AC 2007-870: ARCHITECTURAL ENGINEERING PROGRAMS: FINDING COMMON GROUND

Allen Estes, California Polytechnic State University

Allen C. Estes is a Professor and Head for the Architectural Engineering Department at California Polytechnic State University in San Luis Obispo. Until January 2007, Dr. Estes was the Director of the Civil Engineering Program at the United States Military Academy (USMA). He is a registered Professional Engineer in Virginia. Al Estes received a B.S. degree from USMA in 1978, M.S. degrees in Structural Engineering and in Construction Management from Stanford University in 1987 and a Ph.D. degree in Civil Engineering from the University of Colorado at Boulder in 1997.

Hector Estrada, University of the Pacific

Hector Estada is currently Professor and Chair of the Department of Civil Engineering at the University of the Pacific; a position he has held since August 2006. Prior to joining Pacific, Professor Estrada was chair of the Department of Civil and Architectural Engineering at Texas A&M University-Kingsville. While at Texas A&M Kingsville, he was instrumental in establishing a new program in Architectural Engineering and a regional division of the Texas Transportation Institute. Professor Estrada received his B.S. (with honors), M.S., and Ph.D. in Civil Engineering from the University of Illinois at Urbana-Champaign in 1993, 1994, and 1997, respectively.

Architectural Engineering Programs: Finding Common Ground

Abstract

There are currently 17 ABET accredited Architectural Engineering programs in the United States. This paper presents curriculum data for these Architectural Engineering programs and discusses the challenges of finding common ground and conveying program needs to the rest of the academic community – especially when the programs are so small in number and so diverse in their structure and course offerings.

I. Introduction

There are currently 17 ABET accredited Architectural Engineering (AE) programs in the United States. Most are four year undergraduate programs, but almost 25% are five year programs (4 out of 17). Some offer masters degrees, while others do not. A couple of programs offer Ph.D.s in Architectural Engineering or Building Systems. About half of the AE programs are located within departments of civil engineering, while the other half are departments in their own right. Most fall under the college of Engineering, but two of the programs are housed in the School of Architecture. One is located in the College of Engineering, but admits students through the College of Architecture. The ABET program accreditation criteria require coverage in two of the three areas of structures, electrical/ mechanical systems, and construction. Some programs are very balanced and offer a full complement of courses in electrical, mechanical, acoustical and lighting design. Others focus heavily on the structures area and offer little in at least one of the other categories. Two of the programs are very focused on architecture, with nearly half of the AE content concentrated in architecture. This paper will examine the undergraduate curriculum data on the 17 ABET accredited Architectural Engineering programs and will discuss the challenges of finding common ground and conveying program needs to the rest of the academic community – especially when the programs are so small in number and so diverse in their structure and course offerings.

II. The Nation's Architectural Engineering Programs

Because there are so few AE programs, many incoming students are confused about the major and how it differs from Architecture or Civil Engineering. Architectural Engineering involves the engineering design, construction and operation of safe, functional, efficient, economical, aesthetically-pleasing buildings. AE deals with all engineering aspects of a building's performance that support the architectural and functional requirements. These engineering aspects commonly include structural systems; mechanical systems such as heating, ventilation, air conditioning, and plumbing; electrical systems such as lighting, power distribution, control and communications; and other systems such as acoustics and fire safety.

Table 1 shows a listing of the 17 Architectural Engineering programs in the United States that are currently accredited by ABET. Geographically, seven of the programs are located in the Midwest and three are in the South. There are two programs in the Southwest, Rocky Mountain, and Northeast regions, with only one program located on the West Coast. All of the AE programs reside in a College/School of Engineering, with the exceptions of Oklahoma State and Cal Poly San Luis Obispo,

which are included in the Colleges of Architecture. Ten of the programs are collocated in departments that also manage civil engineering programs while the remaining seven are either separate departments or are collocated with programs other than civil engineering such as facilities or construction engineering,

The relationship between architectural and civil engineering is an interesting one since there are so many more civil engineering programs in the U.S. In 2005, there were 722 bachelor degrees awarded in architectural engineering while there were 8247 awarded in civil engineering[1] – more than ten times as many. While the relative difference in enrollments will vary from school to school, civil engineering gets more attention and emphasis at the national and professional society level. One can draw inferences about the relative influence within a university from the number of degrees conferred. Figure 1 shows the number of bachelor degrees in both AE and CE awarded in the 2004-2005 academic year for those schools with accredited AE programs.[1] Milwaukee School of Engineering is the one school in the study that does not offer a civil engineering program. Also, the University of Oklahoma was not accredited by ABET until 2006.

	University	Department	College/School
1	Drexel University	Civil, Architectural and Environmental	Engineering
2	Kansas State University	Architectural Engineering and Construction Science	Engineering
3	Illinois Institute of Technology	Civil and Architectural	Engineering
4	University of Nebraska	Architectural Engineering	Engineering and Technology
5	Milwaukee School of Engineering	Architectural Engineering and Building Construction	Engineering
6	University of Wyoming	Department of Civil and Architectural Engineering	Engineering
7	Oklahoma State University	School of Architecture	Engineering , Architecture and Technology
8	Penn State University	Architectural Engineering	Engineering
9	California Polytechnic State University	Architectural Engineering	Architecture and Environmental Design
10	University of Kansas	Civil and Architectural	Engineering
11	University of Texas	Civil, Environmental and Architectural Engineering	Engineering
12	North Carolina A&T State College	Civil, Architectural and Agricultural and Environmental Engineering	Engineering
13	Tennessee State	Architectural and Facilities Engineering	Engineering, Technology and Computer Science
14	University of Colorado	Civil, Environmental and Architectural Engineering	Engineering
15	University of Miami	Civil, Architectural, and Environmental	Engineering
16	University of Missouri Rolla	Civil, Architectural, and Environmental	Engineering
17	University of Oklahoma	Civil and Environmental	Engineering

Table 1. A listing of the seventeen accredited architectural engineering programs and their associated departments and colleges

The most common overlap between the two disciplines is in the area of structures. While structures is one of the most common sub-disciplines of civil engineering, all of the current AE programs include structural design of buildings in their curricula. In cases where the AE and CE programs are collocated in the same department, it is common for faculty with a structures background to teach both

AE and CE students, often in the same class. In universities where they are in separate departments and in some cases separate colleges; there is either some duplication of effort or at least some cross-listing of courses.

It is difficult to compare the 17 AE programs since four of the programs (Penn State, University of Kansas, Kansas State, and Oklahoma State) are five year programs, while the others are four year programs. Most of the schools are on a semester system with the exception of Cal Poly, Drexel, and Milwaukee which are on a quarter system. Table 2 shows the seventeen AE programs and lists the length, type of system, credit hours and equivalent semester credit hours. For schools on the quarter system, the equivalent semester credit hours were obtained by multiplying by two-thirds.

The Academic Council of the ASCE Architectural Engineering Institute (AEI) recently discussed how the various national programs could be ranked with the possible inclusion of AE programs in the annual U.S. News and World Report rankings, or other such a ranking avenue. Because the programs have different areas of emphasis and are of different lengths, such a ranking would require making some value judgments. Is a program that is balanced in the designated AE specialties better or worse than a program that focuses more heavily in one area at the expense of others? Is the material that is covered in the extra year of a five year program better or worse than the year of experience gained by those who graduate in four years? It is probably better to advertise the strengths of the available programs and let the students and industry help decide. However, the exposure at the national level in such a magazine would help strengthen the status of AE as an engineering discipline, and provide advertisement for the profession.

University	Length of Program (Years)	Semester or Quarter	Credit Hours	Equivalent Semester Credit Hours
Drexel	4	Quarter	200[2]	133
Kansas State	5	Semester	158[3]	158
Illinois Institute of Technology	4	Semester	136[4]	136
University of Nebraska	4	Semester	126[5]	126
Milwaukee School of Engineering	4	Quarter	197[6]	131
University of Wyoming	4	Semester	132[7]	132
Oklahoma State University	5	Semester	160[8]	160
Penn State	5	Semester	160[9]	160
Cal Poly SLO	4	Quarter	203[10]	135
University of Kansas	5	Semester	165[11]	165
University of Texas	4	Semester	126[12]	126
North Carolina A&T State College	4	Semester	128[13]	128
Tennessee State	4	Semester	126[14]	126
University of Colorado	4	Semester	128[15]	128
University of Miami	4	Semester	129[16]	129
University of Missouri Rolla	4	Semester	128[17]	128
University of Oklahoma	4	Semester	128[23]	128

Table 2. A listing of the length and type of program for the seventeen accredited AE programs

III. Curriculum Analysis

The seventeen AE programs have a number of differences, but share more similarities than it initially appears. Once the number of credits are adjusted to equivalent semester hours, the four year programs range between 126 and 138 credits hours. The five year programs are closer to each other containing between 158 and 165 credit hours.

The program accreditation criteria undoubtedly account for a number of similarities in the programs. The ABET program criteria for AE programs[18] require "proficiency in mathematics through differential equations, probability and statistics, calculus-based physics, and general chemistry" which mandates a substantial math and science component to every program. Because there is a specific requirement for proficiency in statics, strength of materials, thermodynamics, fluid mechanics, electric circuits, and engineering economics, those topics appear in each program, usually through a dedicated course. In the specific areas associated with architectural engineering, the criteria are more flexible requiring proficiency in only two of the three areas of structures, electrical/mechanical systems, and construction. Finally, architecture is included into each curriculum with the minimal requirement for "understanding of architectural design and history leading to architectural design that will permit communication, and interaction, with the other design professionals in the execution of building projects."

For each of the programs, the curriculum was analyzed and each course was classified into one of the following categories:

- A: *Communications* –includes any course with the purpose of writing, public speaking, technical presentation, or a required English elective. This category was separated from general humanities electives because of the increased industry emphasis on producing graduates with adequate communication skills, and ABET specifically requires this as part of the outcomes assessment criteria. Admittedly, some universities include their communication courses on a larger list of electives that were included as humanities electives.
- B: *Humanities* – most programs had some breadth requirement that included courses in political science, economics, history, psychology, sociology, etc.
- C: *Math and Science* – these courses included math (calculus, statistics, differential equations), basic science (chemistry, physics, biology, ecology), and computer science where the emphasis is on programming or computer theory rather than CAD drawing or computer applications.
- D: *Engineering Science* – courses such as statics, thermodynamics, electrical circuits, fluid mechanics etc. that provide the theoretical concepts that will be used for engineering design.

The next three categories are all engineering analysis and design courses

- E: *Structures* – this categories include those courses commonly included in structural engineering. In this study, structural analysis and soil mechanics were included in this category
- F: *Electrical/Mechanical Systems* – this category includes courses that support the design of electrical and mechanical systems in buildings. Courses that cover lighting, acoustics, fire safety, and environmental controls fell into this category.

- G: *Construction* – courses that would normally be part of a construction program fell into this category and include project management, contracts and specifications, construction materials, construction methods, construction law and construction estimating. In cases where the engineering economics course had an obvious emphasis on construction financing or investment, that course was included in this category.
- H: *Technical Electives* – this category became too cumbersome to be useful. Every program offers a different number and variety of electives. Some offered program options into one of the areas listed in categories E, F, and G above. For this study, the technical electives were incorporated into categories E, F, and G in the relative proportion that they appeared on the electives or options list.
- I: *Other* – this category included those courses that did not fit logically elsewhere. It included courses such as physical education, university experience, engineering economics, professional practice, and surveying.
- J: *Freshman Engineering* – these are courses offered to freshman that precede any of the engineering science courses. The courses in engineering graphics, introduction to engineering, and the engineering profession were all included in this category.
- K: *Architecture* – courses taken from the university's architecture program are included here. Almost every program has something in this category because of the accreditation requirement for the history of architecture. Those AE programs that require students to participate in architecture design studio courses have a much greater number of these courses.
- L: *Capstone Design* – many programs offer a senior project course that requires a complete design of a complex system. It is a culminating experience that requires students to synthesize and use all of the skills developed in the program. The content of these courses would mostly fit into the categories E, F, and G above, but is listed here.

The information for making this assessment was taken from the website postings for the individual universities listed in the references from Table 2. In many cases, the on-line course catalogue description was consulted to place a course in the appropriate category. The advantage of this approach is the consistency achieved when the same individual conducts the assessment for each program. The disadvantage is the lack of familiarity with a program that could lead to a mistaken classification or misrepresentation of a program. In many cases, compromises were made, particularly with electives, where a different individual might make a different classification for some courses. In any event, the assessment is sufficiently accurate to highlight the various strengths and differences within these AE programs.

Figure 2 shows the curriculum analysis for the AE program at Drexel University. It indicates that a student attending the AE program at Drexel will receive significant coverage of math, basic science and engineering science. There appears to be a stronger emphasis on electrical/mechanical systems than on structures or construction and there is significant exposure to courses in architecture. Similar figures are available for the other 16 programs, but limited comparative information can be gained from looking at the programs in isolation.

Figure 3 offers comparative information in the specific AE areas of structures, electrical/mechanical systems, and construction. Courses in architecture are included as well. Because the senior design consists primarily of the AE specialty areas, it is also present. Several

key differences are immediately apparent. The programs at Cal Poly and Oklahoma State offer a heavy emphasis in structures and architecture at the expense of both construction and electrical/mechanical systems. A student at the University of Kansas or the University of Oklahoma will take a substantial number of Architecture courses. The most balanced program with the most number of semester hours seems to be Penn State. Since Figure 3 is based on semester hours, the four five-year programs stand out over the four year programs.

Figure 4 attempts to remove this bias towards the five year programs by looking at the AE specialty areas as a relative percentage of emphasis. It becomes clearer from this figure that the University of Colorado and University of Miami also have created balanced programs that draw somewhat equally from all of these AE specialty areas. Conversely, Tennessee State has a perfectly balanced program in these areas, but as Figure 3 indicates, they offer relatively few credit hours in any of these areas. These figures indicate that a student who wants more emphasis in a particular area can choose an AE program accordingly. For example, a student wanting to study electrical/mechanical systems in a four year program would be well served by either the University of Wyoming or the University of Nebraska. However, the cost is that there is very little Architecture at Wyoming and almost no construction taught at Nebraska. Similarly, the University of Texas would be an excellent program for someone wanting additional emphasis in construction.

Figure 5 shows the relative emphasis as a percentage of the total curriculum that each AE program devotes toward communications, humanities, math and basic science, and engineering science. Most programs devote 20-30% of the curriculum to math and basic science and 10-20% of the curriculum to engineering science. Tennessee State stands out as offering a greater percentage of its curriculum to communications courses (12%) than the remainder of the programs.

IV. Why is this important?

When the AE programs are so diverse, it can be difficult to find common ground and collaborate in an effective manner. One might ask why this is important. Some diversity in programs should be embraced and one would not want all of the programs to be the same. While these differences in emphasis in the AE specialties allows more choice for prospective students, there is some need for commonality, collaboration, and consensus among the nation's AE programs for some of the following reasons.

- Because there are only 17 accredited AE programs, it is easy for their needs to be overlooked. If the programs can develop a common position on many issues, it will be easier to communicate their perspective forcefully to the rest of the academic community.
- The AE programs need to provide input and attempt to reach consensus toward what the AE program accreditation criteria should be. In many ways, the accreditation criteria are the biggest contributor to the degree of commonality that currently exists among AE programs. All seventeen programs offer the history of architecture probably because the accreditation criteria require it. The common list of engineering science courses is at least partially attributable to the accreditation requirements. The differences in the structural, electrical/mechanical, and construction offerings are present because the accreditation criteria are flexible enough to require proficiency in only two out of three of

these sub-disciplines. Because the accreditation criteria are so important to the content of AE programs, the various programs all need to be providing input to both the criteria and the commentary that supports it.

- The American Society of Civil Engineers (ASCE) is the lead professional society for writing the program accreditation criteria for both civil engineering and architectural engineering programs. In 2005, there were 213 colleges and universities offering civil engineering degrees[1], a number that brings overpowering influence and dominance of effort toward civil engineering programs over architectural programs. The Academic Council of the ASCE Architectural Engineering Institute (AEI) is the primary means by which the various AE programs confer and discuss issues that affect their respective programs. There are many other professional society venues where the AE programs do not appear to be well represented. The ASCE Committee on Curricula and Accreditation (CC&A) focuses exclusively on civil engineering programs. The only comparable body in AEI is a recently formed ad hoc committee charged with developing a commentary for the ABET AE program criteria The ASCE Department Head Council Executive Committee (DHCEC) is a committee of civil engineering department heads that provides oversight and advice to the ASCE Educational Activities division. DHCEC currently has no AE representative and there is no equivalent committee to provide the AE perspective for educational activities. The AE programs would benefit greatly by uniting and lobbying for greater participation and input into the various ASCE educational activities.
- The civil engineers are leading ground-breaking initiatives that will ultimately affect AE programs. ASCE Policy 465, which makes the masters degree the first professional degree in civil engineering[19], is making great strides toward completion. The National Council of Examiners in Engineering and Surveying (NCEES) recently voted to amend the model law to require thirty hours of coursework above the bachelor degree for professional licensure[20]. Graduates of AE programs will inevitably be affected by this as many states will certainly adopt the model law into their own professional licensure requirements. Up to this point, AE programs have provided little input or participation in this effort.
- The civil engineers have published a body of knowledge (BOK)[21] that lists the skills and attitudes that civil engineers are expected to attain. These include additional skills beyond those required by ABET, such as leadership, project management, business policy and ethics. The new ABET civil engineering program criteria[22] have been approved by the Engineering Accreditation Commission and will probably go into effect after the one year review period. The AE program criteria will likely be affected by these initiatives in the future.
- Many prospective students do not understand what architectural engineering is and are confused as to how it differs from architecture. When the available programs have widely different areas of emphasis, it becomes more difficult to communicate what constitutes architectural engineering.
- Many engineering majors and their professional societies sponsor student chapters and conduct student regional conferences that hold student competitions. With the exception of the Midwest, it is hard for AE programs to conduct a regional conference due to the small number of programs. A standardized student competition has not been developed because the AE content varies so widely among programs that it is difficult to devise a competition in which all programs could fairly compete.

V. Conclusions

It is to the advantage of the seventeen accredited AE programs to continue to meet, discuss and develop unified positions on the various issues that affect their programs. The AE programs should become more involved in the ASCE educational activities committees and with the civil engineering programs. Because there are so many more civil engineering programs, the AE programs should join with the civil engineering programs whenever it is to their advantage and receive the increased exposure and influence that larger disciplines provide. Still, the AE programs should retain their individual identity as a separate discipline, also when it is to their advantage. This paper has shown that the various AE programs are very similar in some regards and very different in others. The ABET program accreditation criteria seem to be the mechanism for enforcing standards of commonality and for allowing the flexibility to be different. The various AE programs should all be actively participating in the drafting of these program criteria.

Disclaimer: The opinions expressed in this article are those of the authors and do not necessarily reflect the viewpoints of the AEI Academic Council, ASCE, or the AE programs listed herein.

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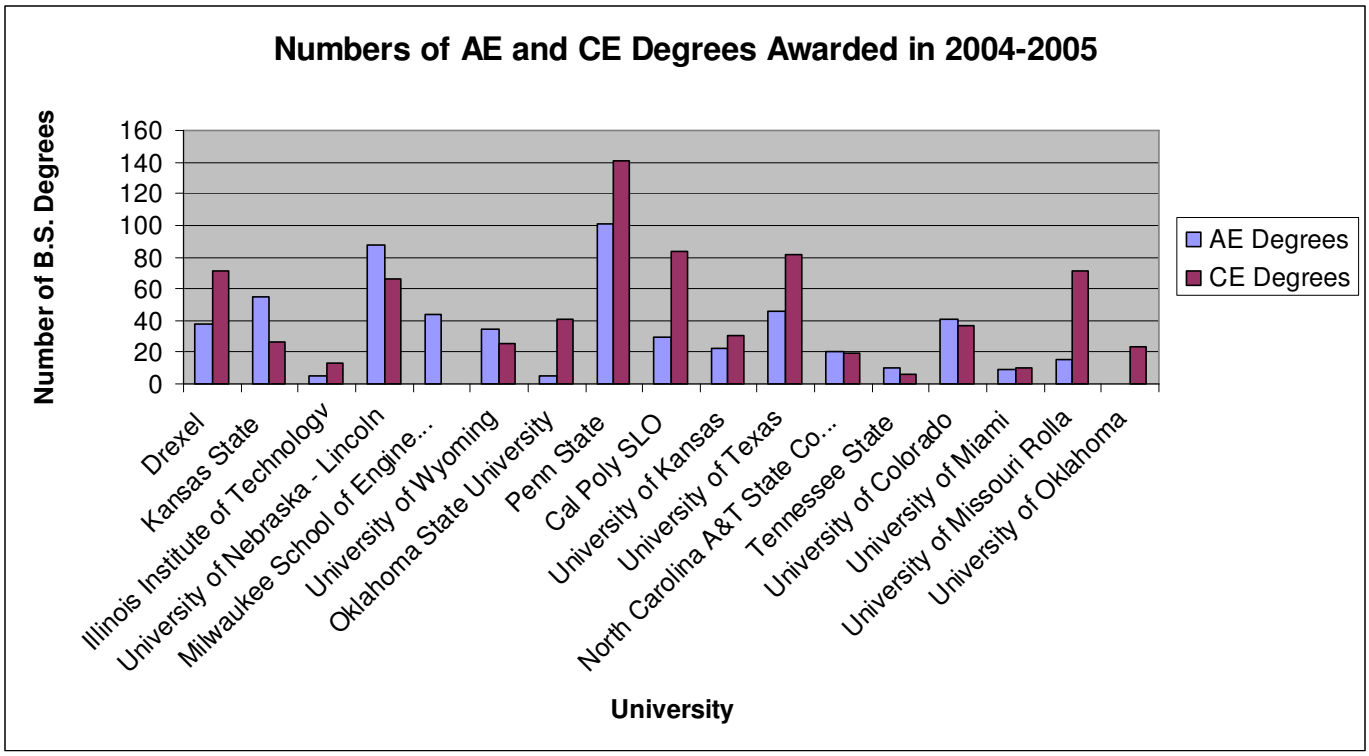

Figure 1. A comparison of the number of bachelor degrees awarded in the 2004-2005 academic years awarded in both Architectural Engineering (AE) and Civil Engineering (CE) for those universities with an accredited AE program.[1]

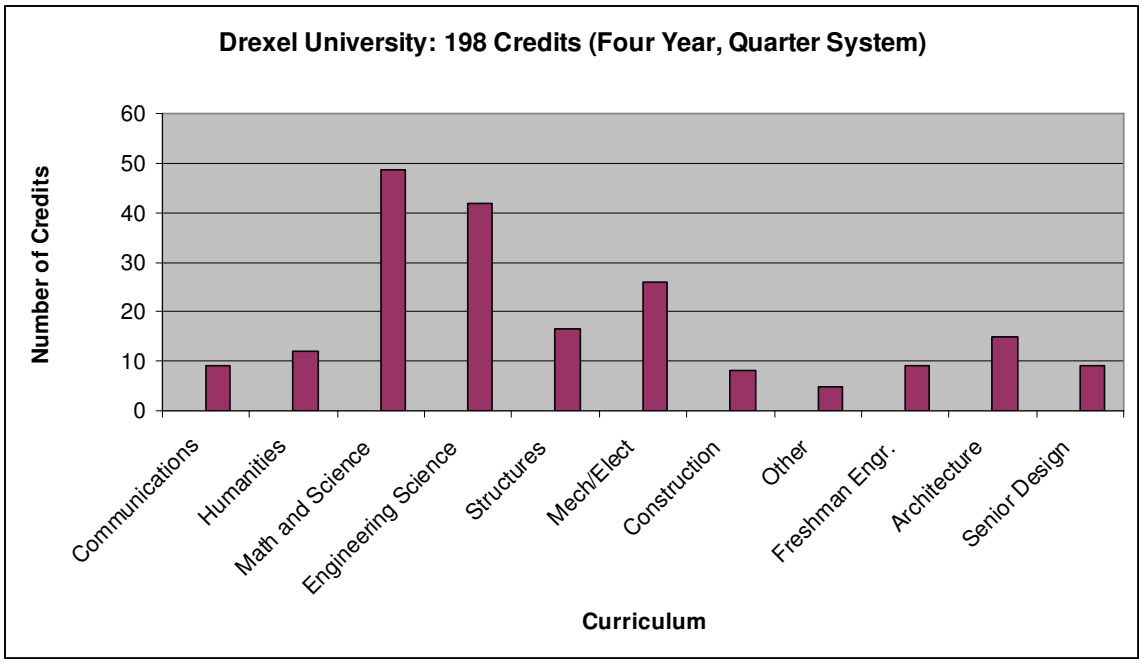

Figure 2. Curriculum analysis for the architectural engineering program at Drexel University.

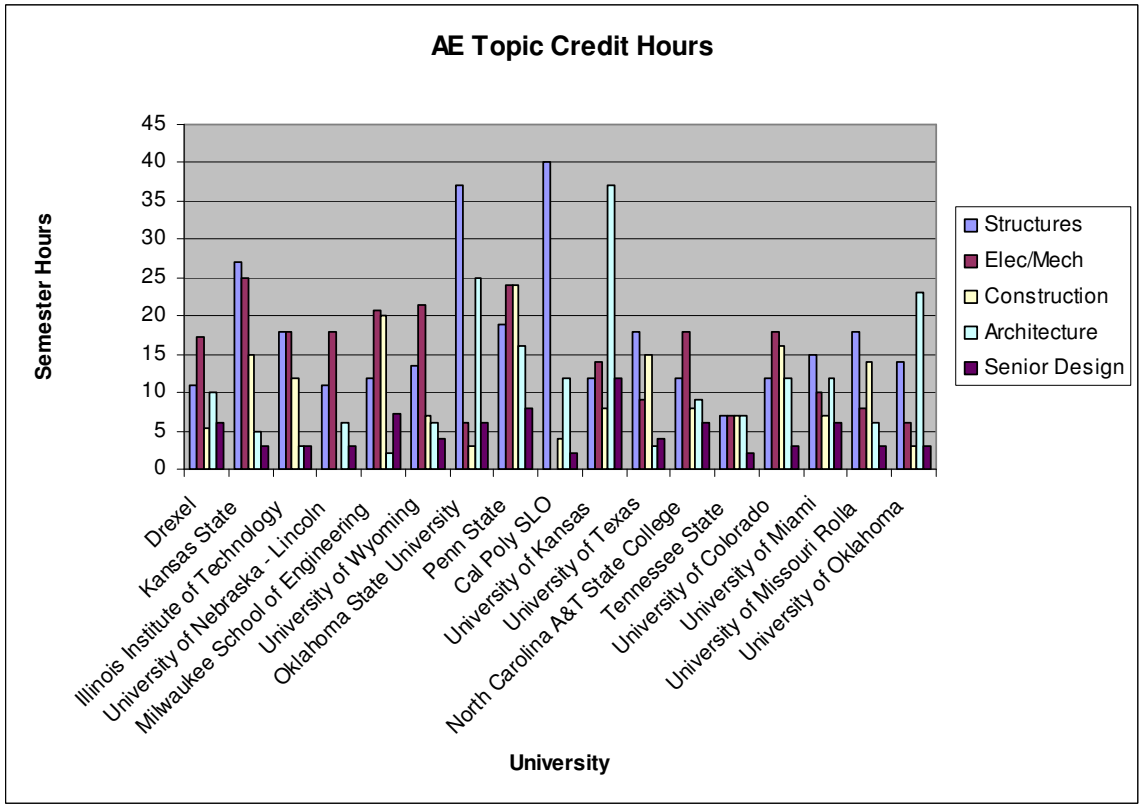

Figure 3. An analysis of the AE specialty areas by semester hours for the 17 accredited AE programs.

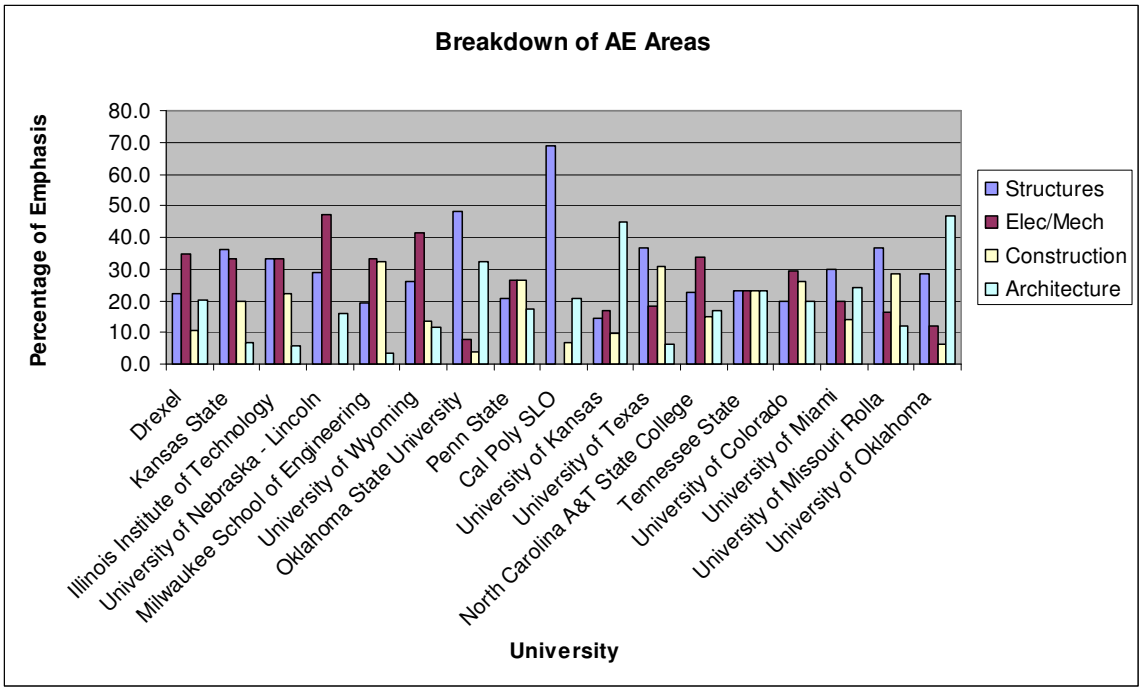

Figure 4. An analysis of the relative emphasis placed on structures, electrical/mechanical systems, construction, and architecture in the accredited AE programs

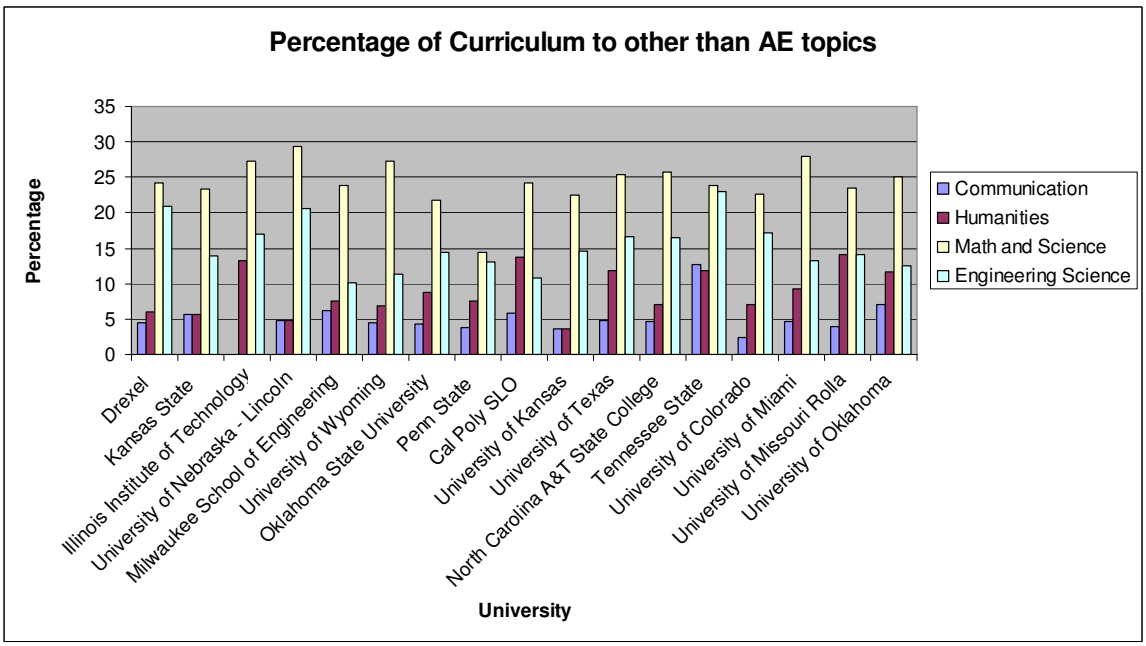

Figure 5. An analysis of the relative emphasis on communications, humanities, math and science, and engineering science in the accredited AE programs.