Certification Exam-Aided Assessment of Student Learning

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Abstract

In the spring of 2016, an accredited undergraduate design technology program adopted the Association of Technology Management and Applied Engineering's Certified in Engineering Graphics certification exam to assess student learning. Once analyzed, the exam data tend to suggest that the program's students' understanding of engineering graphics was consistent with that of the comparator population that sat for the exam and that their overall performance was not significantly different than that of the comparator population. And while there were exceptions where the program's students' understanding was significantly higher than that of the comparator population, there were no instances where students understanding was significantly lower than that of the comparator population. Based on the nature of this exam, the results of this study, and the pass rate, placement of this means of assessment in the curriculum may need to be reconsidered.

Introduction

Exams are classified as direct means, in contrast to indirect means, of evaluating and assessing student learning (Rogers, 2011). They can be used to diagnose, provide information and feedback during the instructional process, and summarize the instructional/learning process (Yale Center for Teaching and Learning, 2019). Exams can be classified as standardized exams or curriculum-based exams. Key though is when exam items are aligned with the instructional objectives, the results can serve as an accurate measure of whether learning has taken place.

In contrast to indirect means, exams provide observable and measurable means for evaluating what students know and can do, which can be examined and provide stronger evidence of student learning. Given the evidence of student learning, instructional programs will have at their disposal meaningful data that will help identify what was taught well and what needs more attention. Indirect means in contrast, do not. Moreover, the administration and evaluation of standardized norm referenced exam results—exams that provide information on how a student's performance on an exam compares to others in a reference group—can provide additional evidence.

An Association of Technology, Management, and Applied Engineering (ATMAE) accredited undergraduate design technology program recently switched from one certification exam to another—ATMAE's Certified in Engineering Graphics (CEG) certification exam—because of the former's cost, the fact the administrator of the former's exam doesn't provide comparative data, and because of concerns over the quality of maintenance of the exam. The intent was to continue evaluating student learning, compare undergraduate design technology program student performance against a norm or comparator population, and to identify improvement opportunities.

Beta tested in 2011, ATMAE's CEG exam is a 2-hour, computer-based, open-book exam that is comprised of 160 multiple choice items (ATMAE, 2014). ATMAE suggests the exam can be used for individual certification and for program assessment. For certification purposes, the exam is a criterion reference exam in that the examinee must respond correctly to 95 of the 160 items to continue the process for certification. For program assessment, the exam can be used as a norm-referenced exam given the data provided by ATMAE in the what is referred to as the Score Report.

The exam is organized around 16 content areas (aka Categories) and include those listed in Table 1.

Content Area[1]	Question Count[2]
ASME Standards, Terms, and Line Conventions	10
ASME Standard Sheets, Title Blocks, Revision Blocks, and Part Lists	5
Units, Measuring Devices, Scaling Issues, and Metric/Inch Conversion	10
Geometry Terms, Definitions, and Constructions (2D and 3D)	10
Orthographic Projection Theory, Standard Representation, and Spatial Visualization	25
Sectional View Standards, Terms, and Conventional Practices	10
Auxiliary View Standards, Terms, and Conventional Practice	5
Pictorial Drawings and 3D Modeling Representation Methods	5
Assembly Drawing Methods	5
Dimensioning Standards, Including Choice and Placement Methods	15
Tolerancing Calculations and Practices	10
Geometric Dimensioning and Tolerancing (GDT)	15
Machining Specifications, Callouts, and Surface Texture Symbols	10
Screw Thread Representation	5
Springs and Fasteners	5
Specialized Examples – Gears, sheet metal, welding, castings, plastics, etc.	15

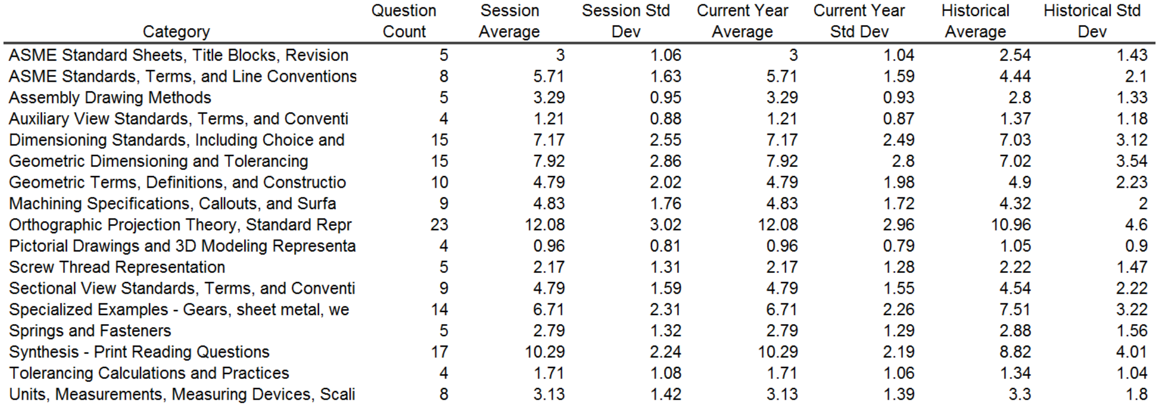
[1] According to the CEG Study Guide, there are 16 Content Areas. According to the Score Report, there are 17 Categories.

[2] Seventeen items were taken from many of the original 16 Content Areas listed to form the 17th Category.

Table 1. The 16 Content Areas that Comprise the Certified in Engineering Graphics Exam.

Performance data are released to the exam proctor in the form of a seven-part Score Report after the exam is administered and upon receipt of payment. The Category (aka Content Area) Breakdown for session report is among seven provided—see Table 2. This report provides data that are key to making comparisons—specifically the session average, session standard deviation, historical average, and historical standard deviation.

Inspired by Crawford, Steadman, Whitman, and Young (2019) and their ongoing work, an initiative was undertaken by the program to ascertain, with greater rigor, the extent of student learning. The program examined whether the performance of those sitting for the exam, design technology program students, was comparable to those of a comparator, a population comprised of those who have sat for the exam. Specifically, the program wanted to know whether there was a difference between the knowledge and skills of their students and that of all those who have sat for the exam—the comparator population. And if there were differences, in which categories did those differences exist and what was the nature of those differences.



Category	Question Count	Session Average	Session Std Dev	Current Year Average	Current Year Std Dev	Historical Average	Historical Std Dev
ASME Standard Sheets, Title Blocks, Revision	5	3	1.06	3	1.04	2.54	1.43
ASME Standards, Terms, and Line Conventions	8	5.71	1.63	5.71	1.59	4.44	2.1
Assembly Drawing Methods	5	3.29	0.95	3.29	0.93	2.8	1.33
Auxiliary View Standards, Terms, and Conventi	4	1.21	0.88	1.21	0.87	1.37	1.18
Dimensioning Standards, Including Choice and	15	7.17	2.55	7.17	2.49	7.03	3.12
Geometric Dimensioning and Tolerancing	15	7.92	2.86	7.92	2.8	7.02	3.54
Geometric Terms, Definitions, and Constructio	10	4.79	2.02	4.79	1.98	4.9	2.23
Machining Specifications, Callouts, and Surfa	9	4.83	1.76	4.83	1.72	4.32	2
Orthographic Projection Theory, Standard Repr	23	12.08	3.02	12.08	2.96	10.96	4.6
Pictorial Drawings and 3D Modeling Representa	4	0.96	0.81	0.96	0.79	1.05	0.9
Screw Thread Representation	5	2.17	1.31	2.17	1.28	2.22	1.47
Sectional View Standards, Terms, and Conventi	9	4.79	1.59	4.79	1.55	4.54	2.22
Specialized Examples - Gears, sheet metal, we	14	6.71	2.31	6.71	2.26	7.51	3.22
Springs and Fasteners	5	2.79	1.32	2.79	1.29	2.88	1.56
Synthesis - Print Reading Questions	17	10.29	2.24	10.29	2.19	8.82	4.01
Tolerancing Calculations and Practices	4	1.71	1.08	1.71	1.06	1.34	1.04
Units, Measurements, Measuring Devices, Scali	8	3.13	1.42	3.13	1.39	3.3	1.8

Table 2. The spring 2019 Category Breakdown for session report.

Method

An undergraduate design technology program sought to determine whether there were differences in their majors' performance over the past four years in the categories that comprise ATMAE's CEG certification exam. Because of the data available, specifically the population's standard deviation, z-scores, $z = (x - \mu) / (\sigma / \sqrt{n})$, were calculated using the session (x) and historical (μ) averages and the historical standard deviation (σ) for the categories that comprised the major parts of the exam over the four years the exam was administered (2016-2019).

Since the program chose 5% for its level of significance, the size of the rejection region would be .05. And because the rejection region was divided equally among the two tails, the 5% was divided into two equal part of 2.5% each. In an examination of the normal distribution, the program found that the critical values that divide the rejection and nonrejection regions are +1.96 and -1.96. That is, observed values of Z greater than 1.96 or less than -1.96 would indicate that the observed average is so far from the historical average that it is unlikely to be consistent with the historical average.

And while the priority was on student learning, the program also examined whether there was a significant difference between the overall annual session averages and the historical averages for the comparator population.

Results

To determine whether there was a significant difference between the overall annual session averages and the historical averages, z-scores were calculate using the four annual session and historical averages and historical standard deviations. The data suggest there wasn't a significant difference between the design technology program student's knowledge and skills and that of the comparator population. The implication being that there wasn't a significant difference between the pass rate for the design technology program's students and that of the comparator population—see Figure 1.

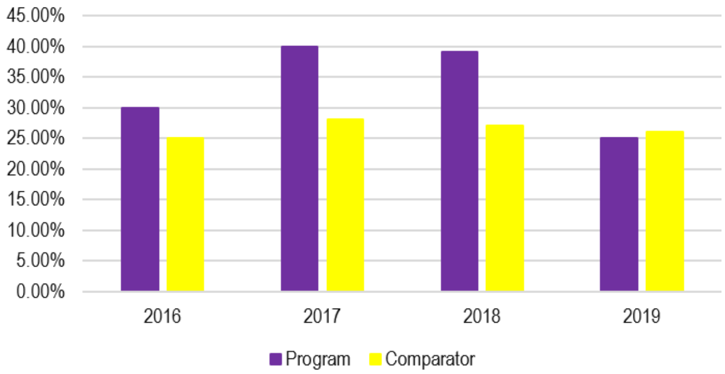
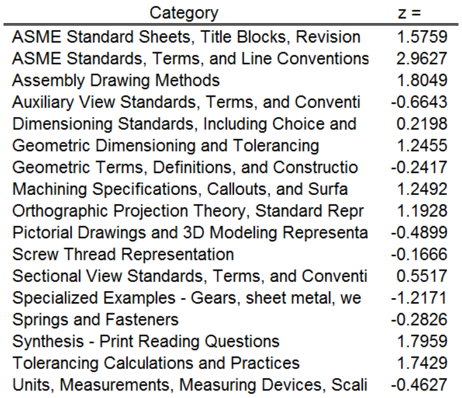


Figure 1. Pass rate comparison between the design technology program and the comparator.

Z-scores were also calculated for all categories for all annual sessions in which the exam was administered. The z-scores for the exam administered in the spring of 2019 appear in Table 3.

Analysis of the spring 2019 exam z-scores suggest that student knowledge and skills were for the most part consistent with the knowledge and skills of the comparator population. Except for the students' performance on items in the ASME Standards, Terms, and Line Conventions category, which was significantly higher, the students' performance on the individual exam categories was not significantly different than that of the comparator population of exam takers. And while the spring 2019 students did not exhibit significantly more knowledge and skills when compared to the comparator population in selected categories, their performance was not significantly worse either. Moreover, the overall performance of the students for the other three annual sessions—2016-2018—were similar.



Category	z =
ASME Standard Sheets, Title Blocks, Revision	1.5759
ASME Standards, Terms, and Line Conventions	2.9627
Assembly Drawing Methods	1.8049
Auxiliary View Standards, Terms, and Conventi	-0.6643
Dimensioning Standards, Including Choice and	0.2198
Geometric Dimensioning and Tolerancing	1.2455
Geometric Terms, Definitions, and Constructio	-0.2417
Machining Specifications, Callouts, and Surfa	1.2492
Orthographic Projection Theory, Standard Repr	1.1928
Pictorial Drawings and 3D Modeling Representa	-0.4899
Screw Thread Representation	-0.1666
Sectional View Standards, Terms, and Conventi	0.5517
Specialized Examples - Gears, sheet metal, we	-1.2171
Springs and Fasteners	-0.2826
Synthesis - Print Reading Questions	1.7959
Tolerancing Calculations and Practices	1.7429
Units, Measurements, Measuring Devices, Scali	-0.4627

Table 3. Z-scores for the exam administered in the spring of 2019.

To more effectively convey the students' performance, z-scores for each category were graphed. Moreover, by graphing the z-scores, the program can more readily note trends once additional data are collected. As an example, while not significantly lower than the comparator population, the design technology program students' performance in responding to items in the Pictorial Drawings and 3D Modeling Representation Methods category has been about a half a standard deviation below that of the comparator population—see Figure 2.

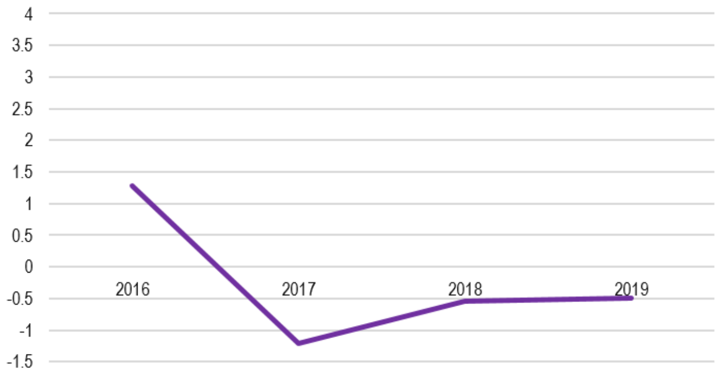


Figure 2. Z-scores for the Pictorial Drawings and 3D Modeling Representation Methods category.

While consistent over three of the four years, the design technology program's students' performance in the Screw Thread Representation category spiked significantly in 2018—see Figure 3.

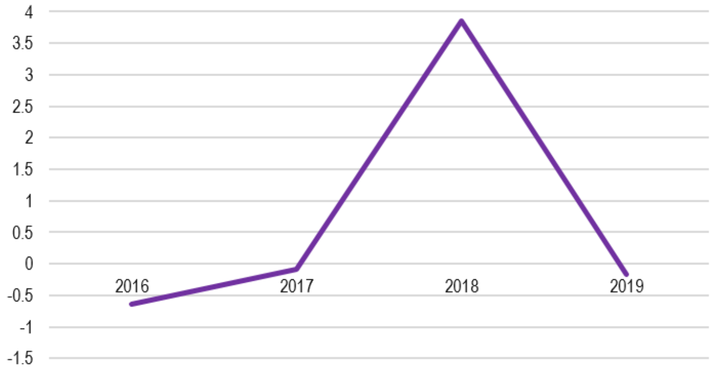


Figure 3. Z-scores for the Screw Thread Representation category.

In the Orthographic Projection Theory, Standard Representation, and Spatial Visualization category, the design technology program's student's performance was consistently above that of the comparator population, even spiking significantly above the comparator population in 2018—see Figure 4.

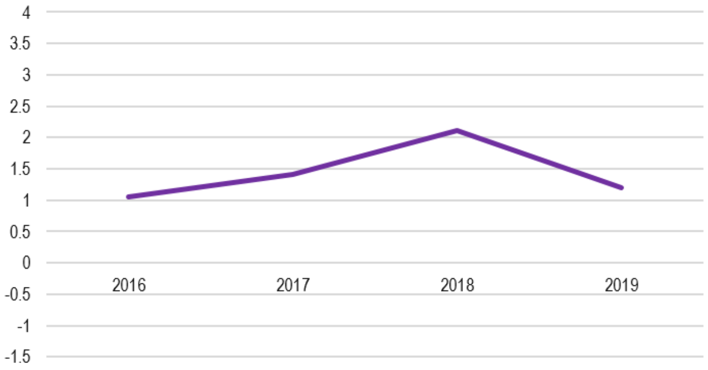


Figure 4. Z-scores for the Orthographic Projection Theory, Standard Representation, and Spatial Visualization category.

Discussion

While Crawford et al. (2019) suggest that the pass rate on exams have merit, it should not be the focus. If it becomes the focus, some might argue we are potentially jumping on the preverbal slippery slope—ie teaching to the test and compromising the program goals, which are in part developed with input form professional that comprise our advisory committees.

A low pass rate however may suggest that the exam is being administered or students are taking the exam too soon. Too soon in that they are not benefiting from relevant instruction offered subsequent to having sat for the exam.

In contrast, the focus should be on the examinees' performance in a given category and what needs to be done to improve the examinees' performance. As an example, if the data that appear in Table 3 is representative, more or less, of the design technology programs' examinees' performance over the past four years, it stands to reason the program might want to reassess the delivery of instruction in the categories in which the z-scores are, as an example, below that of the comparator population represented by maybe a -X.XXXX z-scores or some other criteria.

We are also cautioned, again referring to the data that appear in Table 3, that if the goal of the program does not include being skilled and knowledgeable with Auxiliary View Standards, Terms, and Conventional Practice, as an example, then the program should not be forced into increasing its efforts in improving student skills and knowledge in this category simply to up the pass rate.

Key for this undergraduate design technology program is whether the exam is being administered too early. As an example, the course in which the exam is being administered, Engineering Graphics II, is a prerequisite course for Geometric Dimensioning and Tolerancing (GD&T). Moreover, almost 10% (n=15) of the CEG exam is comprised of GD&T items. While student performance has generally improved as a result of instructional intervention, their GD&T knowledge and skills are still hovering only about a half to a standard deviation above the population mean—see Figure 5.

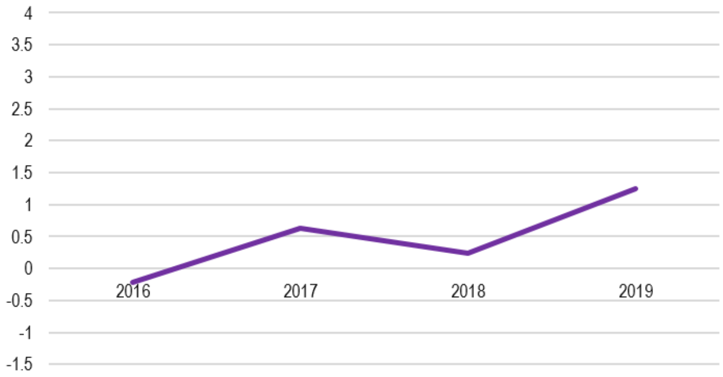


Figure 5. Z-scores for the Geometric Dimensioning and Tolerancing (GDT) category.

This level of performance, a proxy for the students' knowledge and skills, logically could be improved upon by administering the exam while the students are in the process of completing the GD&T course. Of course, delaying the administration of the exam should also help the students reap additional experiences and perform even better on the exam.

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