

Using the Constructor Qualification Examination to Assess Student Learning

Keith E. Sylvester, Ph.D.
East Carolina University
Greenville, North Carolina

Today, construction management programs face growing academic accountability resulting in the need to define new program outcomes to measure student learning. In most cases, student learning is only analyzed within the context of a program's University using survey methods which do not accurately quantify student learning. Contrary to this condition, construction management programs increasingly require students to take level 1 of the nationally administered Constructor Qualification Exam (CQE) upon graduation. However, little or no analysis of this data is conducted beyond basic interpretation of the national and program averages provided by the testing agency. Providing a statistical approach to analyze this data and to propose recommended strategies for improvement, this research develops and investigates statistical methods to analyze the national test data as a program assessment tool for student learning. Specifically, this work seeks to develop performance standards and expectations for students when taking the CQE exam, to define correlations between student GPA and student performance CQE exam. Likewise, this work presents methods to identify program weakness and strategies for improvement by comparing the CQE exam with American Council for Construction Education (ACCE) accreditation standards.

Key Words: Assessment, Student learning, Accreditation, Certification

Introduction

The American Institute of Constructors (AIC) was developed in 1971 and was expanded in 1994 by the AIC Constructor Certification Commission to offer a recognized written certification process known as the Constructor Qualification Exam (CQE) (AIC, 2001). As a peer process, construction qualification is a two step examination process that provides an analysis of strength and weakness related to defined skills required of a constructor. The first examination leads to the Associate Constructor Certification, typical of most college graduates, and the second examination leads to the Certified Professional Constructor which requires an additional seven years of experience. In each case, level of education and years of experience are factored to qualify to take each exam (AIC 2001). The CQE exam is now endorsed by the Associated Schools of Construction, the American Council for Construction Education, the American Society of Professional Estimators, the American subcontractors Association, the Associated Builders and Contractors, and the Associated General Contractors of America (AGC).

Today, construction management programs face growing academic accountability resulting in the need to define new program outcomes to measure student learning. In most cases, student learning is only analyzed within the context of a program's University using survey methods which do not accurately quantify student learning. Contrary to this condition, construction management programs increasingly require students to take level 1 of the nationally administered Constructor Qualification Exam (CQE) upon graduation. However, little or no analysis of this data is conducted beyond basic interpretation of the national and program averages provided by the testing agency. Providing a statistical approach to analyze this data and to propose recommended strategies for improvement, this research develops and investigates statistical methods to analyze the national test data as a program assessment tool for student learning. Specifically, this work seeks to develop performance standards and expectations for students when taking the CQE exam, to define correlations between student GPA and student performance CQE exam, and to identify program weakness and strategies for improvement by comparing the CQE exam with American Council for Construction Education (ACCE) accreditation standards (ACCE, 2008b).

When reviewing the CQE exam, the level 1 exam reports national and institutional averages for the pass and fail rate, the average score, and the high and low scores. Area scores for each CQE testing category are also provided. See below.

ACCE Program Assessment

As defined by ACCE, construction management programs are required to maintain a curriculum that is responsive to social, economic, and technical developments. Construction management programs must also reflects the application of evolving knowledge in construction, behavioral and quantitative sciences. Likewise, ACCE further states that the program goals and objectives must have outcomes that are measurable. Most important, ACCE requires that the curriculum be designed to accommodate continually expanding requirements of the profession, advancements in knowledge, and the contributions of related disciplines (ACCE 2008b). As such, ACCE has defined minimum requirements for core subject matter (Table 1).

Method

This research uses a case study construction management program that is accredited by ACCE to examine the CQE exam as a measure to improve student learning. This research compares cohort GPA with CQE test scores for the level one examination. The data analyzed included CQE level one test score including categories, cohort GPA, GPA Grouping at 4 levels, credit hours completed, and the pass rate by GPA Group. To analyze the data six analyses were conducted including 1) Competency Mapping, 2) Trend Analysis, 3) Pass Rate Analysis, 4) Descriptive Analyses, 5) Analysis of Variance, 6) Multivariate Correlation. The purpose of each analysis is presented in the table below.

Table 1 ***Data analyses conducted in this study***

#	Analysis	Description	Significance
1	Competency Mapping	Mapping of CQE testing categories with ACCE Curriculum areas	Identify courses in the curricula the correlate to the CQE testing categories
2	Pass Rate and Mean	Benchmarking student performance against expected standards	Develop baseline performance standards for future comparisons
3	Trend	Longitudinal assessment of historical student performance	Define causal relationship between programmatic changes and historical CQE test performance
4	Frequency	Assessment of GPA and test score distribution for normal distribution	Identify differences in the competency standards of the academic program and professional practice
5	ANOVA	Test for significantly different test means among GPA groupings	Identifies how student learning as ranked by GPA compares to the professional competency standards expected by the CQE level 1 examination.
6	Correlation	Identification of factors affecting student learning and test performance	Identify core course areas in the curriculum that require improvement and their interdependency

Results

This research uses a case study construction management program that is accredited by ACCE and that contains a study population of 81 cohorts who completed a minimum 126 credit hours to obtain a Bachelor Science in Construction Management degree. Earned credit hours by the cohort range from 60 to 231, where as the lower range represents transfer students and the higher range represents students who received a second degree, who received a minor degree, and who changed their major. Important characteristics to note are that 75.6% of the cohort population received a minor degree in Business, 96.3% of the cohort population are male. Based on ethnicity, 90.2% are white, 1% Hispanic, 2% Black, 1% Alaskan Native and Native Indian, and 2% unknown. When analyzing the cohort by age, 53 students are between 22 and 25 years of age, 22 students are between 25 and 30 years of age, and 6 students are 30 years of age and above.

Comparison of CQE Level 1 Test and ACCE Accreditation Requirements

Since academics program are accredited by ACCE and curriculum standards have already been met, the CQE exam content is compared to the ACCE accreditation requirements only (Table 2) and no comparisons are made to the program curriculum.

Table 2
Comparison of CQE Testing and ACCE Accreditation Requirements

CQE Testing Category	ACCE Curriculum Category	ACCE Core Subject Matter	Instruction	
Communication	General Education	Oral and Written Communication	4 cr.	6 quar.
Engineering Concepts	Mathematics and Science	Physical and/or Environmental Science Statistics and or Mathematics	15	22 quar.
Management	Business and Management	Economics Principles of Management Accounting Business Law	18 cr.	27 quar.
Materials Methods and Plan Reading	Construction Science	Design Theory Analysis and Design of Construction Systems Construction Methods and Materials Construction Graphics	20 cr.	30 quar.
Bidding and Estimating	Construction	Estimating	3 cr.	3 quar.
Budgeting, Costs, and Cost Control	Construction	Accounting and Finance	1 cr.	1.5 quar.
Planning, Scheduling, and Control	Construction	Planning and Scheduling	3 cr.	4 quar.
Construction Safety	Construction	Safety	1 cr.	1.5 quar.

Surveying and Project Layout	Construction Science	Construction Surveying	1 cr.	1.5 quar.
Project Administration	Construction	Project Management Construction Law	4 cr.	5.5 quar.

Trend Analysis

In the case study, early tests of the CQE exam had few participants because students were not required to take the exam until 2004. Likewise, the CQE exam became a CMGT requirement with the Fall 2004 catalog. Students graduating under the 2004-2005 catalogs were required to sit for the exam. Effective Spring 2006 – all CMGT 3000 registered students were required to sit for the exam.

The graphs in Figure 1 represent trend data generated from CQE examination results ranging from the year 2004 to 2009 and ranging in population from 24 to 84 students. Data from lower years were trimmed due to small test populations which occurred in the first few years of initiation of the CQE examination. The graphs below seek to find correlations between the tested students and their pass rates and test deficiencies since 2004.

From 2004 to approximately 2006, the number of areas of deficiency increased as the test population increased. Since that time, this trend has been remediated with a gradual reduction in the number of areas of deficiency. Since requiring students to take the CQE exam in 2001, the test population has grown significantly stabilizing between 2006 and 2008. Pass rates reduced from approximately 30% in 2004 to 17% in 2005.

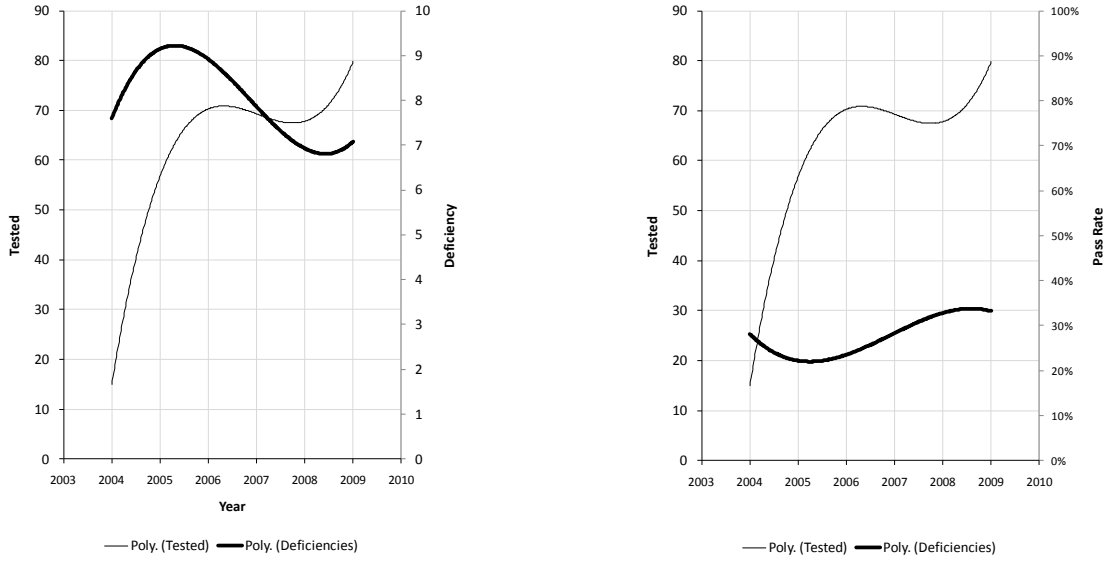


Figure 1. Trend analysis for select test years.

Pass Rate Analysis

In this portion of the analysis, the student GPA was divided into four groups representing average students (2.0 – 2.5 GPA), above average (2.5 – 3.5 GPA), and excellent students (3.5 – 4.0 GPA). See Table 3. Average students, typically defined as "C" students rarely pass the CQE exam, while above average students, typically referred to as "B" students, have an average pass rate of 36%. For excellent students, whom we would expect to have a minimum 80% pass rate, a 67% pass rate was found. See table below. To assess the construction management curriculum, the following program outcomes (in relation to the CQE exam) were postulated.

- Average students will pass the CQE exam **some** (between 0 and 30%) of the time,
- Above Average Students will pass the CQE exam **majority** (more than 50%) of the time, and
- Excellent Students will pass the CQE exam **most** (more than 80%) the time

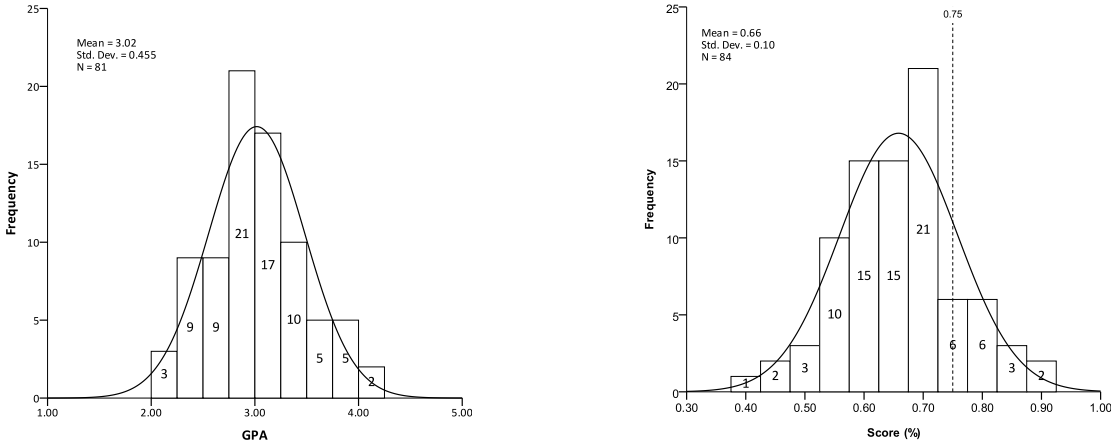
Table 3

Test Pass Rate by GPA Subset

Group	GPA	Pass Rate	N	Mean	Std. Deviation	95% Confidence Mean	
1	(2.0 – 2.5)	17%	11	.5918	.07083	.5442	.6394
2	(2.5 – 3.0)	23%	31	.6506	.09179	.6170	.6843
3	(3.0 – 3.5)	48%	27	.6615	.08342	.6285	.6945
4	(3.5 – 3.9)	67%	12	.7583	.09694	.6967	.8199
Total		**32%**	**81**	**.6622**	**.09726**	**.6407**	**.6837**

Analysis of Frequency

To understand student test performance in relation to the students GPA, distributions of test score and GPA of cohort were analyzed as shown in Figure 2. Analyzing for normal distribution, ideally we should see 75% as the median score for the tests and 3.0 as median score for the GPA. While the expected median GPA score is 3.0, the overall student population of the case study has a significantly low pass rate of 66.2%. Please note that University minimum GPA requirements is factored modifying the median GPA of the population. In the case study below, the minimum University GPA is 2.0 moving the expected median performance to a 3.0 GPA. When analyzing the case study data, student performance on the CQE level 1 exam is normally distributed, indicating that the graduating cohort is representative of a normal population taking the CQE level 1 exam, with a mean score significantly below the projected test mean.



(a) *(b)*

Figure 2. Test score and GPA distribution for 2009 cohort.

Analysis of Variance by GPA Category

This analysis conducted a one way ANOVA to test for homogeneity in the treatment means by GPA Group. That is, are the students statistically scoring better in relation to their GPA score? Is their linear relationship in GPA and test score? To reveal these relationships, an ANOVA and Tukey test, a single-step of multiple comparisons, were

conducted. The ANOVA revealed that test score and GPA did not have a positive linear relationship due to significant variability in Test score when factored by GPA group. See Table 4.

Table 4

ANOVA: Test for linear and quadratic relationship by mean score

Between Groups (Combined)		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
		.170	3	.057	7.410	.000
Linear Term	Un-weighted	.159	1	.159	20.858	.000
	Weighted	.141	1	.141	18.546	.000
	Deviation	.028	2	.014	1.842	.165
Quadratic Term	Un-weighted	.006	1	.006	.778	.380
	Weighted	.006	1	.006	.733	.395
	Deviation	.023	1	.023	2.951	.090
Within Groups		.587	77	.008		
Total		.757	80			

The Tukey analysis compared the means of each GPA group to the means of every other GPA group; that is, all pair-wise comparisons were simultaneously applied identifying the difference between means that were greater than the standard error would be expected to allow. The data revealed that significant difference exist between the Group 4 (excellent students) and all other groups. Likewise, the data shows that the mean score for students contained in GPA groups 1, 2 and 3 are relatively the same showing no performance difference for those groups. When testing the hypothesis that GPA is an indicator and predictor of student learning, ideally we would expect to see significance between all groups. See Table 5.

Table 5

ANOVA: Multiple comparisons of the dependent variable score

Control Group	**GPA Group**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval Lower / Upper**	
1.00	2.00	-.05883	.03065	.229	-.1393	.0217
	3.00	-.06966	.03124	.124	-.1517	.0124
	4.00	**-.16652***	.03645	.000	-.2622	-.0708
2.00	1.00	.05883	.03065	.229	-.0217	.1393
	3.00	-.01084	.02299	.965	-.0712	.0495
	4.00	**-.10769***	.02969	.003	-.1857	-.0297
3.00	1.00	.06966	.03124	.124	-.0124	.1517
	2.00	.01084	.02299	.965	-.0495	.0712
	4.00	-.09685*	.03030	.011	-.1764	-.0173
4.00	1.00	**.16652***	.03645	.000	.0708	.2622
	2.00	**.10769***	.02969	.003	.0297	.1857
	3.00	**.09685***	.03030	.011	.0173	.1764

*. The mean difference is significant at the 0.05 level.

When reviewing the case study data in Figure 3, program outcomes must be clearly defined to establish a baseline. In this case study, the mean exam score for excellent students in GPA Group 4 is 76%. That is, excellent students correlate with the median of average test population, with unpredictable variability in pass rate in all other groups. Likewise, we can assume that most students within all other groups (1, 2 and 3) would not pass the CQE level one examination. To measure changes in student learning, multiple data sets are required for comparison.

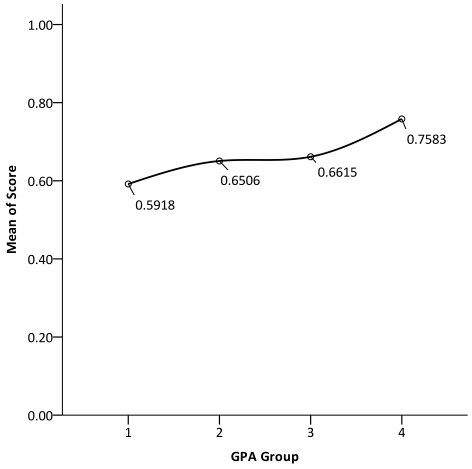


Figure 3. Analysis of means score by GPA group.

Multivariate Correlation

In the final analysis shown in Table 6, we examine each test score category and their individual correlation to GPA and credit hours. Using the Pearson correlation coefficient for normally distributed variables, this analysis reveals CQE exam categories that are affected by the students GPA and completed credit hours. In review of Table 6, clear correlations are revealed that must be noted. To interpret, Score = 1, GPA = 2, Communication = 3, Engineering = 4, Management = 5, Methods = 6, Estimating = 7, Cost = 8, Scheduling = 9, Safety = 10, Surveying = 11, and Administration = 12. Please note that test score categories in relation to each other are not discussed because of their interdependencies.

Table 6

Bivariate Correlation Scatter plot Matrix

Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Score	1	.467**	.622**	.794**	.538**	.763**	.887**	.809**	.807**	.644**	.453**	.774**
GPA	.467**	1	.441**	.379**	.220*	.312**	.444**	.280*	.341**	.306**	.290**	.456**
Communication	.622**	.441**	1	.410**	.256*	.432**	.540**	.413**	.475**	.457**	.188	.430**
Engineering	.794**	.379**	.410**	1	.460**	.596**	.631**	.599**	.623**	.470**	.321**	.605**
Management	.538**	.220*	.256*	.460**	1	.425**	.447**	.381**	.314**	.200	.192	.419**
Methods	.763**	.312**	.432**	.596**	.425**	1	.608**	.512**	.516**	.533**	.249*	.563**
Estimating	.887**	.444**	.540**	.631**	.447**	.608**	1	.728**	.655**	.496**	.439**	.622**
Cost	.809**	.280*	.413**	.599**	.381**	.512**	.728**	1	.612**	.489**	.423**	.534**
Scheduling	.807**	.341**	.475**	.623**	.314**	.516**	.655**	.612**	1	.502**	.475**	.560**
Safety	.644**	.306**	.457**	.470**	.200	.533**	.496**	.489**	.502**	1	.235*	.395**
Surveying	.453**	.290**	.188	.321**	.192	.249*	.439**	.423**	.475**	.235*	1	.254*
Administration	.774**	.456**	.430**	.605**	.419**	.563**	.622**	.534**	.560**	.395**	.254*	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Most important, correlation exists between Test Score and GPA. That is, changes in the GPA are being detected that relate to changes in the Test Score. However, the correlation coefficient indicates that this relationship is not linear. In the case study, the greatest areas of correlation are Management Concepts and Budgeting, Costs, and cost Control.

Conclusions

Six analyses are discussed to use the CQE Level 1 exam as an assessment measure of student learning within programs of construction management. The analyses conducted in this study include 1) Competency Mapping, 2) Trend, 3) Pass Rate, 4) Frequency, 5) Analysis of Variance, 6) Correlations. Overall, using the CQE level 1 exam is a viable tool to assess student learning. However, the expectation of high pass rates on the CQE leve 1 exam is unrealistic for programs that minimally adhere to ACCE accreditation requirements. Likewise, 7 of the 10 CQE testing categories account for 4 credits or less each of required instruction within the ACCE core course requirements. This study shows that average students (GPA ranging from 2.0 to 3.0) is highly unlikely to pass the CQE exam and excellent students are likely to pass the CQE exam with a score of 75%. Student GPAs show normal distribution and align with the expected mean GPA. Student CQE exam scores show normal distribution and are significantly below the expected mean CQE exam score.. Positive changes in GPA reflect positively in changes in CQE exam scores and are not, however, linearly related.. Because students with varying GPA's are passing the CQE exam, the researcher believes that to improve student performance on the CQE Level 1 exam, the quality in work experience must be improved. Future assessments will investigate this assumption by analyzing correlations in the quality of work experience and CQE exam pass rates.

Competency Mapping: Given ACCE accreditation standards and the required adherence of construction management programs to these accreditation requirements, competency mapping must occur at the program's curricula level to use the CQE Level 1 exam as a program assessment tools. Most importantly, competency mapping facilitates the self assessment process when using the CQE level 1 exam to assess student learning. Since deficiencies identified by the testing agency can be directly linked to ACCE core course requirements, curricula changes can be made to improve student testing performance.

Trend Analysis: Early in the study, a trend analysis is conducted to provide points of reference when making future projections. In this paper, the case study program was analyzed for pass rate and competency deficiencies over time. The goal is to understand changes in student performance (pass rate) and test deficiencies by category. Ideally, we seek to reduce the number of deficiencies and improve the pass rate of the students over time. When assuming a normal distribution with a 0.1 confidence interval, a construction management program should expect approximately 69% of the students to pass the CQE level 1.

Pass Rate: When defining learning outcomes they must be measurable. As a first step, this paper proposes an analysis of pass rate by GPA grouping. The purpose of this grouping is to establish measurable student outcomes that can be factored at various levels of student learning – GPA score. To accomplish this objective, this paper defines performance benchmarks representative of each GPA group. Overall, the four groups defined represent average (Group 1), above average (Group 2 & 3), and excellent students (Group 4). Using a descriptive analysis of the CQE test results that factors pass rate, expected student performance is compared to the actual test results. In this analysis, assumptions are tested to establish a baseline performance benchmark for future test comparisons, revealing improvements in student learning.

Frequency: As with all program of construction management, we assign superior abilities to our graduates. However this assignment and general expectation of academic excellence can only be expected within the construction management curricula as defined and mandated for ACCE accreditation. As the case study shows, despite their GPA which ranges from 2.0 – 4.0, the performance of the cohort group is representative of an average professional population. That is, the CQE level 1 exam is a national standard examination of construction professional that factors both professional and academic experiences. Thus, the performance of the case study cohort as an average test population is acceptable from a distribution standpoint. This analysis identifies differences in the competency standards of the academic program and professional practice.

Analysis of Variance: Using the benchmarks stated earlier, programs can then set measurable goals of student performance as that would reflect in a trend analysis as well as in the mean score of the GPA grouping. These changes can be plotted and compared using the analysis of means shown in the ANOVA plot. The results show that the relationship between GPA Groups and test score cannot be adequately described by a linear or quadratic term. Overall, the case study data show high variability within GPA groups and significant difference in the mean score of excellent students and all others. As a program goal, variability of test score should be reduced and overall high mean scores for all groups should increase and be significantly different. This analysis identifies how student

learning as ranked by GPA compares to the professional competency standards expected by the CQE level 1 examination.

Correlation: Finally, an analysis of correlation provides a statistical measure of the effect of student learning within the curricula and the exam categories of the CQE examination. This analysis reveals the effects of small changes in the curriculum on student learning. While a correlation coefficient of 1 is desired and represents an optimum linear relationship, student GPA and score in the current study are not linearly related and dependent. Overall, this analysis identifies core course areas in the curriculum that require improvement and the interdependency of core course areas. Categories that have no significant correlation require more attention in the case study curriculum.

References

American Council for Construction Education (2008a). Best Practices: Outcomes Assessment. ACCE Guidance Committee. http://acce-hq.org/accreditationprocedures.htm.

American Council for Construction Education (2008b). Document 100: Policy manual. http://acce-hq.org/accreditationprocedures.htm.

American Council for Construction Education (2008c). Document 102: Manual for preparing self-evaluation study. http://acce-hq.org/accreditationprocedures.htm.

American Institute of Constructors (2001). Certified Professional Constructor, Candidate handbook. St. Petersburg, Florida.