Adopting a Means for Assessing an Engineering Graphics Body of Knowledge

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Abstract

A decision was made to begin administering the Association of Technology, Management, and Applied Engineering's Certified in Engineering Graphics certification exam for the purpose of assessing the effectiveness of a three-course series of engineering graphics core courses and as part of a means for assuring quality and fostering a culture of continuous and ongoing improvement. Based on the results of the first administration of the exam, it was concluded that a reexamination of that three-course series of courses needed to be undertaken. This conclusion was drawn based on the preparation of an assessment report, which included Actions Taken, Results, and an Analysis of Results, and preparation of an action plan designed to address weaknesses identified from the Analysis of Results.

Introduction

Three engineering graphics courses, whose content build upon one another and are taken sequentially, comprise the engineering graphics core of an undergraduate program whose mission is to prepare "individuals to apply technical skills to the management and creation of working drawings and computer simulations for a variety of applications. This shall include but will not be limited to instruction in specification interpretation, dimensioning techniques, drafting calculations, material estimation, technical communications, computer applications, and interpersonal communications". (National Center for Education Statistics, 2010, para. 3)

The program is reviewed annually using the scheme illustrated in Figure 1 (Chin, 2014), which is based on the four–step model advocated by the American Society for Quality or ASQ (n.d.) for carrying out change. The scheme suggests that "just as a circle has no end, the PDCA cycle should be repeated again and again for continuous improvement" (para. 2).

The program review includes (a) an examination of the curricular or pedagogical actions faculty took to improve student learning that are related to the respective Student Learning Outcomes (SLO), or the *Actions Taken*; (b) a look at the data collected from the Means of Assessment in terms of the Criterion for Success, or the *Results*; and (c) production of a summary of the relationship between Actions Taken by faculty to improve student learning and the Results and an explanation of the relationship, and based on a thorough analysis of the Results, and a

summary of what area faculty will target to improve or reinforce, or the *Analysis of Results*. In addition, *Actions Planned* are then developed to address the identified weaknesses from the Analysis of Results.

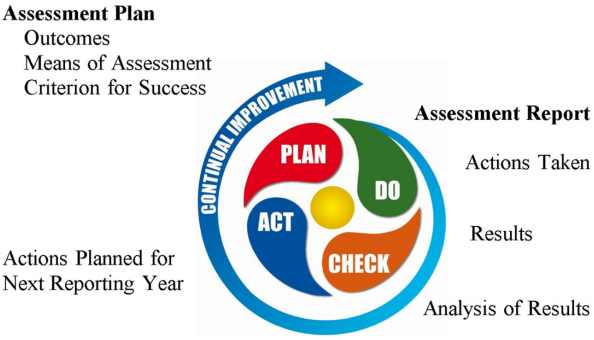

Figure 1. The Plan, Do, Check, Act or PDCA Cycle.

During an annual review of this program at the end of the 2014-15 academic year, a decision was made to add a summative means of assessment to the battery of formative means of evaluation and assessment used during the delivery of instruction in the three courses. Specifically, a decision was made to administer the Association of Technology, Management, and Applied Engineering's (ATMAE) Certified in Engineering Graphics (CEG) certification exam as a summative means of assessment.

The CEG exam is among a battery of certification exams administered by ATMAE's Board of Certification. Initial deployment of the CEG exam took place according the following schedule: April 2011, ATMAE's CEG exam was ready for Beta testing (Miller, 2011); September 2011, ATMAE's CEG exam was ready for use and fact checking data collection began for the initial data set (Miller, 2011); January 2012, the first person to earn CEG status was announced (Miller, 2012); and February 2012, Fernandes (2012) announced the availability of ATMAE's CEG exam and noted that Illinois State University's Ryan Brown was ATMAE's Engineering Graphics Exam Commission Chair.

Later that year, Brown and Devine (2012) delivered a presentation at the 2012 ATMAE Conference. Their presentation examined the relationship between Worldwide Youth in Science and Engineering (WYSE) high school student performance in engineering graphics and post-secondary performance using the CEG exam. No conclusions, however, were provided in their presentation abstract. Key, though, was the fact both presenters have been involved with the production of engineering graphics tests for WYSE since at least 2003 (Worldwide Youth in Science and Engineering, 2003).

Case Presentation

Among the program's ten SLOs is the following: Graduates will exhibit an appropriate mastery of the knowledge, techniques, skills, and modern tools of their discipline. One of the two Means of Assessment for this SLO is the following: Standardized Test—Association of Technology, Management and Applied Engineering's Certified in Engineering Graphics certification exam. The Criterion for Success for this Means of Assessment says that one hundred percent of the enrolled students will correctly respond to 60% (95/160) of all examination items. Sixty percent is minimum score needed for earning CEG certification (Association of Technology Management and Applied Engineering, 2014).

The exam was administered near the end of the semester in which the third course of the sequence of three was last offered—the spring of 2016. Shortly after the exam was administered, the results of the CEG exam were forwarded by ATMAE to the faculty member teaching the course. Actions Taken, Results, Analysis of Results, and Actions Planned were prepared by the course owners and the program coordinator as part of the program's agenda for continuous and ongoing improvement and included the following:

Actions Taken: Administered the Association of Technology, Management and Applied Engineering Certified in Engineering Graphics certification exam after (a) reevaluating the course competencies for Eng Graphics II by mapping the current content and laboratory activities to the outcomes associated with ATMAE's CEG exam; (b) ensuring all students transferring into the design program have successfully completed an Engineering Graphics I course; (c) developing and administering a pre-certification exam at the beginning of the semester to determine the knowledge base of each student in Eng Graphics II, especially transfer students; and (d) the instructor took a more active role in the preparation of students for the certification exam by seeking clarification from ATMAE on behalf of the students.

Results: Six of 20 students passed the ATMAE CEG certification exam by correctly responding to at least 60% of the ATMAE CEG certification exam items for a class pass rate of 30%.

Analysis of Results: Student performance in five of the seventeen exam categories was below the historical performance of all who have taken the exam. And while those who sit for the exam do not have to correctly respond to 60% of the items in a given category, the students also failed to achieve a 60% in seven other exam categories. In total, the students failed to respond correctly to 60% of the items in 12 of 17 CEG exam categories. According to the content area analysis conducted by ATMAE, those taking the exam never-the-less performed above the national average on 12 content areas and did not perform the same as the national average on any of the content areas.

Table 1, which was, in part, extracted from the exam report provided by ATMAE, summarizes the students' performance by category and includes the number of questions and the number of questions on the exam the students answered correctly per category.

Table 1. Performance Breakdown on the CEG exam by Category.

Category	Question Count	Session Average	Proportion Correct
ASME Standard Sheets, Title Blocks, Revision	5	3.5	70%
ASME Standards, Terms, and Line Conventions	8	5.05	63%
Assembly Drawing Methods	5	2.75	55%
Auxiliary View Standards, Terms, and Conventional Practices	4	1.65	41%
Dimensioning Standards, Including Choice and Placement Methods	15	8.15	54%
Geometric Dimensioning and Tolerancing	15	7	47%
Geometric Terms, Definitions, and Construction (2D and 3D)	10	5.5	55%
Machining Specifications, Callouts, and Surface Texture Symbols	9	4.45	49%
Orthographic Projection Theory, Standard Representation, and Spatial Visualization	23	12.45	54%
Pictorial Drawings and 3D Modeling Representation Methods	4	1.5	38%
Screw Thread Representation	5	2.15	43%
Sectional View Standards, Terms, and Conventional Practices	9	5.5	61%
Specialized Examples - Gears, sheet metal, welding, castings, plastics, etc.	14	7.15	51%
Springs and Fasteners	5	3.25	65%
Synthesis - Print Reading Questions	17	9.55	56%
Tolerancing Calculations and Practices	4	1.5	38%
Units, Measurements, Measuring Devices, Scaling Issues, and Metric Conversion	8	3.2	40%

Management and Outcome

Based on the assessment report, an action plan was developed to address the weaknesses identified by the Analysis of Results. The following summarizes the curricular or pedagogical steps in the action plan that faculty will take to improve or reinforce student learning for this Means of Assessment: Map the content of the CEG exam categories and their associated bodies of knowledge to the two prerequisite courses—Eng Graphics I and CADD—to ensure the students are receiving adequate preparation prior to taking Eng Graphics II in addition to doing the following: (a) reevaluating the course competencies for Eng Graphics II by mapping the current content and laboratory activities to the outcomes associated with ATMAE's CEG exam; (b) ensuring all students transferring into the design program have successfully completed an Eng Graphics I course; (c) developing and administering a precertification exam at the beginning of the semester to determine the knowledge base of each student in Eng Graphics II, especially transfer students; and (d) ensuring the instructor takes a more active role in the preparation of students for the certification exam by seeking clarification from ATMAE on behalf of the students.

Discussion

A sample from the curricular map based on the CEG exam categories and the associated bodies of knowledge (Association of Technology Management and Applied Engineering, 2014) and the three core engineering graphics courses is depicted in Table 2. Prior to the start of the 2016/17 academic year, the map will be completed in accordance with best practices (Accreditation Board for Engineering and Technology, Inc., 2015; Accreditation Board for Engineering and Technology, Inc., n.d.; Cermak, 2014; Huckabee, 2012; Jankowski, 2014). The three courses and the associated instruction will be revised using the results of this mapping process. During the course of the academic year, student performance will be monitored. In the spring of 2017, the CEG exam will be administered and the process repeated in anticipation that an incremental improvement in student performance will be realized.

Because ASQ's four–step model—the PDCA cycle—is a proven method for carrying out change, it is anticipated that improvements in student performance on the CEG exam will be realized in the spring of 2017.

Table 2. Partial Curriculum Map.

	Abbreviated Courses Names		
Category (approximate number of items on exam)	Eng Graphics I	CADD	Eng Graphics II
1. ASME Standards, Terms, and Line Conventions (10)			
ASME and their role in standardizing engineering graphics			
Terms relevant within the scope of standardized engineering graphics			
Conventional lines and lettering used in standardized engineering graphic prints			
2. ASME Standard Sheets, Title Blocks, Revision Blocks, and Part Lists (5)			
Sheet sizes and layouts available for imperial and metric applications			
Common terms used for blocks on sheets and prints			
Techniques, such as zoning and parts lists, important to standardized prints			
3. Units, Measuring Devices, Scaling Issues, and Metric/Inch Conversion (10)			
Common units, decimal and fractional expression, imperial and metric			
Common devices, scales, calipers, rulers, etc.			
Various scaling issues for views and drawings			
Metric-to-inch conversion and expression			
4. ….			

Key: I, Introduced; R, Reinforced; M, Mastered; A, Assessed.

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