

What to Teach – Electrical Survey Industry Response

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Advances in construction technology and practices reflect the need for a curriculum that addresses an increasingly complex construction environment. Most higher education learning institutions that offer a construction management program subscribe to the American Council for Construction Education (ACCE) accreditation requirements. While these guidelines for accreditation provide a degree of uniformity among institutions, they typically cover only essential core skills and do not identify every element that should be taught over an entire curriculum. This paper describes the results of an industry survey to gain feedback on what they desired from our graduates in the area of electrical knowledge. An important conclusion from this study is that skills are ranked differently by electrical contractors and construction managers or general contractors. The survey results are presented with a limited analysis of the data and observation on the findings.

Key Words: Construction Curriculum, Electrical Knowledge, Construction Education, Electrical Survey

Introduction

Historically construction management programs have risen from a variety of other disciplines. There is a wide variety of degrees and courses of study that can ultimately land a college graduate in a construction management position within the construction industry. Aspects of early civil engineering programs lend themselves to the area of construction education. Throughout the 1900's there was a growth of knowledge that somewhat formalized specialty tracts of civil engineering. In the first half of the twentieth century there were a few civil engineering programs that showed a specialization in construction engineering. As this specialization gained popularity there was more curriculum than could adequately be incorporated in the civil engineering degree. After World War II there was a gradual need for the formation of construction specialty degree undergraduate programs (Abudayyeh, Russell, Johnston, & Rowings, 2000). This specialty degree was civil engineering at its roots but incorporated aspects of structural engineering. Initially construction engineering education was civil engineering with a focus on the entire life cycle of a physical facility, which includes conception, design, procurement, construction, operation, and maintenance (Householder & Rutland, 1990). The construction boom following WWII created a demand for more construction engineers. In response to this boom there was an establishment of a Bachelor of Science degree in construction. The BS in construction was not engineering accredited but incorporated many engineering courses as its foundation.

The construction industry recognized the need for educational programs that teach the "business of managing the construction process" (Badger, Robson, & others, 2000). Construction management education's mission was to create college educated constructors. A number of universities currently offer non-engineering BS degrees in construction management, building science, building construction, and industrial technology. The American Council for Construction Education (ACCE) accredits these degrees. There are currently 62 baccalaureate construction programs accredited by the ACCE. These curricula are a combination of engineering technology, construction techniques, business and management. There is a larger emphasis placed on management and business and less on math, science, engineering and other technical knowledge in many of today's construction management programs (Abudayyeh et al., 2000).

The skills a construction manager brings to a company or project team play a major role in the success of the projects. As the demand for higher performance throughout the life cycle of new buildings increases, owners call for more complex projects insisting teams complete them "better, faster, cheaper, and always safer" (Tatum, 2005). With trends like these, industry is looking for graduates whom are able to manage the construction process and are job ready as they leave their construction management programs. Providing a construction education that parallels the changing expectations of the construction industry is the only way to achieve this. With ACCE program accreditation there is some uniformity, however a wide variety of degree titles and locations of programs within different departments at different universities exists. Construction management programs must constantly be adjusted and enhanced to address the education needs of industry and hence the students (Farooqui & Ahmed, 2009). There is no absolute way to do this without research into what the industry's perception is on the current state of construction management education.

To gain the knowledge necessary to properly adjust the spotlight of construction education curriculums is a difficult process. There is no easy or quick way of determining what is necessary to most effectively prepare the building professionals of tomorrow for their career in the construction industry. The rapid development of new technologies and innovations combined with new delivery methods and construction practices have created a demand for graduates with a strong foundation of technical knowledge to effectively manage the ever changing construction process. Within this foundation of technical knowledge there needs to be emphasis placed on electrical skills that lend themselves to a majority of construction activities.

The majority of graduates from a construction management program begin employment with either a construction management (CM) or general contracting (GC) firm. Placement opportunities with specialty contractors do occur however, as the general knowledge offered by the construction management program's in estimating, scheduling, contracts, materials, and management skills make graduates attractive to specialty contractors. In developing a course in the electrical area it is desirable to teach topics that not only benefit the GC/CM environment, but also the electrical contractor (EC).Within the past 3 years, Auburn University conducted curriculum reviews to ensure compliance with ACCE requirements and to also determine if the needs of supporting industry partners were being met. One result of the review concluded that industry would like to see graduates have a better understanding of electrical and mechanical subjects. In response to this, the curriculum was expanded from one combined three hour mechanical/electrical course to two separate three hour courses, each with a lab component. Once the decision was made to change the course content, the next logical question was to ask just what should be taught in these courses. To answer this question a survey was developed and distributed to various members of industry. Since only a limited number of curriculum hours can be devoted to the electrical subject, it became clear that a research tool needed to be structured so that topics could eventually be ordered in a most desirable to least desirable hierarchy. An added advantage to obtaining results that allow topics to be ranked makes the results useful for other institutions that may devote additional hours to the subject with multiple courses or specialty tracts. The results of this research led to the development of an extensive survey which was delivered to industry professionals, both GC/CM companies as well as electrical contractors, to answer the question, what topics should be covered in an electrical course as part of a construction management degree.

Objectives

To identify what key skill sets need to be contained within the construction management curriculum for an electrical systems course to fulfil the needs of specialty contractors as well as general contractors and construction management firms.

Methodology

The research methodology consisted of the following steps:

Development of a questionnaire based survey used to elicit information about the desired skills construction management students should have upon graduation in the area of electrical systems.
Conducting the survey through in-person as well as email and online distribution methods.
Analysis of the survey results to identify the industry's desired skills.

The focus of the survey was to identify electrical skills the respondent thought would be beneficial for a graduate of a construction management program. The questions were prepared after an extensive review of current curricula being taught at Auburn University including many texts typically used in the electrical classes within construction management programs. The National Electrical Code® was also used to determine appropriate skill set questions.

Two initial questions were asked to gather information about the respondent's type of company - General Contractor (GC), Construction Management (CM), Electrical Contractor (EC), or Other, and to determine the type of work the respondent is most involved with (e.g. healthcare, educational, office, retail, hotel/apartment/ condo, industrial, or other). Fifty two questions identified specific electrical skills divided into 11 categories: 1) electrical project execution, 2) electrical utilization equipment, 3) electrical circuits, 4) general electrical requirements, 5) electrical materials, 6) emergency systems, 7) special systems, 8) lighting, 9) electrical distribution equipment, 10) building electrical systems, and 11) electrical principles. Participants were asked to rate each question using a Likert scale, with 1 being the least important and 6 being a crucial topic.

Details on how the survey was developed can be found in an ASC Proceedings Paper entitled "Deciding What to Teach in a Specialty Contracting Field – an Industry Survey" by Mark C. Tatum and David Nelson.

The survey was distributed to electrical industry throughout the United States using Electri International and the National Electrical Contractors Association (NECA). Respondents from the general building industry in the South Eastern United States were solicited using the Associated Builders and Contractors Association (ABC), and the Associated General Contractors Association (AGC).

Data and Results

To date 160 surveys have been distributed with 87% or 139 respondents completing the survey. Figure 1 shows the breakdown of respondents based on their company's category. Figure 2 indicates the respondent's particular area of expertise.

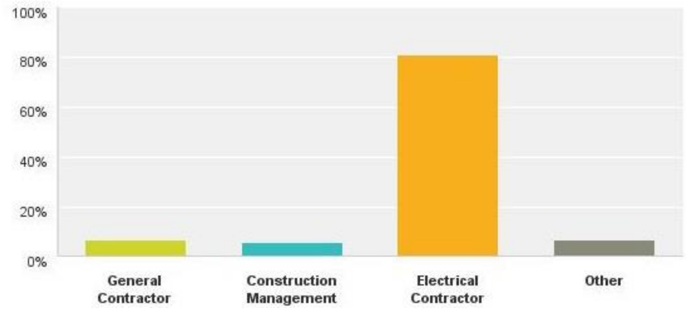

Figure 1: Survey Respondent's Company Demographics

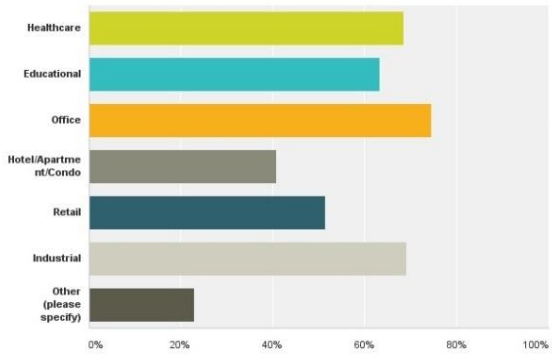

Figure 2: Survey Respondent's Area of Expertise

Data Analysis

The data collected from the survey was analyzed by using the mean level of significance for each electrical skill based on the Likert scale response. This was used to compare and rank the relative importance of the individual skills and to determine what the respondents felt were the most important skills for a construction management graduate. The overall survey results can be found in the appendix.

The first observation was to notice the overall mean level of significance of the electrical subjects as registered by the respondents. In Figure 3 it can be seen that the electrical contractors placed more overall importance on the electrical subjects than did the respondents outside the electrical contracting field. This can most likely be attributed to the electrical contractor's focus in this area. While all the questions are limited to electrical subjects, this difference in respondent's level of importance could impact the relative ranking of a given subject. For example, estimating or scheduling might receive an overall higher ranking than another subject because of the GC and CM's familiarity with this activity and its importance in their area of work. This impact would also vary according to the number of survey responses obtained from the different groups.

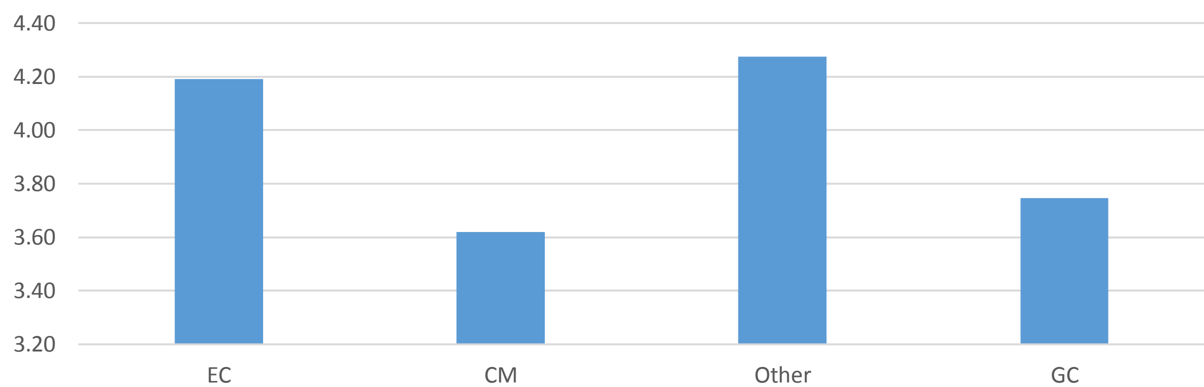

Figure 3: Overall Survey Mean Responses by Trade

Figure 4 shows the 11 categories of electrical questions. These category mean ratings were obtained by averaging the ratings of all the questions asked within that category. This allows one to find which category has the highest level of value according to the industry respondents. From the figure, it can be seen that the categories with the highest mean value are: general electric requirements, electrical project execution, building electrical systems, and electrical distribution equipment.

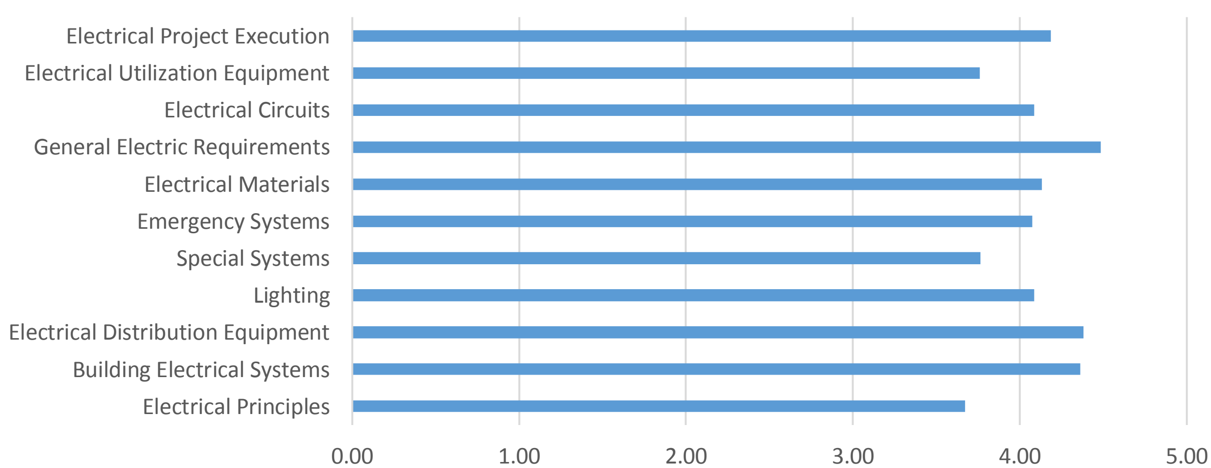

Figure 4: Average Rating for Electrical Question Categories

Within these categories, there are important skills for all trades encompassing areas from management skill to safety knowledge. The electrical project execution subcategory was especially rated highly by the Construction Management profession. This category includes skills paramount to the safety of the jobsite such as OSHA requirements and compliance with the National Electrical safety code. The electrical project execution category also includes items such as the ability to understand temporary jobsite power and lighting requirements, the ability to write and review contract documents, and the ability to coordinate work with other trades. These are all skills needed to be a successful CM or GC where the responsibility to oversee the jobsite is theirs.

The appendix shows the survey responses to all individual questions. It is presented in a way that allows one to see the question, the category, and the group (EC, GC, CM or Other) responding. Each group (trade) rank is an average of all responses for that question from that group. The overall ranking at the right of the table is weighted by the number of responses obtained from each group.

The electrical contractor felt knowledge of building electrical systems was of high importance. The knowledge of how single phase and three phase systems as well as voltage differences in systems is desired of graduates. These very technical skills are required to have an understanding of why a certain system was specified within a building and how that system works. By looking at how each group answered the questions one can begin to develop an understanding of why the different trades may value different skills differently. By looking at how the trades answer the question “please rate on a scale of 1-6, Ability to read and understand control diagrams, ladder diagrams, relays, interlocks, and switches” it can be seen that the electrical contractor assigned this skill a mean value of 4.39 on a scale of 1 to 6. It is safe to say that this is a skill necessary to carry out their daily work and important to the electrical contractor’s scope of work. The GC rated this with 3.2. While a GC may understand relays and interlocks, he may not know how to read the ladder diagrams. Since this is not in his immediate scope of work, it may be of lesser importance to the GC and thus received a lower level of importance than for the electrical contractor. This same process can be used to analyze any of the other skills and traits.

Conclusions

Every trade places a different amount of value or priority to electrical education within a building science curriculum. What was found was industry desires graduates who have an overall knowledge of the electrical field. Many students will end up working for a GC or CM where the ability to interact and communicate with other trades especially the electrical trade is paramount to the success of a project. The GC and CM trades would like to see a curriculum that provides students an overview of the electrical field. They would like to have the curriculum concentrate and provide a more in depth knowledge of areas such as OSHA regulations, the ability to coordinate work between trades. They also seek students who are able to read the documents, both plans as well as contract documentation. Some students will end up working for an electrical contractor where students who are proficient in understanding electrical plans and electrical equipment are desirable. The electrical contractor would like to hire students with a good understanding of the electrical field but who also have the skills taught in other areas of the building science curriculum.

Even though there are some differences in the responses among the groups, there is much agreement as to the electrical skills desired in students. These skills therefore should be the basis for the curriculum for a building science electrical course. Some of the skills found common to all groups include:

The ability to provide coordination with both other contractors and systems found on a job
The ability to understand and read panel schedules
The ability to understand and read single line diagrams
The ability to understand basic electrical plan symbols
The knowledge of OSHA requirements
A knowledge of electrical distribution systems
A understanding of major electrical equipment

There are numerous other statistical analysis exercises that can be done to extract useful information from this data. Due to the limitation of space for a proceedings publication, this paper only deals with the presentation of the data itself. Using the results from this survey, one can not only determine what subjects should be taught but also how much time should be spent in specific areas. Since individual programs allot different course hours to be devoted to electrical subjects, the relative time spent on individual subjects is an important result of the analysis.

A subsequent paper is planned where further analysis will be performed to develop an electrical course outline suitable for a construction management program. This study will define what will be taught and how much time should be dedicated to each topic. It will also define how much depth each topic will address.

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Appendix A

Survey Response Data

Rank	Question # and Descriptions	EC	CM	GC	Other	Overall Rank
1	Understanding and reading electrical single line (or riser) diagrams	5.05	4.63	4.50	5.17	4.88
2	Understanding basic electrical plan symbols	4.92	5.00	4.60	5.17	4.81
3	OSHA requirements	4.79	5.13	4.80	4.83	4.71
4	Types of major electrical equipment-switchboards, switchgear, panel boards, load centers, motor control centers, and transformers	4.75	4.25	4.50	5.00	4.63
5	Lock-out/Tag-out procedures	4.72	4.88	4.40	4.33	4.60
6	Learning typical coordination requirements with other contractors and systems	4.64	4.75	4.30	4.50	4.53
7	Electrical distribution systems- why are there different system voltages	4.62	4.50	4.20	4.71	4.51
8	Familiarity with the National Electrical Safety Code	4.71	3.63	3.90	4.67	4.50
9	How single phase and three phase systems work-what is the difference	4.57	3.78	4.90	4.57	4.46
10	Preparing an electrical bid including labor and markups	4.75	3.63	3.10	4.00	4.44
11	Ability to perform an electrical plan take-off	4.80	2.38	3.20	4.33	4.44
12	Review of typical contracts for electrical work with different delivery methods-prime contractor, sub-contractor,	4.55	4.63	3.80	4.83	4.43

	design build, etc.					
13	Understanding and ability to read panel schedules	4.51	4.38	4.20	5.00	4.42
14	Lighting sources- fluorescent, incandescent, HID, LED, etc.	4.50	3.88	4.40	4.29	4.37
15	Electrical equipment clearances and installation requirements	4.56	4.13	3.60	4.00	4.37
16	Wiring methods-conductor cables, conductors in raceways	4.47	3.38	4.40	4.60	4.34
17	Electrical grounding and bonding requirements	4.55	3.25	3.30	4.50	4.32
18	Electrical raceway systems-conduit types, cable tray, wire ways, flexible conduit, etc.	4.46	3.50	4.10	4.33	4.30
19	Circuit Breakers and Fuses- overcurrent and short circuit protection	4.44	3.25	4.10	4.83	4.30
20	Writing an electrical scope of work	4.40	4.00	4.10	4.33	4.28
21	Determining crew size and project man loading schedules	4.58	3.00	3.20	3.67	4.28
22	Calculating basic circuit sizes- finding the ampacity requirements for branch circuits and feeders	4.42	3.13	3.40	4.67	4.22
23	Acquiring pricing information from vendors and other sources	4.31	4.50	3.90	4.17	4.22
24	How electrical panels supply different voltages- 1 pole, 2 pole, & 3 pole circuit breakers	4.33	3.50	4.10	4.57	4.22
25	Generators and UPS systems	4.31	4.25	3.70	4.00	4.19
26	Ability to read and understand control diagrams-ladder diagrams, relays, interlocks and switches (limit, proximity, temperature, pressure, flow, etc.	4.39	3.00	3.20	5.00	4.19
27	Lighting control systems- dimming, automation, and energy savings	4.23	3.75	3.80	4.67	4.14
28	Understanding conductor ratings-insulation type, temperature, and ampacity	4.32	2.75	3.70	4.50	4.14
29	Arc Fault and Ground Fault equipment requirements	4.30	3.25	3.40	4.33	4.12
30	How series and parallel circuits are used in buildings-switches and load connections	4.14	4.00	4.60	4.33	4.12
31	Voltage drop in circuits and how to calculate	4.27	2.38	3.30	4.43	4.06
32	Fire Alarm systems	4.10	4.13	4.20	3.83	4.05
33	Electrical devices-receptacles, switches, disconnects, and fixtures- NEMA designations	4.13	3.25	4.00	4.50	4.03
34	Battery backup for egress/emergency lighting	4.09	4.13	3.40	3.83	3.99
35	Transformer Types-how they function	3.98	3.38	3.60	4.14	3.90
36	Temporary jobsite power and lighting	3.83	4.88	4.30	3.83	3.89
37	Methods used to make wiring connections-marking & color coding	3.90	3.88	3.40	4.33	3.85
38	Requirements and calculations for motor circuits- short circuit and overload protection for single phase and 3 phase motors	4.03	2.63	2.80	4.33	3.83
39	Lighting design-calculating lighting levels	3.92	2.75	3.60	3.86	3.80
40	Residential and commercial service calculations	3.81	2.38	3.30	4.20	3.68
41	Requirements and calculations for air conditioning circuits-nameplate ratings, minimum circuit ampacity, maximum fuse/circuit breaker size and full load amps	3.79	3.00	3.00	4.17	3.68
42	Measuring AC voltage and current-true RMS values and harmonics	3.77	3.00	3.30	3.71	3.67
43	Ability to use typical metering and test equipment	3.69	3.00	3.90	4.17	3.67
44	Communication systems-telephone and data	3.61	4.00	3.80	4.17	3.66
45	AC and DC systems-why do we use AC for buildings	3.59	3.78	3.80	4.57	3.65
46	Access control systems- (card, keypad, etc.) and intrusion detection	3.46	3.88	3.20	4.00	3.48
47	Electrical Energy Sources-solar, batteries, generators, hydro-electric, nuclear, coal, etc.	3.50	2.78	3.40	4.00	3.47
48	Intercom, Nurse Call, and other audio systems	3.32	4.25	3.10	3.33	3.36

49	Power factor in AC circuits-primarily caused by motor loads and is considered in generator sizing	3.34	2.88	2.90	3.43	3.29
50	Installing and connecting basic electrical devices and equipment- outlets, switches, fixtures, etc.	3.29	2.88	3.30	3.17	3.27
51	How to bend conduit and pull wire	3.28	2.25	2.90	3.00	3.20
52	Ability to make electrical connections- including communication cable terminations	3.22	2.75	2.90	3.33	3.19