Defining Architectural Engineering Design

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Abstract

An online survey of representative faculty at ABET-accredited Architectural Engineering schools addressed the question of what constitutes "Architectural Engineering Design" (AED). The faculty are first characterized in multiple ways: university, academic rank, years of experience, registration status and discipline. The results of their open-ended definition of AED are examined using nine categories derived from responses rated on 1-5 Likert scales, with the analysis broken down using the same faculty characterization. Faculty opinions about the disciplines necessary to include in AED are also analyzed. Overall there is general agreement that disciplinary "skills" are an important part of AED as are, to a lesser extent, the "products" produced. There is some agreement about the idea of "integration" of the disciplines and much less agreement on many of the other concepts, with several barely mentioned. Most faculty feel that their definition of AED is the same as their school's, but many express uncertainty about the existence of a national definition. Similarly there is considerable agreement that more than one discipline (Architecture, Structure, HVAC, Electrical, Construction Management) is required to constitute AED, but there is marked disagreement about what specific ones should be included, with opinions ranging from two to all five.

Introduction

Design is what most of our graduates do. Some, of course, will work constructing other's designs, funding and approving designs, or perhaps analyzing the successes and failures of the design process. Design in its many facets is the heart of the Architectural Engineering (AE) profession. All the tools of mathematics, the sciences, communication, and the varied analytic methods of the disciplines in which our students specialize are chosen to support and enhance the design process and product.

How we teach design for Architectural Engineers is the subject of a year-long sabbatical project. In the literature there are many papers addressing specific aspects of design classes, particularly freshman and capstone design, as well as some looking at the entire curriculum. There is also a vast literature about general engineering design, addressing everything from the latest theories in the learning sciences to highly practical "how-to" books[1][2][3]. A literature search failed to find an overview on how the accredited schools of Architectural Engineering in the US define Architectural Engineering Design (AED), who teaches it, what methods are used to teach it, and what are the issues that those who teach it regard as important. This paper addresses the questions: what are the characteristics of those who teach AED; how do they define it; which disciplines should be included in an AED course?

The work presented here uses data from an online survey completed by a fairly complete sample of faculty at all the AE schools[1]. It breaks that data down in a variety of ways, and presents

[1] The version published in the ASEE-2009 proceedings (AC 2009-448) was prepared before all schools were visited. The data contained there is updated here to include responses from all schools.

some opinions and conclusions. It shows some areas of agreement, quite a range of opinions, and areas deserving attention. The most general conclusion is that the definition of Architectural Engineering Design is worth considering at the National, School and individual level.

Approach taken – a survey of faculty only

There are many stakeholders in the education process: students, administrators, employers, funders and of course faculty. This study focuses on faculty for several reasons. The first was pragmatic: they were accessible and interviewing them both in person and online was feasible within the scope of a one-year individual project. Because human subjects approval for the survey was necessary, it would have been far more difficult to receive approval in a timely manner had students been the subject, not to mention the difficulties of framing questions in an appropriate manner given the greater language and experience difference.

The second reason is that the faculty set the curriculum and make the fundamental decisions about the scope of, and approach to, the content. In essence the study address the question of what do those who make the curricular decisions deem important, without addressing the equally important question of how successful they are at imparting the content.

More particularly, this paper reports on the results of a survey taken by faculty at the schools being visited. Further reports may address the results of the interviews as opposed to those from the survey, but the survey results are far more controlled and lend themselves to detailed analysis.

How it might benefit the profession

As the results below show, there is some general agreement about the ingredients of architectural engineering design, but there are a number of areas where concepts that I would argue are important are not considered, or there is explicit disagreement. Isolating these agreements and disagreements for public discussion may improve both what is considered appropriate for architectural engineering design and potentially the way it is delivered, with consequent benefit for students, faculty and the general public.

Completion Status

All seventeen schools have been visited and survey participation by their faculty solicited. They are also available on my sabbatical blog [9].

Results – Major Groupings

In the results section below there are three major groupings.

- Faculty characteristics
- Analysis of the definition of architectural engineering design
- Disciplines essential to architectural engineering design

Methodology

Survey

As noted above, the results presented here are the results of an online survey addressing a number of issues related to architectural engineering design education. While I have attempted to ensure the quality of the survey, it has limitations delineated below.

The survey had only four required questions, those necessary to categorize the individuals: University; disciplines that the department includes; academic rank; primary discipline. All other questions were voluntary. There was one open-ended question on the definition of architectural engineering design. Most others were checkboxes or single-line answers (e.g. course title). For each group of questions respondents had the opportunity to leave open-ended comments if they chose.

Response Rate - Site Visits and Departmental Interviews

An online survey of this length (18-screen) is daunting indeed to most people. The response rate for an unsolicited survey is typically around 1-20% for a "general public" survey, and 5-40% for "customers and members" [10]. 137 faculty members were interviewed and 105 survey responses were received, a 77% response rate. Although there is not a one-to-one correspondence between the interviews and those who take the survey (25% were anonymous),those who identified themselves are essentially those that I interviewed.

Coding Method

One major portion of the results presented below relies on "coding" an open-ended response to the question "What is your definition of Architectural Engineering Design?" The method used was to first review all of the responses to that question, developing "themes" from each of the questions. Then, following the ethnographic qualitative research methods those themes were grouped into a representative subset, nine in total [11][12]. Several of those themes have very low response rates and are therefore not statistically significant in their specific answers, but seem to indicate areas where there might be beneficial discussion.

Each theme was given a one line definition which was referred to throughout the coding process – they are given in that section of the report. Each of the respondent answers was categorized on a Likert scale from strongly negative (1), to strongly positive (5). A value of three indicated that the theme was not mentioned or implied in the definition.[2]

[2] Note that this is a change from the draft published in the proceedings. This "neutral" value of "3" allows a more meaningful statistical analysis.

This coding method is subjective and good research technique would have a second coder independently code the same material with subsequent checking for agreement and resolution of differences. A second coder was not available and there were concerns about subject privacy. I did review each response twice in addition to the initial quick theme-identification pass to minimize this difficulty.

Validity of the survey instrument

As with the coding method, the construction of the survey was as rigorous as possible, but could be improved. There were four versions of the survey generated before the final version. One almost-final version was reviewed by the University's human subjects committee. Another version was reviewed by a psychologist colleague who raised substantial questions that were addressed. A near-final version was given to two colleagues who provided feedback that shaped minor changes.

Respondents were given the opportunity for almost every question to comment on the question. They were also given the opportunity to comment on the survey overall at the end. There were almost no comments identifying ambiguities in the question, and there were several commendations in the overall comments on the appropriateness of the survey.

Are the Responses Representative?

By the end of this project 100% of the accredited architectural engineering programs in the United States (17 as of 1/2008 when visit plans were fixed). The survey therefore is comprehensive in its population, although the sampling of that population is voluntary rather than the ideal of a random selection. Because the response rate is high there is a reasonable chance that this is close to a representative sample.

When visiting the schools the faculty interviewed were chosen by the department or program head or an individual designated by them. The request to the visit coordinator was that they include those architectural engineering faculty responsible for architectural engineering design, and also faculty offering allied courses such as discipline-specific design courses and analytic courses. Of course some individuals were unavailable, but I believe that I met and solicited for the survey the vast majority of appropriate faculty.

Are the Responses Significant?

In the tables that summarize most of the responses it is important to check the "count" of responses. In a number cases this count is quite low and therefore the likelihood of a particular number being statistically significant is equally low. Since the major benefit of this work is likely to be promoting discussion in the community it is worth presenting all of the numbers despite the current lack of statistical analysis.

For the Likert Tables an analysis of significance was used. The calculation of significance uses a VBA Macro explained at:

> http://www.pages.drexel.edu/~mitcheje/AEResources/Excel%20Tools/Likert%20Excel%20Code.shtml

It assumes, as explained there, that the null hypothesis is a normal distribution about a Likert of 3.0, which in this case was "no mention or implication". Using that assumption a "Goodness of Fit" analysis is performed.

Unless noted otherwise all the Likert analysis results are "significant". Note, however, that some of the means are extremely close to 3.0 meaning that they are little different from not being mentioned - in other words they don't have much general meaning.

Faculty Characteristics

The first group of results addresses the characteristics of those who responded to the survey. As presented in the above section on representation, it is reasonable to believe that this is close to an overall picture of the faculty who teach architectural engineering design and areas related to architectural engineering design.

Count by Rank of respondents

University	Professor	Assoc. Professor	Assistant Professor	Instructor	Adjunct	Grand Total
Cal Poly San Luis Obispo	1	6	4			11
Drexel University	3	4	2		1	10
Illinois Institute of Technology	1	1	1	1		4
Kansas State	2	2	5			9
Milwaukee School of Engineering	2	1	1			4
Missouri University of Science and Technology	1		2	2		5
North Carolina A&T State University	2	1	2			5
Oklahoma State University	2	2				4
Penn State University	3	7				10
Tennessee State	1	2			1	4
University of Colorado	4	1	3	1	1	10
University of Kansas	1	3	1	1		6
University of Miami		1	1		1	3
University of Nebraska - Lincoln	1	1	1			3
University of Oklahoma		1	1			2
University of Texas	3		3			6
University of Wyoming	3	2	3			8
Other	1					1
Grand Total	**31**	**35**	**30**	**5**	**4**	**105**
Percent	30%	33%	29%	5%	4%	100%

Table 1- Count of Respondents by University and Academic Rank

Comments

- The rankings are as the respondents chose to provide them.
- Most of those who are categorized as "other" should probably be characterized as "instructor". There is considerable variation in terminology between institutions for these categories.
- The number of survey responses by institution is generally representative of the Department size of the institution.
- Note that all the programs presented here offer undergraduate accreditation of the AE degree with the exception of Nebraska, which has a bachelor's/masters program with the masters program being the accredited degree.

Teaching Experience

	Professor	Assoc. Professor	Assistant Professor	Instructor	Adjunct	Grand Total
Cal Poly San Luis Obispo	12.0	9.2	6.8			8.5
Drexel University	15.0	11.3	3.5		30.0	12.6
Illinois Institute of Technology	30.0	16.0	10.0	3.0		14.8
Kansas State	27.0	7.0	5.6			10.7
Milwaukee School of Engineering	27.0	16.0	3.0			18.3
Missouri University of Science and Technology	22.0		6.5	9.5		10.8
North Carolina A&T State University	22.5	29.0	12.5			19.8
Oklahoma State University	18.0	8.5				13.3
Penn State University	14.7	14.0				14.2
Tennessee State		32.0			14.0	26.0
University of Colorado	20.0	15.0	2.7	8.0	28.0	13.9
University of Kansas	35.0	10.7	4.0	0.0		11.8
University of Miami		20.0	2.0		26.0	16.0
University of Nebraska – Lincoln at Omaha	18.0	21.0	3.0			14.0
University of Oklahoma		12.0	5.0			8.5
University of Texas	33.3		3.0			18.2
University of Wyoming	20.0	21.5	6.0			15.1
Other	6.0					6.0
Overall Average	**21.6**	**14.3**	**5.4**	**6.0**	**24.5**	**13.7**

Table 2 - Average years of teaching experience

Comment

- The count on several of these items is fairly low so the averages in those case are not particularly meaningful.
- For both Cal Poly and Drexel it would appear that there are responses from younger faculty members, lowering the overall level of experience. Based on my visits to the institutions both appear to be somewhat unrepresentative of the overall faculty although both are engaged in hiring faculty.

Teaching AE Design Experience

University	Professor	Assoc. Professor	Assistant Professor	Instructor	Adjunct	Grand Total
Cal Poly San Luis Obispo	12.0	9.0	3.0			7.9
Drexel University	10.0	8.7	0.0		10.0	7.0
Illinois Institute of Technology	6.0	0.0	6.0	0.0		3.0
Kansas State	23.0	7.0	5.0			10.0
Milwaukee School of Engineering	22.5	16.0	7.0			17.0
Missouri University of Science and Technology	0.0		4.5	8.5		5.2
North Carolina A&T State College	18.0	29.0	6.5			15.6
Oklahoma State University	18.0	8.5				13.3
Penn State University	11.7	9.8				10.5
Tennessee State	25.0	30.0			5.0	22.5
University of Colorado	15.0	0.0	2.3	2.0	26.0	9.5
University of Kansas	3.0	7.3	3.0	0.0		4.7
University of Miami		10.0	2.0		26.0	12.7
University of Nebraska - Lincoln	15.0	21.0	3.0			13.0
University of Oklahoma		5.0	5.0			5.0
University of Texas	30.0		0.0			18.0
University of Wyoming	15.0	0.0	2.3			7.4
Other	6.0					6.0
Overall Average	**16.0**	**10.5**	**3.4**	**3.8**	**16.8**	**10.2**

Table 3- Average years of teaching AE design

Comment

- This is a self-identified group, which is particularly relevant since the definition of AED is not agreed upon.
- The total count for this group is 95 (90%) so most of those surveyed believe that they have experience teaching AE design.

Industry Experience

University	Professor	Assoc. Professor	Assistant Professor	Instructor	Adjunct	Grand Total
Cal Poly San Luis Obispo	7.0	14.5	9.3			11.9
Drexel University	0.0	21.3	1.5		30.0	13.9
Illinois Institute of Technology	30.0	8.0	8.0	20.0		16.5
Kansas State	34.0	14.5	16.2			19.8
Milwaukee School of Engineering	8.5	20.0	12.0			12.3
Missouri University of Science and Technology	0.0		12.0	8.5		8.2
North Carolina A&T State College	6.0	7.0	15.5			10.0
Oklahoma State University	21.5	17.0				19.3
Penn State University	13.7	19.5				17.6
Tennessee State	9.0	6.5			35.0	14.3
University of Colorado	3.8	3.0	2.0	10.0	7.0	4.3
University of Kansas	5.0	0.3	6.0	0.0		2.0
University of Miami		10.0	7.0		53.0	23.3
University of Nebraska - Lincoln	23.0	8.0	12.0			14.3
University of Oklahoma		8.0	1.0			4.5
University of Texas	2.7		6.7			4.7
University of Wyoming	9.7	2.5	5.3			6.3
Other	10.0					10.0
Overall Average	**10.9**	**12.5**	**9.0**	**9.4**	**31.3**	**11.7**

Table 4 - Average years of industry experience

Comment

- Count of 93 (89%) – a somewhat surprising number after the interviews, excluding those with "0" years experience.
- It would be intriguing to compare these numbers to other engineering departments. The expectation would be that these are higher.

Professional Registration

	Professor		Assoc. Professor		Assistant Professor		Instructor		Adjunct		Total PE	Total RA
University	**PE**	**RA**	**PE**	**RA**	**PE**	**RA**	**PE**	**RA**	**PE**	**RA**		
Cal Poly San Luis Obispo			6		4						10	
Drexel University	1		2	1					1		4	1
Illinois Institute of Technology	1		1		1						3	
Kansas State	1		2		4						7	
Milwaukee School of Engineering	2			1	1						3	1
Missouri University of Science and Technology	1				1	1	1				3	1
North Carolina A&T State College	2				1	1					3	1
Oklahoma State University	1	1	2	1							3	2
Penn State University	2	1	4	1							6	2
Tennessee State	1			1					1		2	1
University of Colorado	4				1						5	
University of Kansas	1		2	1			1				4	1
University of Miami			1		1					1	2	1
University of Nebraska - Lincoln	1		1		1						3	
University of Oklahoma					1						1	
University of Texas	3				1						4	
University of Wyoming	3		1			1					4	1
Other												
Grand Total	**24**	**2**	**22**	**6**	**17**	**3**	**2**		**2**	**1**	**67**	**12**

Table 5 - Professional Registration

Comment

- There are two individuals with dual PE/RA registration
- A number of individuals reported other kinds of registration/certification – e.g. surveying, LEED etc.
- This data should be available from ABET self-studies in more detail and could be used to check the representative nature of these respondents. The year of the self-study varies, however so there would be inaccuracies there.

Discussion of the results

There are no big surprises other than the near-universality of industry experience in these characterizations of the faculty. It is nonetheless worthwhile to know the background against which the opinions about teaching AE design is set.

Definition of Architectural Engineering Design

In the survey the first question asked after the respondents had characterized themselves was "What is your definition of Architectural Engineering Design?"[3] The overall characteristics of the answers are:

- Length range from 2 words to 127 words
- Average length 29 words

Legend

In the tables that follow the coding was performed as described above. The specific terms used in the coding (not known to the respondents) were as follows:

Value	Meaning
1	Explicit disagreement or support
2	Disagreement or lack of support mentioned or implied
3	No mention or implication
4	Agreement or support mentioned or implied
5	Explicit agreement or support

Table 6 - Rating scale used for AE Design definitions

Label on Results	Definition used when coding
Concepts	Addresses the concepts that produce or are essential for AE Designs - distinct from values
Differentiation	Differentiates AE Design from other kinds of design
External References	Refers to other definitions of AE Design
Integration	Addresses integration between the disciplines including Architecture
Miscellaneous	Addresses issues not covered by the other rating scales.
Process	Addresses the processes of AE Design - distinguished from specific skills
Products	Addresses products of AE Design including calculations; models; physical reality.
Skills	The skills necessary for AE Design - including discipline-specific skills, analysis, communication, teamwork etc.
Values	Considers values and goals that AE Design should or does address.

Table 7- Categories used for AE Design definitions

Comment on the categories

[3] In the interviews I also learned to ask the question "What is your definition of Architectural Engineering". To be consistent the survey was not changed to include this question, though ideally it would have been.

- As noted in the methodology section these categories were determined as a result of reviewing the AE definitions submitted by the faculty. They were informed by my reading of the learning sciences literature but do not directly to refer to any concepts that are current in that literature.[3]

Overall – Design category average ratings for the entire Survey

Scale	Concepts	Differentiation	External Ref	Integration	Miscellaneous	Process	Products	Skills	Values
Count Non-Neutral (3)	20	81	3	37	6	59	66	33	41
Pct Non-Neutral	23%	93%	3%	43%	7%	68%	76%	38%	47%
Mean	3.3	3.9	3.0	3.5	3.1	3.8	3.8	3.5	3.6

Table 8 - Design category average ratings overall[4]

Comment

- All the responses for the Likert ratings are “significant” in the sense that they’re different from a normal distribution about “neutral” value, but see the explanation in the section "Are the responses significant?" See above. Responses with less than 10 non-neutral counts are shaded as not providing enough data to make real distinctions.
- In this and therefore the other tables that follow the *Differentiation* category has the highest response rate and the highest rating. This is unsurprising because almost every respondent mentioned that AED applies to buildings – which was enough to warrant a score of (4) in that area.
- Both the *products* and the *skills* categories represent the same kind of graduates job emphasis.
- In one or two cases people explicitly stated that AE Design is no different than other design approaches.
- Note the low response rate in two categories: *concepts*, *external reference*. They’re included, however, for the following reasons.
    - *Concepts* represents the ideas or principles that are being imparted or used in the AE design process. In discipline courses there is often significant emphasis on concepts or principles. It seems striking that this kind of emphasis is relatively low in discussions of design.
    - *External reference* would seem to be appropriate for a definition, whether it be from a dictionary or from ABET. That only one person included an external reference may just represent the hurried nature of taking the survey. It's conceivable however that it represents a larger issue of a lack of common agreement in the field.

[4] The comments that follow are considerably changed from the version in the conference proceedings. This is a result of the changed rating scale defined above.

By Average Years of Experience Design – 3 types

Years Teaching Experience	Count	Concepts Tch	Differentiation Tch	External Ref Tch	Integration Tch	Miscellaneous Tch	Process Tch	Products Tch	Skills Tch	Values Tch
'0	6	3.2	3.3	3.0	2.8	3.0	3.8	3.7	3.7	3.5
1-2	3	3.7	4.0	3.0	4.3	3.0	3.7	4.0	3.0	3.7
3-10	30	3.3	3.9	3.0	3.5	3.1	3.8	3.9	3.5	3.6
>10	48	3.3	4.0	3.1	3.5	3.1	3.9	3.8	3.5	3.6
Average	87	3.3	3.9	3.0	3.5	3.1	3.8	3.8	3.5	3.6

Years Teaching AE Design		Concepts AET	Differentiation AET	External Ref AET	Integration AET	Miscellaneous AET	Process AET	Products AET	Skills AET	Values AET
'0	22	3.4	3.8	3.0	3.2	3.0	4.0	3.9	3.5	3.6
1-2	2	3.5	4.0	3.0	5.0	3.5	4.5	4.0	4.0	3.5
3-10	33	3.2	3.9	3.0	3.5	3.1	3.8	3.8	3.3	3.6
>10	30	3.2	4.0	3.1	3.6	3.1	3.7	3.8	3.6	3.5
Average	87	3.3	3.9	3.0	3.5	3.1	3.8	3.8	3.5	3.6

Years Industry Experience		Concepts Ind	Differentiation Ind	External Ref Ind	Integration Ind	Miscellaneous Ind	Process Ind	Products Ind	Skills Ind	Values Ind
'0	8	3.3	3.6	3.0	3.5	3.1	4.3	3.8	3.4	3.5
1-2	9	3.4	3.8	3.1	3.1	3.2	3.7	3.9	3.4	3.8
3-10	42	3.3	4.0	3.0	3.6	3.0	3.9	3.8	3.5	3.6
>10	28	3.1	4.0	3.0	3.5	3.0	3.7	3.7	3.4	3.5
Average	87	3.3	3.9	3.0	3.5	3.1	3.8	3.8	3.5	3.6

Table 9 - AE Design Definition ratings by years teaching, AED teaching, Industry Experience

Comment

- As previously, the low counts for *External Reference* and *Miscellaneous* make any conclusions for those columns doubtful. That is the reason those columns are gray as well as for the low counts for specific years of experience bins.

By University

University	Count	Concepts Unv	Differentiation Unv	External Ref Unv	Integration Unv	Miscellaneous Unv	Process Unv	Products Unv	Skills Unv	Values Unv
Cal Poly San Luis Obispo	7	3.4	3.9	3.0	3.0	3.0	3.9	3.9	3.9	3.9
Drexel University	8	3.1	4.1	3.0	3.6	3.0	3.6	3.8	3.1	3.4
Illinois Institute of Technology	4	3.5	4.3	3.0	3.3	3.0	3.5	3.5	3.5	3.8
Kansas State	8	3.1	4.0	3.0	3.9	3.0	3.5	3.8	3.4	3.4
Milwaukee School of Engineering	3	3.0	4.0	3.0	3.0	3.3	3.3	3.7	3.3	4.0
Missouri University of Science and Technology	4	3.0	4.0	3.0	4.0	3.3	3.5	3.8	3.0	3.3
North Carolina A&T State University	5	3.4	4.0	3.2	3.2	3.2	4.0	3.8	3.6	3.8
Oklahoma State University	3	3.0	3.7	3.0	2.7	3.0	4.3	4.0	3.3	3.7
Penn State University	7	3.1	4.1	3.0	3.9	3.0	4.0	4.0	3.4	3.6
Tennessee State	4	3.3	4.0	3.0	3.5	3.0	3.8	4.0	3.8	3.0
University of Colorado	8	3.5	4.1	3.0	4.3	3.1	4.1	3.9	3.6	3.6
University of Kansas	6	3.3	3.3	3.2	3.2	3.3	4.2	4.0	3.7	3.7
University of Miami	2	3.0	4.0	3.0	4.5	3.0	3.5	3.0	3.0	3.5
University of Nebraska - Lincoln	3	3.0	4.3	3.0	2.3	3.0	3.7	3.3	3.3	3.3
University of Oklahoma	2	3.0	4.0	3.5	3.0	3.0	3.5	3.5	3.0	3.5
University of Texas at Austin	4	3.3	4.0	3.0	3.5	3.0	4.0	3.8	3.3	3.3
University of Wyoming	8	3.6	3.5	3.0	3.4	3.0	4.1	3.9	3.8	4.0
Other	1	3.0	3.0	3.0	5.0	3.0	4.0	4.0	4.0	3.0
Grand Total	87	3.3	3.9	3.0	3.5	3.1	3.8	3.8	3.5	3.6

Table 10 - AE Design definition ratings by University

Comment

- *Integration* seems to be a higher value for a group of universities: Drexel, Kansas State, Missouri, Penn State, Colorado, Miami
- *Integration* is explicitly not a value for at least some individuals – note the low value for Nebraska.
- *Concepts* are important to several universities whereas they don't appear in most.

By Faculty Discipline

Discipline		Concepts Disc	Differentiation Disc	External Ref Disc	Integration Disc	Miscellaneous Disc	Process Disc	Products Disc	Skills Disc	Values Disc
AE	14	3.2	3.9	3.1	3.1	3.1	3.6	3.9	3.6	3.5
Architecture	10	3.6	3.5	3.1	3.5	3.1	3.8	3.8	3.6	4.0
Construction Management	8	3.3	4.0	3.0	3.9	3.0	3.8	4.3	3.1	3.4
Electrical Power	5	3.2	4.0	3.0	4.0	3.0	3.6	3.4	3.2	3.6
Environmental	6	3.3	4.2	3.0	3.2	3.0	3.8	3.5	3.5	3.7
HVAC	9	3.4	4.1	3.0	4.0	3.2	4.1	3.9	3.7	3.7
Lighting	3	3.3	4.0	3.0	5.0	3.3	4.3	4.0	4.0	4.0
Structures	32	3.1	4.0	3.0	3.3	3.0	3.9	3.7	3.4	3.4
Grand Total	87	3.3	3.9	3.0	3.5	3.1	3.8	3.8	3.5	3.6

Table 11- AE Design definition ratings by faculty discipline

Comment

- Architects, ranked *concepts* higher.
- *Process* was important for all.

Sample Faculty Definitions of AE Design

To give a sense of the definitions provided by the faculty members the following definitions were selected by first arranging them in increasing length and then picking every eighth definition starting with the second.

- The design of building systems.
- Design of a structural system to meet desired needs/requirements.
- AED encompasses the engineering design of the different systems that require engineering design in a building.
- Design of all the engineered systems within buildings: structural, mechanical (HVAC/Plumbing/FP), and electrical/lighting.
- The study of the design and integration of building systems to ensure a complete and operable facility with optimal economic efficiency.
- The design of an building component, integrated with the designs of other components, to meet the needs of the Architect, the CM, and the building owner.
- Architectural Engineering Design is the design of building systems through the integration of architecture, structures, mechanical systems, electrical and lighting systems, and construction.

- An open ended problem related to a building or building system component where the student must supply missing information, not all constraints are known ahead of time and where more than one possible solution exists.
- Architectural Engineering Design covers many aspects of the built environment. AE design should not only concerned with the architectural aspects but they are also concern with the building functional aspects (structural, mechanical, electrical, to name a few.)
- The application of scientific and engineering principles to the design of the built environment, including building structure, enclosure, power, lighting, and HVAC systems. Design can be interpreted to apply on the level of each of the above subsystems or as an integrated process involving two or more of them.
- Architectural Engineering design expands the "technology" of building concept of years past. It is the synthesis of the principles of engineering to the design of building systems that include but not limited to structural, mechanical, electrical systems design. The concept may also include fire protection design, acoustical design, or other system design that requires the skills of engineering analysis and design applied to the design and operation of buildings.

Discussion of the results for all breakdowns of the survey responses

- Potentially significant differences between the schools are noted at each table.
- The most significant agreements are on the idea of what I have called *processes* and *products.*
- Differentiating architectural engineering design from other types of design was identified by almost every respondent in some way, but there was very little emphasis put on it. The majority of the differentiation was by use of the word *building* in the definitions.
- There appear to be significant differences about the importance of the various categories within all of the breakdowns.
- Several of the categories I created have very low response rates. It is entirely reasonable to conclude that that means the category is irrelevant. It is also possible that these identify aspects of architectural engineering design worth considering by the community.

Faculty Opinions about Their School's and National Definitions of AE Design

Immediately after the question asking respondents to give their definition of architectural engineering design they were asked if their definition agreed with that used by their school and that used nationally. The specific questions asked were:

- Is your school's definition of AED the same as yours?
- Is the national definition of AED the same as yours?

They were also given the opportunity to comment about the question. A number of them chose not to explicitly reply respond *yes* or *no,* but instead wrote comments which are sampled below in the same manner as for the definitions of AE Design. No one answered either *yes* or *no* explicitly and then wrote a comment.

Response	Count	Comments	*"Don't Know"*
Yes	52	0	
No	18	0	
Blank	35	39	10

Table 12 - Congruence of school with individual definition

Sample Comments by Faculty

- ????.
- Don't Know
- Probably not
- For the most part. Each faculty member varies in their definition
- To my knowledge, the Department does not have a formal definition for AED so I would be very surprised if my colleagues and I have reached consensus at this time.
- I feel most of the faculty here would have a difficult time defining AED. They do not look at AED as a holistic process. Here each faculty member see only the importance of his or her area.

Response	Count	Comments	*"Don't Know"*
Yes	25	0	
No	22	0	
Blank	58	49	37

Table 13 - Congruence of national with individual definition

Sample Comments by Faculty

- Not sure
- I don't know.
- I don't know the national definition
- I don't think there is a firm national definition (or goals) of AED, at least not clearly defined.
- Since I am not exactly clear on what a "national definition" is, I will assume so.
- Design of one or more of the engineered systems within buildings: structural, mechanical (HVAC/Plumbing/FP), and electrical/lighting.
- 'Some what. AEI definition:" Architectural Engineering is the discipline concerned with planning, design, construction and operation of engineering systems for commercial, industrial, and institution facilities. Engineering systems include electric power, communication and control, lighting, ventilation, and air conditioning; and structural systems. An architectural engineer works closely with those in the areas of the building process to design and possibly to construct the engineering systems that make building come to life for their inhabitants"

- The eminent structural engineer, Professor Mario Salvadori, has written: A good architect today must be a generalist, well-versed in space distribution, construction techniques and electrical and mechanical systems, but also knowledgeable in financing, real estate, human behavior and social conduct. In addition, he is an artist entitled to the expression of his aesthetic tenets. He must know about so many specialties that he is sometimes said to know nothing about everything. The engineer, on the other hand, is by training and mental makeup a pragmatist. He is an expert in certain specific aspects of engineering and in those aspects only. Reference: Mario Salvadori, Why Buildings Stand Up (McGraw-Hill, 1980) p. 24. Is this a national definition of AED? I don't know!

Discussion of the results

- As might be expected there is an increasing amount of uncertainty as one progresses from school to national definitions. This is expressed in the large numbers of "don't know" responses.
- A few, but not many, identify a disagreement between their personal definition and that of their colleagues or school.
- Few if any of the respondents took a position on whether or not there should be a school or a national definition. That leaves open the question of whether a national definition is important

Disciplines Required for AE Design

In another section of the survey of faculty members were asked

> "Which of the following disciplines must be included in a course for the course to be considered as addressing AE Design - (Select all that apply)?"

They were given a choice of the following possible disciplines:

> Architecture; Structure; HVAC; Electrical; Construction Management

The results below show all possible combinations of these five disciplines. The count of those responding in some way was 87, of whom 35 made no choice specific discipline choices. 44 chose to make comments.

Discipline(s) - Required with no others	Count
Architecture (Arch)	2
Structure (Struct)	1
HVAC	0
Electrical (Elect)	0
Construction Management (CM)	0
Arch+Struct	2
Arch+HVAC	0
Arch+Elect	0
Arch+CM	0
Struct+HVAC	0
Struct+Elect	0
Struct+CM	0
HVAC+Elect	0

Discipline(s) - Required with no others	Count
Arch+Struct+HVAC	4
Struct+HVAC+Elect	6
HVAC+Elect +CM	0
Arch+Struct+CM	2
Arch+Struct+HVAC+Elect	6
Arch+Struct+HVAC+Elect +CM	14
Struct+HVAC+Elect+CM	6
Any Two of the above	8
Any Three of the above	10
All of the Above	20
Comment but no choices	7
No Response	11

Table 14 - Discipline Combinations Deemed Required

Sample Comments by Faculty – Following the same sampling scheme

- it should be a complete multi-disciplinary solution
- I think that different programs should be free to make their own decision.
- As the title itself indicates, architectural engineering is a hybrid and thus its emphasis ought to be on the place of intersection.
- previous question--any one of the above. Even if understanding the design considerations of other disciplines may help make design instruction effective, it is not a prerequisite for architectural engineering design.
- AE Design is hard to pin down to a single definition with the varied disciplines that fall under the heading of Architectural Engineering. It must involve aspects of each of the disciplines to some extent in the design process, the extent of each being left to the individual involved in the process ...

- One of the major difficulties with the discipline of architectural engineering is that it means different things to different people. This can lead to numerous problems: unbalanced curricula, employer expectations that are different from the actual abilities of graduates, misconceptions about career paths, vagueness regarding the expectations for the faculty performance, etc. One view of architectural engineers is that they should also master the construction management process. Some people even think that architectural engineers are ideal as project managers. I am not so certain of that. In my opinion, AE design does not necessarily include the project management aspect.

Discussion of results

- Only three respondents believe that a single discipline is sufficient for architectural engineering design.
- Ten thought that two disciplines are sufficient, with eight of those saying "any two".
- Twenty two thought that three disciplines were necessary with ten of those saying "any three"
- Twenty six would like have four or five disciplines included.
- These results indicate a considerable divergence of opinions on what are the ingredients of AE design, a greater differentiation than is evident in the definitions.

Conclusions Overall

The survey results characterize faculty attitudes about Architectural Engineering Design in two ways. The more concrete is their explicit choices about which disciplines must be included in AED. There, we see a considerable variation from two up to all five of the choices provided. To some extent these probably represent the curricula of the schools, since few offer all five options, but in any case it represents a divergence that is worth discussing at the national level.

Similarly, though more disputably because the categories used are ones imposed by the author rather than chosen by the respondents, the responses to the request to define architectural engineering design diverge considerably in their inclusion and emphasis on the different categories. The disciplinary skills are near-universal in emphasis and inclusion whereas other categories are far less often included or emphasized. Again, I propose that these categories and the responses to them merit discussion at all levels.

Further Work

Other work based on the survey and the interviews will primarily be posted on the blog http://aedesigndu.blogspot.com/.

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