

Key Competencies for U.S. Construction Graduates: An Exploratory Factor Analysis

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This study investigated what the construction industry in the United States considered to be the key competencies for construction graduates. Specifically, this study described key competencies through an in-depth literature review and investigated the construction industry's perception of the relative importance of key construction competencies. A survey was administered to graduate recruiters for over 100 construction companies located in the eastern United States. Fourteen survey items were finalized through an in-depth discussion among the researchers and included in the third section of the survey. The competencies for construction graduates were namely ethical issues, problem solving skills, interpersonal skills, leadership, adaptability, collaborative skills, safety issues, interdisciplinary application, practical awareness, technical skills, computer skills, estimating/scheduling skills, communication, and environmental awareness. A total of 148 respondents participated in this study. Descriptive statistics revealed that ethical issues, problem solving skills, and interpersonal skills were considered by recruiters to be significant competencies for construction graduates, while communication and environmental awareness were ranked lowest. An exploratory factor analysis revealed that the competencies for construction graduates fell into four groups as follows: (1) General competency, (2) Affective competency, (3) Cognitive competency, and (4) Technical competency.

Key Words: Construction Education, Competencies, Construction Graduates, Factor Analysis

Introduction

The construction industry is a very significant part of the U.S. economy, with a total annual average employment of about 7.69 million workers as of 2008 employed in 883,000 construction establishments (USDOL 2009). As a key player in the national economy, the construction industry inevitably faces many challenges. The industry is fragmented and often inefficient (Russell et al. 2007), and is also slow to adopt, implement and integrate new information technologies and products, devoting few resources to research and development (R&D) compared to other industries (Joachim and Wible 2003; Loosemore et al. 2002). Furthermore, the construction industry has a significant negative impact on the environment including energy and water consumption, global warming, etc. (USDOE 2008).

Current and emerging technologies have heavily influenced not only construction participants but also construction practices, activities and organization. Recent technological advances in Building Information Model (BIM), mobile communication, and database management, among others, have enabled the construction industry to tremendously increase both its productivity and quality by facilitating coordination, training, supervision, decision making, and technical analysis (Ahmad et al. 1995). The ability to use these new technologies now plays a vital role in giving construction companies a competitive advantage when bidding for new contracts (Kamara et al. 2002).

As a significant part of the national economy, the construction industry has undergone significant changes in recent years and faced increasing challenges due to the complex nature of the industry, global competitiveness, changing regulatory requirements, aging workforce, new technologies, and environmental awareness (Abudayyeh et al. 2000; Ahn and Pearce 2007; Chinowsky and Diekmann 2004). To succeed in today's complex and dynamic industry, those entering the construction professions require not only a strong technical foundation of construction skills but also additional competencies such as leadership, collaboration, and problem solving skills. All these skills and

competencies must be developed and maintained throughout a professional career, starting with the undergraduate construction programs provided by our universities and including Construction Engineering and Management (CE&M) programs accredited by the *Accreditation Board for Engineering and Technology* (ABET) and the Construction Management (CM) programs accredited by the *American Council for Construction Education* (ACCE).

It is therefore crucial that construction educators in construction programs provide high quality, targeted construction education that encompasses the technical skills and competencies needed by the construction industry. In addition, since construction education is strongly related to both the construction industry and society as a whole, it is important to consider the requirements and expectations of each in order to successfully integrate all the necessary skills and competencies into undergraduate construction curricula. As a result, construction academia needs research to identify key competencies for U.S. construction graduates from the perspective of construction industry.

Background

This study was started to review the prior research findings related to competencies for construction graduates. Construction graduates are currently in high demand by contractors in all types of construction, including commercial, residential, highway, and heavy construction. Most work as superintendents; project, field, cost, schedule, design, safety and quality engineers; project managers; sales persons; and owner representatives (Abudayyeh et al. 2000). Colleges and universities in the United States offer several construction undergraduate education options, which include engineering programs such as Construction Engineering and Management (CE & M), Civil Engineering (CE), and Architectural Engineering (AE) that are accredited by the ABET.

As of July 2009, there are six CE&M programs accredited by ABET in the United States, located at: Iowa State University; North Carolina State University; North Dakota State University; Purdue University; University of New Mexico; and Western Michigan University (Abudayyeh et al. 2000; Russell et al. 2007). These CE&M programs offer a curriculum that combines engineering, technology, construction techniques, and management with the same math and science content used for other engineering degrees (Abudayyeh et al. 2000; Russell et al. 2007). The purpose of the CE&M curriculum is to prepare construction students to successfully take up engineering and management positions in the construction industry (Abudayyeh et al. 2000; Russell et al. 2007).

ACCE, established in 1974, is an accrediting agency that specializes primarily in construction education. The mission of ACCE is to be a leading global advocate of quality construction education and to promote, support, and provide accreditation for quality construction education programs (ACCE 2007). Currently, there are 61 baccalaureate CM programs accredited by ACCE, with 7 more in candidate status (ACCE 2009). The ACCE accredited construction programs in the United States are located in a variety of colleges and schools, including engineering, architecture, science and technology, agriculture and business management. ACCE defines the following five curriculum categories, with their respective minimum semester credit hours in parentheses: General Education (15), Mathematics and Science (15), Business Management (18), and Construction Science (20).

To succeed in today's complex, dynamic, interconnected, and global world, construction professionals and graduates require competencies such as a firm technical foundation of construction skills, an awareness of ethical issues, good problem solving skills, leadership abilities, an understanding of safety issues and collaborative skills. All these competencies must be developed and maintained throughout a construction professional's career, building from the base created during their undergraduate construction education. Therefore, it is crucial for educators to teach all these competencies, including both pure construction skills such as estimating, scheduling, project management, cost management, construction materials, and equipment utilization, as well as more general skills such as leadership, cultural dynamics, communication skills, team skills, ethics, critical thinking, and problem solving. For this study, these competencies were synthesized into fourteen categories required for effective construction education as a result of an in-depth literature review, as shown in Table 1.

Table 1

Competencies for Construction Graduates

Competency	Key Content & Supporting Documents
Ethical Issues	Knowledge of ethical responsibility (ABET 2000; Sinha et al. 2007); Awareness of ethical conduct and ability (Badger et al. 2005; Souder and Gier 2006; Splitt 2003; Yadva and Barry 2009)

Problem Solving Skills	Critical thinking (Mead 1995; Sinha et al. 2007); Creative Problem Solving & Research (Abudayyeh et al. 2000; Beliveau and Peter 2002a; Beliveau and Peter 2002b; Bernold 2007b; Chinowsky and Diekmann 2004; Halpern 1996; Montes et al. 2007; Russell et al. 2007)
Interpersonal Skills	Social skills (ABET 2003; Russell et al. 2007); People skills (Beliveau and Peter 2002b; Mead 1995)
Leadership	Professional responsibility (Sinha et al. 2007); Leadership & management (Badger et al. 2005; Beliveau and Peter 2002a; Beliveau and Peter 2002b; Koehn 1995; Mead 1995; Russell et al. 2007; Souder and Gier 2006)
Adaptability	(Beliveau and Peter 2002a; Beliveau and Peter 2002b)
Collaborative Skills	Teams & team work (Badger et al. 2005; Bernold 2005; Bernold 2007a; Manoliu and Bugnariu 2004; Russell et al. 2007; Sinha et al. 2007)
Safety Issues	Focus on safety (Souder and Gier 2006; Splitt 2003)
Interdisciplinary Application	Ability to think across disciplines (Bernold 2007b; Christodoulou 2004; Haselbach and Maher 2008; Russell et al. 2007)
Practical Awareness	(Beliveau and Peter 2002a; Beliveau and Peter 2002b)
Technical Skills	(Beliveau and Peter 2002a; Beliveau and Peter 2002b; Bowman 2000; Koehn 1995)
Computer Skills	Information computer skills (Christodoulou 2004; Russell et al. 2007)
Estimating/Scheduling Skills	Planning, scheduling and cost control, analysis, and operation management (Christodoulou 2004; Russell et al. 2007; Souder and Gier 2006)
Communication	Writing skills (Koehn 1995; Souder and Gier 2006) Verbal communication (Badger et al. 2005; Felder and Brent 2003)
Environmental Awareness	Environmental awareness (ABET 2003; Ahn and Pearce 2007; Montes et al. 2007; Pearce and Ahn 2009; Reynolds and Petersen 1999; Russell et al. 2007)

Purpose of Study

The purpose of this study was to investigate what the construction industry in the United States considers to be the key competencies for construction graduates. Specifically, this study's objectives were: 1) to identify construction competencies through an in-depth literature review; 2) to investigate the construction industry's perceptions of the relative importance of construction competencies and 3) to cluster these necessary skills and competencies into major categories.

Methodology

Survey research was the main method used to accomplish the research objectives. The following subsection discusses the survey instrument, the research population, and data collection procedures and analyses.

Survey Instrument

The survey instrument was developed by the authors through reviewing the literature and other survey questions. The survey instrument is composed of three sub-categories: (1) industry demographic information (company type, state, and LEED project experience); (2) interviewee demographic information (gender & job title) and (3) Key competencies for construction graduates. Fourteen survey items were finalized through an in-depth discussion between the researchers and included in the third section of the survey. Participants were asked to indicate their degree of agreement with the fourteen competencies for construction graduates by selecting one of the following responses for each item: "strongly disagree (1)", "disagree (2)", "neutral (3)", "agree (4)", and "strongly agree (5)".

Research Samples and Procedures

Once the first draft of the survey had been developed by the researchers, two construction educators reviewed the survey items and a pilot survey was performed by eleven graduate students in the Building Construction department. Based on the results and findings of the expert review and pilot study, the survey was revised and finalized for data collection. Before data collection commenced, this study was approved by XX University's Institutional Review Board (IRB). The target population for this study was recruitment specialists from construction companies in the eastern seaboard region of the United States. Major construction companies participate in a Career Job Fair for Construction Graduates hosted biannually (February and October) at XX university. Over 100 construction companies participated at each of the job fairs organized by Virginia Tech in February 2008 and 2009. Researchers distributed the survey to 100 potential interviewers (February 2008) and 120 potential interviewers (February 2009)

attending the job fairs as representatives of the construction companies and asked them to answer all three sections of the survey. This study employed descriptive statistics and exploratory factor analysis to examine participants' responses regarding their perceived key competencies for construction graduates. The analysis of the survey was conducted using SPSS 16.

Findings & Interpretation

A total of 148 respondents completed the survey, for a 67.3% response rate. They were from fourteen different states in the eastern United States, with the two largest groups coming from Virginia (42.6%) and Maryland (26.5%). The majority of the respondents described their company as a "General contractor" (66.7%). Most were male (73.9%) and their job titles included project manager (27.5%), project engineer (21.7%), human resource manager (18.8%), director (13.0%), and vice-president (10.1%).

Descriptive statistics for fourteen key competencies

The means and Standard Deviation (SD) for each of the key competencies for construction graduates as perceived by the survey respondents are presented in Table 2. The reliability (*Cronbach Alpha*) of the fourteen items was 0.827 measuring a synthesized competency for construction graduates.

Table 2

Means and SDs of Key Competency Items for Construction Graduates

Key Competency	Mean	SD	Key Competency	Mean	SD	Key Competency	Mean	SD
Ethical Issues	4.52	0.72	Collaborative Sk.	4.29	0.73	Computer Skills	3.77	0.96
Problem Solving Sk.	4.46	0.68	Safety Issues	4.09	0.94	Estimating/Sche.	3.68	0.95
Interpersonal Sk.	4.45	0.68	Interdisciplinary Ap.	4.04	0.93	Communication	3.32	0.93
Leadership	4.30	0.85	Practical Awareness	3.96	0.79	Environmental	3.00	1.06
Adaptability	4.29	0.71	Technical Skills	3.80	0.88	Awareness		

The highest mean is for ethical issues (=4.52) indicating a strong agreement that this is a key competency for construction graduates. This agrees with previous reports that ethical issues are a major competency for construction graduates, improving the quality of life and contributing to human welfare (Sinha et al. 2007; Souder & Gier 2006). Also, the items such as problem solving skills and interpersonal skills were emphasized by the respondents as key competencies for construction graduates. The lowest mean is environmental awareness (=3.00), indicating only an average agreement that this is a key competency for construction graduates.

Exploratory factor analysis

An exploratory factor analysis was performed to cluster the fourteen key competencies into categories. The key competencies identified in the theoretical background were used to explore the major competency factors for construction graduates. The factor analysis model expresses the variance and covariance in a set of observed variables. Based on the findings of the SPSS analysis (*Principal Component Analysis* and *Varimax Rotated with Kaiser Normalization*), this section presents the findings of the exploratory factor analysis. The preliminary finding of the SPSS data reduction (*Exploratory Factor Analysis*) produced four factors, as shown in Table 3.

Table 3

Principal Component Analysis

Factor	Eigen Values	Percentage Variance	Cumulative Percentage
1	4.597	32.833	32.833
2	1.803	12.876	45.709
3	1.455	10.538	56.247
4	1.117	7.981	64.228
5	0.933	6.667	70.895

Note that the sub-factors linked to the four factors have not been identified at this point; the results of the SPSS statistical analysis must be applied to identify the factors (latent variables) of each of the key competencies for construction graduates. The basic intent of the exploratory factor analysis is to determine the number of the latent variables or factors and identify the nature using the variance and covariance among a set of observed measures (Brown, 2006). The factor loadings revealed by the SPSS Principal Component Analyses are presented in Table 4.

Table 4

Rotated Matrix from SPSS

Item	Factor 1	Factor 2	Factor 3	Factor 4
Environmental Awareness	.853	-.023	.049	.044
Communication	.722	.196	.104	.330
Leadership	-.089	.829	-.002	.076
Collaborative Skills	.322	.495	.226	.179
Interpersonal Skills	.166	.805	.108	.106
Ethical Issues	.228	.389	.640	-.141
Problem Solving Skills	-.209	.493	.660	.034
Adaptability	.161	.082	.715	.391
Interdisciplinary Application	.118	.095	.761	.332
Safety Issues	.011	-.080	.699	.199
Technical Skills	.052	-.078	.351	.686
Practical Awareness	-.025	.203	.209	.700
Estimating/Scheduling Skills	.127	.079	.080	.757
Computer Skills	.297	.115	.069	.752

Based on the results of this statistical analyses, the four factors that can be used to group the competencies for construction graduates are created as follows: (1) Factor 1: *General Competency*, (2) Factor 2: *Affective Competency*, (3) Factor 3: *Cognitive Competency*, and (4) Factor 4: *Technical Competency*.

General competency consists of the two items (*Environmental Awareness* and *Communication*) with the lowest composite mean score (=3.16) and a *Cronbach's Alpha* of 0.586. Compared to the other factors, the construction industry clearly perceives these competencies to be less important. Affective competency consists of three items (*Leadership*, *Collaborative Skills*, and *Interpersonal Skills*) that have the highest mean score (=4.28) and a *Cronbach's Alpha* of 0.652. Cognitive competency consists of five items (*Ethical Issues*, *Problem Solving Skills*, *Adaptability*, *Interdisciplinary Application*, and *Safety Issues*) that have the second highest mean score (=4.28) and a *Cronbach's Alpha* of 0.768. Technical competency consists of four items (*Technical Skills*, *Practical Awareness*, *Estimating/Scheduling Skills*, and *Computer Skills*) that have a mean score of 3.80 and a *Cronbach's Alpha* of 0.794.

Discussion

As a significant part of the nation's economy, the construction industry has undergone important changes and faces new challenges due to the complex nature of the industry. To help the industry thrive, construction educators must adapt their educational goals in order to graduate students who will fit these new needs. The purpose of this study was to investigate which key competencies for construction graduates are perceived by the construction industries in the United States as being most important for their future needs. To accomplish this, researchers conducted an in-depth review of the relevant literature and administered a survey, *Key Competencies for Construction Graduates*, to graduate recruiters from over 100 construction companies located in the eastern United States.

This study was based on three backgrounds: (1) the construction industry, (2) construction education, and (3) key competencies for construction graduates identified by previous studies. In the United States, there are several undergraduate education options for construction. An analysis of previous research results and findings related to construction education produced a list of fourteen items (Table 1) which were then used to construct a survey that included these fourteen items as key competencies for construction graduates. Based on the results of the exploratory factor analysis, the key competencies that the construction industry recruiters considered important for construction graduates fell into four main categories: (1) General competency, (2) Affective competency, (3) Cognitive competency, and (4) Technical competency.

Although it was ranked last among the clusters, the construction industry does require construction graduates to possess the general competency skills, namely communication and environmental awareness. Construction activities are known to have a substantial impact on the environment and the health of those living and working in and around construction sites. The environmental impacts caused by construction activities have been clearly identified and are widely accepted by the public (Ding 2004; ahn and Pearce 2007). These major environmental impacts include global warming, climate change, depletion of the ozone layer, loss of diversity, land, air and water pollution, and the consumption of valuable resources such as fossil fuels, minerals, and gravels (Kibert 2005; Shah 2006). Many scholars have also recognized the importance of communication skills for construction graduates because the construction industry needs people who can communicate clearly and concisely (Love and Haynes 2001). Guthrie (1994) notes that graduates have often been seen as lacking communication skills, both verbal and written.

The second category of competencies, affective competency, was ranked as most important by the graduate recruiters and includes "leadership", "teamwork" "collaboration skills" and "people skills", which are closely interconnected. Many scholars have emphasized the importance of teamwork and collaborative skills for construction professionals and construction graduates. According to Spatz (1999), leadership today is about bringing out the very best people have to offer and helping to focus everyone's energy and enthusiasm along a unified front to achieve common goals. A leader in the construction industry has a people oriented-attitude, builds good relationships, provides visions and guidance, and strives for communication, cooperation, trust, and employee satisfaction (Spatz 1999; Townsend and Geghardt 1997). Because of the importance of leadership, many construction scholars have stressed that it is vital for construction education to build construction students' leadership skills. In addition, people skills are an important part of leadership in the construction industry because of the nature of construction. Because of the complex, dynamic and interrelated work of construction, teamwork and collaborative skills are necessary to successfully accomplish the work (Badger et al. 2005). Effective team skills and collaborative skills help communication between members, which improve work performance, quality and effectiveness (Busseri and Palmer 2000).

The third category of competencies, cognitive competency, was ranked second in importance by the recruiters. These competencies include an understanding of ethical issues, problem solving, critical thinking, adaptability, interdisciplinary thinking, and an awareness of safe working practices. In a sense, these are linked to the affective competencies described above, for example showing the practical side of leadership and people skills by enforcing ethical behavior and safe working practices.

Due to the nature of the construction industry, many technical competencies are required for construction graduates to be able to participate fully in construction projects (Beliveau & Peter, 2002a; 2002b; Bowman 2000). These technical competencies involve process, methods, materials, systems, equipment, planning, scheduling, safety, cost analysis, and cost control, and an understanding of management topics such as economics, business, project delivery system, finance, and accounting (ABET 2000; ABET 2007; Beliveau & Peter 2002a; 2002b; Bowman 2000; Koehn 1995). Nowadays, these technical competencies also include computer skills related to construction such as computer drawing skills, scheduling software, accounting software, project management software, and BIM.

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