Use of MET Capstone Course RADDical Metric

Carlos Oncina, Craig Johnson

Central Washington University

Abstract
This research involves the application of an assessment metric to the first quarter of our capstone course with the purpose of improving both our student preparedness and our overall Mechanical Engineering Technology program. Observations of recent student performance on meeting the course outcomes of the design phase of our capstone course were below expectations. An assessment metric, referred to as RADD (Requirements, Analysis, Design, Drawings), was developed to quantify student performance. The acronym RADD reflects the traditional design process of proceeding from a function statement with requirements, to an analysis that in turn results in some design parameter that is then developed and documented in the form of a drawing of a device. Our experience showed that the student's proposals lacked some parts of this design process. The traditional metrics of grades and post-graduation employment were insufficient in assessing the MET program objectives and did not point to specific actions required to improve student performance.

The intention of creating and applying this metric is two-fold. First, it was used as a metric in our assessment process, reflecting our program and course outcomes. Second, it was implemented to change the course and improve performance.

First, there was value to the MET program in applying a metric such as RADD as part of a continuous improvement process. This aspect offered help in identifying areas for improvement in our pre-capstone courses. With the addition of further parameters to the current RADD metric, we intend to provide data-based feedback that will aid in the modification to pre-requisite course outcomes.

Second, the RADD metric was used to improve the course itself. Analysis of the course performance indicated that a significant shortfall was the ability of students to synthesize and apply their project information and technical skills into a cohesive product design proposal. For comparison, the metric was retroactively applied to the 2003 capstone course. Analysis of the 2004 course performance indicates that performance did not improve significantly based on the formative data gathered using RADD. As a result, the addition of the product design and development course was abandoned and further trials will be made using other methods.

"Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition

Introduction

Motivation for developing metrics embedded in a continuous quality improvement (CQI) process comes from both the inherent need (to improve any process) and from specific requirements in TAC/ABET [1]. Criterion 3 states the need for outcomes and metrics in a CQI process. Similar to work by Besterfield-Sacre [2] and Soundarajan [3], we recognize the need for incorporating assessment metrics into a CQI process for accreditation purposes. Criterion 4 describes 'Program Characteristics' that state the need for a capstone course. At Central Washington University (CWU) we designate this respective course as MET495.

A portfolio system, Livetext™ [4], for documenting our CQI efforts has recently been adopted by CWU. Though the TAC/ABET criteria are listed in its database, the metrics and templates must be developed to implement it. We are currently involved in developing the details on a course and program basis of the CQI system and how it will interface with our accreditation documentation

American Society for Engineering Education (ASEE) [5] provides a suitable forum for discussing and sharing innovative CQI strategies. We consider the development and use of metrics for capstone courses both relevant and necessary for the success of our MET Program. The implementation of CQI metrics is directly linked to research material published by the ASEE and to common industry practice.

The RADD Metric was developed to be simple, usable and valid. These are necessary characteristics for use in our CQI process. We are at the beginning of CQI development for CWU, and can provide feedback for at least the first two conditions.

Capstone Description

The MET495 capstone course was designed to assess the student's ability to apply their skills to an engineering project. It is a year-long effort, which follows a gated integrated product, process and development methodology over three quarters that includes product design, construction and evaluation. During this effort the student prepares a proposal (with an attendant preliminary design review, PDR) to address an engineering opportunity, develops a comprehensive design (with a critical design review, CDR, assessment), constructs the device, and evaluates the device (with a final report). We entertain both individual and team projects, but require each student to fulfill course outcomes.

The design phase includes the creation of a complete proposal. We rely on our technical writing course to provide basic skills to execute this task. We provide a format guide (Introduction, Method, Analysis, Discussion, Budget, Schedule, Conclusion, References, Appendices) and use the student's Schedule to gage progress during the rest of the capstone course.

Course outcomes reflect these artifacts (e.g. the proposal). They include:

The student should show their ability to:

- apply engineering analysis to project conception, definition, development and management by creating an engineering proposal.
- use their mechanical engineering skills, through design, construction, and evaluation of their project.
- communicate their progress and achievements through meetings, reports, and presentations.
- apply teamwork and organizational skills to promote progress, via documentation.

Only the first course outcome refers to the proposal directly, but evidence from all four outcomes will be contained in the proposal.

Senior projects are created to appropriately address particular course criteria. These criteria include:

- Technical Merit (discipline, depth, scope, size)
- Social (legal, cultural, humanitarian)
- Ethical (safety, morality, sustainability)
- Exceptional (external sponsor, published)

Some of the course criteria are addressed by all of the students (e.g. safety) and some are addressed by a subset of the students (e.g. published). It was desired that all the students address the 'depth' of technical merit to a minimum standard.

Method

The initial portion of MET495 concentrates on problem definition and project creation. This is a critical part of the capstone sequence that sets the tone for the rest of the year. Due to this importance, it was appropriate to create a metric to assess the ability of our student's performance. Further, since the capstone sequence is time-sensitive it was desired to have a metric that could be used in a 'formative' assessment process (during the quarter) that gives timely performance indicators as well as a 'summative' (after the quarter) assessment event that gives the MET program overall outcomes and assessment information. This would enable the metric to be used in-situ, and improve student performance.

The metric was developed in response to our desire for a minimum standard. The process of defining a problem and distilling an appropriate set of requirements is a necessary condition for a successful design process. We reviewed the recent literature and concluded that this concise metric was needed and constituted an innovative contribution.

We selected the term 'Requirements' as the first aspect of our metric.

The second necessary aspect was appropriate analysis. We wanted to see evidence that previous engineering skills were being used to quantify some critical parameter of the design. Thus we chose 'Analysis' as the second aspect of our metric.

The third aspect in our critique sequence was the design itself. It was important that a critical design parameter be optimized and used to improve the design of the device. Thus 'Design' was the third aspect of our metric.

Last, it was critical that the student communicate their intentions with the use of appropriate drawings. It is necessary that the critical design parameter be rendered in a drawing of the device. Thus 'Drawings' became the fourth, and last, aspect of our metric.

The complete metric included four aspects: Requirements, Analysis, Design, and Drawings (RADD). We chose to apply a simple ranking of existence to each one. If a student met the definition of that aspect, they received the point. Thus, a maximum of four points was possible for each assessment. This satisfied our intention that the metric be simple. Furthermore, it reduced the variability introduced by changes in instructional staff that using grades or further refined scores may have introduced. It was of equal importance to objectively measure whether the program was or was not preparing the students adequately in prior courses.

We also did not entertain the statistical analyses that Sorby [6] used (e.g. the 't-test'). Our pool of data is small and do not support that level of analysis. We also do not consider the issue of 'rater bias' describe by Woods [7] to be an issue. In our case, we assume that the RADD metric is simple to apply, and our limited pool of 'raters' will not result in any complications or corrupt data.

Unlike other current research, we proposed a quantitative assessment metric. Previous research by Griffith [8] used qualitative survey information to assess course and program outcomes. We also survey, as Griffith, with our Student Evaluation of Instruction (SEOIs). We found that SEOIs represent immediate behavioral responses not adequately tied to the ABET outcomes in question.

Results/Discussion

The MET program outcomes identify items that are uniquely met through the capstone course. These items are stated in the syllabus with their respective assessment means.

Student learning Outcomes

The student is expected to show their ability to: apply engineering analysis to project conception, definition, development and management. Use their mechanical engineering technology skills, through the design, construction, and evaluation of their project. Communicate their progress and achievements through meetings, reports, and presentations.

Course Work Breakdown Structure

The main deliverable of the 1st quarter's effort is a complete proposal. The work breakdown structure for the quarter as delineated by the syllabus is as follows: An introduction, a project scope, the analysis methods or processes used, drawings describing the device, a construction plan, a budget, an overall schedule, a list and description of sponsors, and references. Each of these items is reviewed and drafts are submitted by the students to monitor progress.

The RADD metric

As previously discussed the RADD metric is a minimum standard for students to demonstrate their ability to synthesize their coursework to date on an engineering project. The students are expected to achieve all of the RADD metrics. In addition, the metric serves to quantify and provide feedback to the program's ability to prepare the students.

The RADD metric was retroactively applied to the 2003 class in a summative manner and to the 2004 class both formatively and summatively. The results are shown in Table 1.

Table 1 MET 495A RADD Data															
	03 Summative					04 Formative					04 Summative				
Student	Reqmts R	Analysis A	Design D	Drawings D	Total	Reqmts R	Analysis A	Design D	Drawings D	Total	Reqmts R	Analysis A	Design D	Drawings D	Total
1	0	0	1	0	1	1	1	na	na	2	1	1	1	1	4
2	1	0	1	0	2	1	1	na	na	2	1	1	1	1	4
3	1	1	0	1	3	1	1	na	na	2	1	1	1	1	4
4	1	0	0	1	2	1	0	na	na	1	1	1	1	1	4
5	1	1	1	1	4	1	1	na	na	2	1	1	1	1	4
6	1	1	1	1	4	1	1	na	na	2	1	1	1	1	4
7	1	0	1	0	2	1	1	na	na	2	1	1	1	0	3
8	0	0	0	0	0	0	0	na	na	0	1	0	0	1	2
9	1	1	1	1	4	0	0	na	na	0	1	0	0	1	2
10	1	0	0	1	2	1	1	na	na	2	1	0	0	0	1
11	1	1	1	1	4	1	0	na	na	1	1	0	0	0	1
12	0	0	0	0	0	0	0	na	na	0	0	0	0	0	0
13						0	0	na	na	0	0	0	0	0	0
Count	9	5	7	7		9	7				11	7	7	8	
Average	0.75	0.42	0.58	0.58	2.33	0.69	0.54			1.23	0.85	0.54	0.54	0.62	2.54

Summative 2003

The class of 2003 had 12 students. Two of the students did not complete the course, but their results are still included as they do serve as an indicator of preparedness. Looking at the results 58% of the students were not meeting the analysis criteria and 42% were not meeting the design criteria for parametrically optimized designs. We interpreted this to indicate a lack of understanding of the product design and development process. While the students may have excelled at specific course outcomes previously, the application of analysis and design to self-directed activity was not readily apparent to all of the students.

Formative results for F 2004

The class of 2004 had 13 students. Part of the course entails submitting a preliminary proposal prior to the University's uncontested withdrawal deadline to ascertain the student's progress and to provide timely feedback. We chose to apply the first two metrics (Requirements and Analysis) from our metric at this point to provide early feedback to our process as well. The data in Table 1 for the formative part of the 2004 class indicates 45% did not meet the criteria for analysis. In addition, 30% did not meet the criteria for clear requirements. Summative results for F 2004

The results for the summative portion of the 2004 class are also indicated in Table 1. The requirements and analysis metrics were reapplied to the final submitted proposals and indicated slight improvements even after feedback was provided. The results show that 46% and 38% of the students were not at the minimum criteria for design and drawings, respectively. These results indicate no substantive changes over the previous year and are short of fully meeting the minimum outcome criteria.

Based on the 2003 RADD metric results the MET program decided to implement a pilot pre-capstone junior-level course covering product design and development for the students prior to their enrolling in 2004. Another option considered was to incorporate this subject matter into the existing capstone course. Post 2004 course assessment indicates that expansion of the capstone course may yield better results as it provides a better context to introduce the material. In addition to introducing new material to the course we will be increasing the course credits from two to three contact hours. As the course requires the students to build and test their projects it would have not allowed for sufficient time within the first quarter to both learn and apply the knowledge gained in synthesizing the student's previous core course outcomes with product development problems.

Conclusions

The introduction of CQI in the form of the RADD metric presented serves three main purposes. It formalizes the process for ABET/TAC program evaluation, provides feedback for the course, and for the program. The data thus collected can be quickly acted upon whether by enhancing course content or less traditionally but more effectively integrating design projects and collaborative learning opportunities as documented by Bjorklund, et al. [9] across the program. The immediate benefit of the use of this metric is that it has allowed us to step back from the capstone course itself and look at our program in its entirety. While a more detailed metric may aid in pinpointing the causes of the course or program that lead to the students performance described, it would also obfuscate the performance on key engineering capstone course outcomes. Our approach was to have simple-to-use run-chart type data as is frequently used in process control activities

Future

We intend apply the RADD metric concept to other courses within our program as a tool to benefit course content and delivery methods. In addition, we will extend the process control analogy by implementing elements of root-cause analysis in order to further identify process improvement opportunities at course and program levels.

Acknowledgements

Thanks to Central Washington University, its College of Education and Professional Studies, and the Department of Industrial & Engineering Technology for continued support of efforts in engineering education.

Bibliography

1. TAC/ABET 2004-2005 Criteria for Accrediting Engineering Technology Programs, 111 Market Place, Suite 1050, Baltiimore, MD.
2. Besterfield-Sacre, et al., 'Scoring Concept Maps: An Integrated Rubric for Assessing Engineering Education', ASEE Journal of Engineering Education, Vol.93, No.2, April, 2004.
3. Soundarajan, 'Preparing for Accreditation Under EC2000: An Experience Report', ASEE Journal of Engineering Education, Vol.91, No.1, January 2002.
4. LiveText™, http://college.livetext.com/college/index.html, 2004.
5. American Society for Engineering Education, www.asee.org, 2004.
6. Sorby, 'The Development and Assessment of a Course for Enhancing the 3-D Spatial Visualization Skills of First Year Engineering Students', ASEE Journal of Engineering Education, Vol.89, No.3, July, 2000.
7. Woods, 'Comparison of Two Quantitative Methods of Determining Rater Bias', ASEE Journal of Engineering Education, Vol.92, No.4, October, 2003.
8. Grifith, 'The Impact of Group Size and Project Duration on Capstone Design', ASEE Journal of Engineering Education, Vol.93, No.3, July, 2004.
9. Bjorklund, et al., 'Effects of Faculty Interaction and Feedback on Gains in Student Skills', ASEE Journal of Engineering Education, Vol.93, No.2, April, 2004.

CARLOS ONCINA
Carlos is an Assistant Professor of Mechanical Engineering Technology at Central Washington University. He coordinates the Manufacturing Specialization. He specializes in production technology (www.cwu.edu/~oncinac) and has a P.E. in Mechanical Engineering

CRAIG JOHNSON
Craig Johnson is the Coordinator of the Mechanical Engineering Technology Program at Central Wash. Univ. He is the Foundry Education Foundation Key Professor (www.cwu.edu/~cjohnson) and has a P.E. in Metallurgy. Dr. J. is the ASEE Materials Division Chair. He specializes in test design, interface characterization and process optimization (forming & casting).