Using the Results of Certification Exam Data: A More Deliberate Approach to Improving Student Learning

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Introduction

An accredited undergraduate design technology program adopted an American Design Drafting Association (ADDA) certification exam [1] to help assess student learning in architectural graphics, a key component in architectural design technology. The exam has been administered in a junior level architectural design technology course. All those enrolled in the course must past the exam in order to earn credit for the course. Almost all who don’t pass the exam during their first sitting have retaken the exam before the end of the semester in which the course was offered and in which the exam was administered. There has been the very rare exception in which an exam taker will take an incomplete for the course and retake the exam and clear the incomplete the following semester.

While a kudo, passing the exam however is not the goal of this course requirement. The purpose of administering the exam is to ascertain knowledge and skills. So, rather than just examining the performance data and trying to make improvements in the students’ knowledge and skills in the areas that appeared to need more attention based on individual student and class performance, a more deliberate approach was undertaken.

The program recently asked the exam administrating entity whether other certification exam data were available, which the program could use to make comparisons. Because the data are available, the program undertook an initiative on behalf of its students to compare the exam takers’ performance, and thus the performance of the program, to that of a comparator population—all those who have sat for the exam.

Exam data were collected, compiled, and analyzed. Because the assumptions were met and the data were available, the annual program exam session averages and the annual historical exam averages for the comparator population were used to compute annual t-value for the 20 competencies that comprise the exam. The purpose of the t-values was to determine whether there was a significant difference between the annual competency averages of those sitting for the exam and the averages that were the result of members comprising the comparator population sitting for the exam. While in general the program exam takers’ performance on the exam appear to be consistent with that of the comparator population, the t-values identified competencies that require additional attention and are candidates for instruction improvement.

Exams as a Learning Assessment Tool

Exams are classified as direct means, in contrast to indirect means, of evaluating or assessing student learning [2]. They can be used to diagnose, provide information and feedback during the instructional process, and summarize the instructional/learning process [3]. 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 whether instruction was effective 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.

The Certification Exam

Since the fall of 2013, an accredited undergraduate design technology program has been administering ADDA's architectural apprentice drafter (AAD) certification exam to assess students' architectural graphics knowledge and skills. The intent was to evaluate student learning and to use exam taker performance data to make improvements in the instruction. With the additional data, the program can now compare its student performance against a norm or comparator population and to more effectively identify improvement opportunities.

The exam is a 2.5-hour, computer-based, closed-book exam. It is comprised of 400 objective items—ie true-false, multiple-choice, matching, and the like, and is organized around 20 competencies. Table 1 provides a sense for the proportion of items that comprise each competency based on the number of exam items.

Competency	No. of Items	Proportion
Professional Drafting Practices in the Workplace-Communications	20	5.00%
Drafting Equipment-Media-Reproduction	25	6.25%
Architectural Sketching-Orthographic Projection	15	3.75%
Lines-Lettering-General Terminology	10	2.50%
Mathematics and Geometry	15	3.75%
Architectural Products-Styles-History-Identification and Terminology	25	6.25%
Site Layout-Identifications and Terminology	20	5.00%
Drawing Identification-Architectural Numbering-Drawing Management	30	7.50%
Dimensioning and Notations	25	6.25%
Floor Plan Layout-Relationships-Identification and Terminology	20	5.00%
HVAC-Plumbing-Electrical Plans-Identification and Terminology	25	6.25%
Roof Plans-Identification and Terminology	15	3.75%
Elevations	15	3.75%
Framing-Framing Plans-Identification and Terminology	20	5.00%
Foundation Plans-Identification and Terminology	20	5.00%
Sections, Stairs and Steps	15	3.75%
Building Codes and Governing Bodies	15	3.75%
Schedules-Doors-Windows-Finishes	15	3.75%
Estimations-Specifications-Calculations	15	3.75%
Definitions and Building Materials	40	10.00%

Table 1. The 20 Competencies that Comprise the Certified in Engineering Graphics Exam.

For administration purposes, the exam is broken up into two sections. Both are administered in a single sitting. The first section is comprised of 205 items, the second, 195 items. Descriptive/

demographic data for the two parts appears in Table 2. These data characterize the performance of all exam takers of the exam since the inception of the exam.

Measures	Section 1	Section 2
Number participants:	800	792
Items on assessment:	205	195
Testing range:	11/06/2013 - 06/04/2019	11/06/2013 - 06/04/2019
Time limit:	01:20:00	01:20:00
Minimum score possible:	0	0
Maximum score possible:	205	195
Mean score:	146.32 / 205 (71.38%)	138.21 / 195 (70.88%)
Median score:	147.00 / 205 (71.71%)	139.00 / 195 (71.28%)
Mode score:	occurred 22 time(s)	occurred 20 time(s)
Standard deviation:	23.15	25.48
Reliability coefficient (KR21):	0.9264	0.9428
Range:	205	193
Interquartile range:	29	33

Table 2. Descriptive/demographic data for the ADDA AAD certification exam.

The exam is a criterion referenced exam in that the exam taker must respond correctly to 300 of the 400 items (75%) to be certified. Achieving the 75% threshold is not require for each of the 20 competencies, however. For program assessment, the exam can be used as a norm-referenced exam [4] given the data that can be requested from ADDA.

Exam taker performance data are released to the exam proctor in the form of single page report for each exam taker. A redacted performance report is provided in Figure 1. In addition to the demographic data, the competencies are listed, and the number of items answered correctly by the test taker, incorrectly, not answered, and the proportion of items answered correctly, along with the respective totals are provided.

Inspired by Crawford, Steadman, Whitman, and Young [5] 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. The findings could then be used to identify instructional improvement opportunities.

Method

An undergraduate design technology program sought to determine whether there were differences in their majors' performance over the past six years (2013-2018) in the competencies that comprise ADDA's AAD certification exam. Because of the sample size and the data available, t-values were calculated for each of the competencies for each of the exam years: specifically $\mathbf{t_{n-1} = (x - \mu) / (s / \sqrt{n})}$, where $\mathbf{t_{n-1}}$ is a value from the t-distribution with n-1 degrees of freedom, $\mathbf{x}$ is the session average, $\boldsymbol{\mu}$ is the historical average, and $\mathbf{s / \sqrt{n}}$ is the standard error

Name:				
Proctor				
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Standard	**Correct**	**Incorrect**	**Unattempted**	**Percent Correct**
Standard 1: Architectural Apprentice Drafter	**313**	**87**	**0**	**78.25%**
Competency 1: Professional Drafting Practices in the Workplace-Communications	15	5	0	75.00%
Competency 2: Drafting Equipment-Media-Reproduction	17	8	0	68.00%
Competency 3: Architectural Sketching-Orthographic Projection	10	5	0	66.67%
Competency 4: Lines-Lettering-General Terminology	8	2	0	80.00%
Competency 5: Mathematics and Geometry	15	0	0	100.00%
Competency 6: Architectural Products-Styles-History-Identification and Terminology	23	2	0	92.00%
Competency 7: Site Layout-Identifications and Terminology	16	4	0	80.00%
Competency 8: Drawing Identification-Architectural Numbering-Drawing Management	22	8	0	73.33%
Competency 9: Dimensioning and Notations	20	5	0	80.00%
Competency 10: Floor Plan Layout-Relationships-Identification and Terminology	14	6	0	70.00%
Competency 11: HVAC-Plumbing-Electrical Plans-Identification and Terminology	18	7	0	72.00%
Competency 12: Roof Plans-Identification and Terminology	14	1	0	93.33%
Competency 13: Elevations	14	1	0	93.33%
Competency 14: Framing-Framing Plans-Identification and Terminology	18	2	0	90.00%
Competency 15: Foundation Plans-Identification and Terminology	14	6	0	70.00%
Competency 16: Sections, Stairs and Steps	12	3	0	80.00%
Competency 17: Building Codes and Governing Bodies	12	3	0	80.00%
Competency 18: Schedules-Doors-Windows-Finishes	10	5	0	66.67%
Competency 19: Estimations-Specifications-Calculations	13	2	0	86.67%
Competency 20: Definitions and Building Materials	28	12	0	70.00%
Total	**313**	**87**	**0**	**78.25%**

Figure 1. An exam taker's performance report.

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 t distribution, the critical values corresponded to the degrees of freedom, which varied annually. This along with the fact the t-distribution has fatter tails than the z-distribution, the chance of rejecting the null is reduced creating higher burden of proof.

Results

To determine whether there was a significant difference between the overall annual session averages and the historical averages, t-values were computed using data from the six annual sessions and the historical averages. The t-values tend to suggest that for the most part there wasn't a significant difference between the design technology program students' knowledge and skills and that of the comparator population—see Table 3.

The t-values also suggest that the 2013 exam takers performed significantly better on the exam in contrast to the comparator population and that the 2017 exam takers performed significantly better than the comparator population on almost half the competencies.

Negative t-values suggest that exam taker performance on selected competencies was worse than that of the comparator population. Except for the competency 'Definitions and Building

Materials' in 2015 and the competency 'Foundation Plans-Identification and Terminology' in 2018, where the exam takers' performance was significantly worse than the comparator population, the performance of the exam takers was comparable to the comparator population.

Competency	2013	2014	2015	2016	2017	2018
Professional Drafting Practices in the Workplace-Communications	1.01	0.14	0.27	1.28	0.34	0.86
Drafting Equipment-Media-Reproduction	**3.39**	0.62	1.88	**2.37**	1.14	-0.89
Architectural Sketching-Orthographic Projection	**3.05**	1.86	-0.74	0.65	**3.09**	0.54
Lines-Lettering-General Terminology	1.69	**2.96**	0.77	**4.58**	**2.48**	0.90
Mathematics and Geometry	**4.46**	0.86	**2.84**	**6.51**	**3.14**	2.10
Architectural Products-Styles-History-Identification and Terminology	**3.18**	-0.12	-0.67	1.89	0.33	0.46
Site Layout-Identifications and Terminology	**3.51**	-0.62	0.15	0.65	0.36	0.79
Drawing Identification-Architectural Numbering-Drawing Management	**2.32**	0.95	-0.35	1.63	**2.66**	0.38
Dimensioning and Notations	**6.79**	1.60	-0.59	0.91	**5.25**	2.87
Floor Plan Layout-Relationships-Identification and Terminology	**3.62**	0.27	-0.04	0.83	1.50	-1.97
HVAC-Plumbing-Electrical Plans-Identification and Terminology	**5.22**	1.27	1.61	0.45	0.04	-2.31
Roof Plans-Identification and Terminology	**2.44**	**3.79**	1.63	-0.61	**2.34**	2.06
Elevations	**2.83**	2.19	1.47	1.91	1.99	1.08
Framing-Framing Plans-Identification and Terminology	**3.52**	1.66	1.16	0.32	**3.25**	-0.26
Foundation Plans-Identification and Terminology	0.78	1.78	2.02	0.02	0.42	**-3.65**
Sections, Stairs and Steps	**3.81**	**3.44**	**4.11**	**3.36**	**3.43**	0.48
Building Codes and Governing Bodies	**4.00**	1.97	1.04	0.16	1.26	-2.12
Schedules-Doors-Windows-Finishes	**6.27**	-0.64	1.85	-0.02	0.37	-1.66
Estimations-Specifications-Calculations	**4.98**	**4.01**	**7.53**	1.64	1.83	**3.76**
Definitions and Building Materials	**5.03**	0.55	**-2.79**	0.65	2.06	-0.14
Degrees of Freedom	13	7	4	7	12	3

Table 3. Annual Test Statistics (t_{n-1}) for Competencies. Values in bold are significance at 0.05.

Discussion

While Crawford et al. [5] 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 from professionals that comprise the program's advisory committee.

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. However, this does not seem to be the case. The few that have not passed the exam the first time, normally pass it during the second sitting.

In contrast, the focus should be on the exam takers' performance on given competencies and what needs to be done to improve the exam takers' knowledge and skills. That is, if the data that appear in Table 3 are representative, more or less, of the design technology programs' exam takers' performance over the past six years, it stands to reason the program might want to reassess the delivery of instruction in the categories in which the t-values are, as an example, below that of the comparator population represented by maybe a -t-value.

We are also cautioned, again to referring to the data that appear in Table 3, that if the goal of the program does not include being skilled and knowledgeable with Architectural Products-Styles-History-Identification and Terminology, 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.

One of the reasons for conducting this study could have been to determine whether this exam was being administered too early. It does not seem to be the case. If anything, the timing of its administration appears to be about right.

While all the exam takers in the program that earn credit for the course passed the exam, their performance in and among select competencies was not as consistent as it could be. Their knowledge and skills also varied when comparisons were made to that of the knowledge and skills exhibited by the comparator population. Their performance also varied from year to year.

The data will now be offered to the program's advisory committee for its consideration and recommendations. The data will also be examined by faculty who teach prerequisite courses for their consideration. The focus of these reviews will be on that of student learning and the knowledge and skills they possess upon completion of the program.

While this study and its findings focused on the performance of a limited number of students from a specific program whose performance served as a proxy for the performance of their program, the additional key take-aways are the reminders in the literature on the role of exams. The literature reminds us that to be of value, exams—criterion referenced exams in particular—need to be administered at the appropriate time, that criterion referenced exams can be used to guide curricular revision but should not drive curricular decisions, that the exam results should be used to help improve instruction and that exam pass rates should not be the desired effect—that the development of student knowledge and skills is key

References

[1] American Design Drafting Association. (2020). Professional Certification. Retrieved from http://adda.org/index.php/professional/professional-certification

[2] Rogers, G. (2011). *ABET Assessment Planning: Direct and Indirect Assessment*. Retrieved from https://www.abet.org/wp-content/uploads/2015/04/direct-and-indirect-assessment.pdf

[3] Yale Center for Teaching and Learning. (2019). *Formative and Summative Assessments*. Retrieved from https://poorvucenter.yale.edu/sites/default/files/basic-page-supplementary-materials-files/formative_and_summative_assessment_handout.pdf

[4] Owens, C. (2015). *Certification and Licensure Examinations: Norm Referenced or Criterion Referenced?* Retrieved from http://www.proftesting.com/blog/2015/08/26/2015826 certification-and-licensure-examinations-norm-referenced-or-criterion-referenced/

[5] Crawford, B. G., Steadman, J. W., Whitman, D. L., & Young, R. K. (2019). *Using the Fundamentals of Engineering (FE) Examination as an Outcomes Assessment Tool*. Retrieved from https://ncees.org/wp-content/uploads/FEOAT-white-paper-2019.pdf