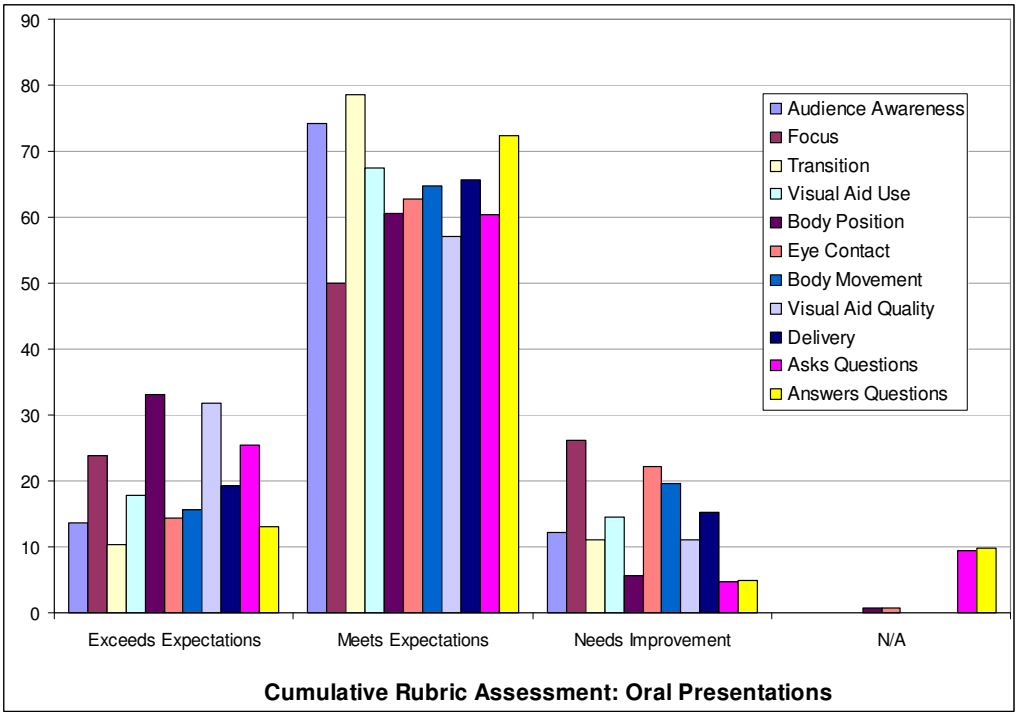

Figure 4: The results of the individual component breakdown for rubric analysis (Table 2) for ABET Criteria 3g oral presentations.

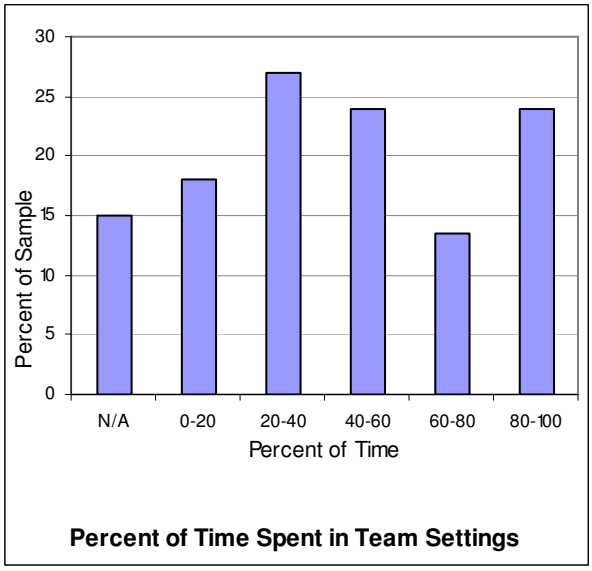

Figure 5: Alumni survey showing the amount of time spent in team settings.

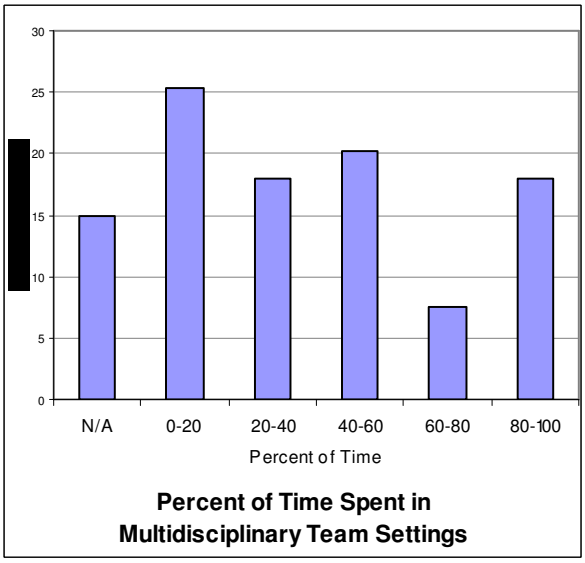

Figure 6: Alumni survey showing the amount of time spent in multidisciplinary team settings.

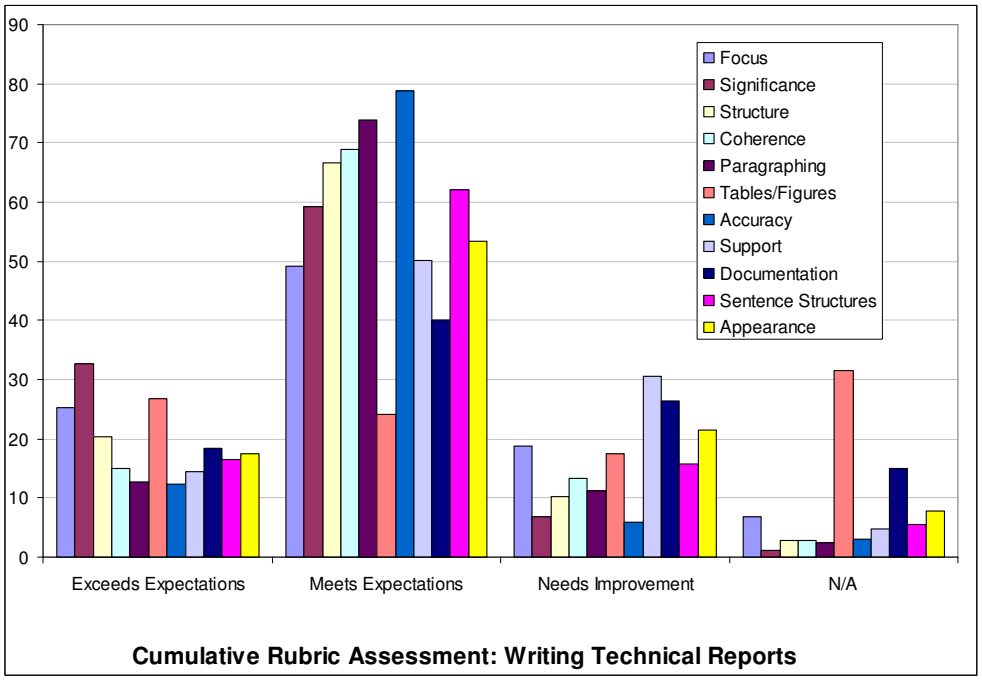

Figure 7: The results of the individual component breakdown for rubric analysis (Table 3) for ABET Criteria 3g written reports.