Curriculum Changes Informed by the Architectural Engineering and Construction Industry

Samuel Underwood, University of Nebraska - Lincoln

Samuel Underwood is an architectural engineering doctoral student at the University of Nebraska-Lincoln and an acoustical consultant in the building design industry. His research interests include soundscapes, building information modeling, and engineering education.

Dr. Markeya S. Peteranetz, University of Nebraska - Lincoln

Dr. Peteranetz is the Learning Assessment Coordinator for the University of Nebraska-Lincoln College of Engineering. Her research interests include the impact of instructional practices on student learning and motivation, and sources of within-person variation in motivation and self-regulated learning.

Dr. Clarence Waters, University of Nebraska - Lincoln

Aaron Douglas Professor of Architectural Engineering in the Durham School of Architectural Engineering and Construction at the University of Nebraska-Lincoln

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Abstract

Responses from 445 working professionals in the Architectural Engineering & Construction (AE&C) industry were collected through a recent survey to inform curriculum changes to an architectural engineering program in the Midwest. Responses were collected across 52 closed and eight open-ended items to gain an industry perspective on the relative importance of course topics in the curriculum, the selection of Architectural Engineering (AE) degree concentration options, the format of graduate degree capstone projects, and the factors that AE&C employers consider when hiring graduates and experienced employees. The curriculum changes inspired by this survey are presented together alongside the program's previous AE curriculum to more thoroughly characterize the program attributes that are desired by the AE&C industry.

Introduction

The Architectural Engineering (AE) program considered in this study is at the University of Nebraska-Lincoln and offers four degrees: a Bachelor of Science in AE (BSAE); a fifth year ABET accredited Master of AE program following the BSAE; a Master of Science in AE (MSAE); and a Doctor of Philosophy in AE (PhD-AE). The BSAE and the fifth-year Master's program combine to create a 4+1, 5-year accredited degree program.

The 4+1 curriculum has traditionally consisted of coursework in calculus, physics, chemistry, core engineering courses like statics, dynamics, mechanics of materials, and architectural engineering discipline courses. A full listing of all course topics covered in this curriculum is presented in Table 1.

Within the AE program, students select a specialization option in building structural systems, mechanical systems and acoustics, or building lighting and electrical systems. The first three years of the accredited 4+1 track are common to all students in the program, covering core engineering courses and introductory courses related to each specialization option. In the fourth year of the program, students begin coursework related to their selected specialization. In the fifth-year master's program, students complete graduate coursework related to their specialization and must complete an interdisciplinary capstone team design project. Student teams, advised by industry and faculty members, complete a building design in a simulated professional practice and compete in a national student design competition. Prior to 2019, fifth-year master's students were also required to complete an individual graduate project advised by a faculty mentor. However, this requirement was phased out of the curriculum to allocate more course credits to the interdisciplinary team design project and other technical electives.

Table 1 – Full Selection of Course Topics in 4+1 Program

Four-year Undergraduate Course Topics	
Mathematics and Physics:	**Architectural Engineering:**
Calculus I/II/III	Introduction to Architectural Engineering
Differential Equations	AE Design & Simulation Studio Courses
General Chemistry	Fundamentals of Lighting Design
General Physics I/II	Fundamentals of Building Acoustics
Probability & Statistics	Fundamentals of Structural Design & Analysis
Core Engineering Courses:	Fundamentals of HVAC
Engineering Statics	Electrical Systems for Buildings
Engineering Dynamics	Steel Design I
Engineering Thermodynamics	Building Envelopes
Fluid Mechanics	**Lighting/Electrical Specialization:**
Mechanics of Elastic Bodies	Theory, Design, Application of Lighting
Fundamentals of Electrical Engineering	Lighting Design
Engineering Economics	Building Energy
Other Required Coursework:	Introduction to Psychology, Sensation & Perception
Public Speaking	Building Communication Systems (Master's)
Technical Writing	Advanced Building Electrical Systems
Introduction to Programming	**Mechanical/Acoustics Specialization:**
Construction Business Methods	Building Energy
Structural Specialization:	HVAC Design
Reinforced Concrete Design	Advanced Noise Control
Advanced Structural Analysis	Building Controls (Master's)
Structural Design and Planning	Advanced Building Electrical Systems
Introduction Geotechnical Engineering	Technical Elective
Foundation Engineering (Master's)	
Fifth-year Master's	
Internship in Architectural Engineering	Graduate Probability & Statistics
Interdisciplinary Team Design Project	Professional Practice
Technical Electives:	
Indoor Air Quality Engineering	Renewable Energy
Advanced Architectural Acoustics	Structural Dynamics
Special Topics in Architectural Engineering	Advanced Steel Design
Health and the Built Environment	Blast-Resistant Structural Design
Healthcare Design & Construction	Stage and TV Lighting

In 2021, program faculty decided to administer a survey of program alumni and AE industry professionals in order to gain an industry perspective on the fifth-year master's curriculum, determine if the individual graduate project requirement should be reinstated, and re-evaluate the importance of course topics to inform decisions on the reduction of the fifth-year Master's degree from a 36-credit hour program to a 30-credit hour program. There was also interest in understanding the factors that employers deem most important when deciding to hire new graduates and experienced employees. The purpose of this study is to outline how the alumni/industry perspective was used to make changes to the program curriculum.

Background

In AE education, previous work has identified the challenge of preserving curricular integrity while reducing program credit hours [1]. In curricular matters, cooperative engagement with industry has been shown to help programs meet the demands of the AE&C industry [2], and therefore many AE programs choose to form industry advisory boards. Surveys of industry have also been shown to provide valuable insight toward curriculum development in other engineering disciplines [3,4].

Methods

An online survey was distributed via email using a snowball method to participating industry practitioners in April 2021. Respondents were asked to complete the survey within one week. All responses were finished or closed within that timeline. A total of 445 people accessed the survey, and 384 participants completed it. The survey took most respondents 15 minutes or less. For each item, all available data were included in the analysis, regardless of whether the respondent completed the entire survey. Industry practitioners with less than 5 years of experience ($N = 68$), 5 to 10 years of experience ($N = 95$), 10 to 15 years of experience ($N = 82$), 15 to 20 years of experience ($N = 57$), and greater than 20 years of experience ($N = 122$) were represented. The sample consisted of both program alumni ($N = 234$) and non-alumni ($N = 201$; 10 respondents did not answer this question). Respondents reported working in lighting/electrical ($N = 140$), mechanical/acoustics ($N = 126$), structural ($N = 92$), and other technical disciplines ($N = 56$). Respondents also reported their current employer, for which over 100 different employers were represented in the sample. Participants reported that their companies operated locally ($N = 42$), regionally ($N = 109$), nationally ($N = 165$), and internationally ($N = 117$). Respondents indicating regional operation were asked to select one or more regions for their firm's operation. Responses included the Midwest ($N = 99$), the Mountain West ($N = 31$), the Southwest ($N = 15$), the Southeast ($N = 13$), the West Coast ($N = 9$), the Northeast ($N = 8$), and Alaska/Hawaii ($N = 1$).

The online survey was designed to assess industry professionals' perspectives on the relative importance of course topics in the curriculum, the selection of AE degree concentration options, the format of graduate degree capstone projects, and the factors that AE&C employers consider when hiring graduates and experienced employees. Additional demographic questions pertaining to years of experience, level of education, alumni status, employer size, employer area of operation, and technical discipline were also included.

Most items in the survey asked respondents to rate their perception of "how essential" or "how important" of various components of the fifth-year Master's degree, including the available specializations and specific courses. Response options for most items were integers 0 to 10 with labels at 0, 5, and 10. For items about essentialness, those labels were 0 = Not at all necessary, 5 = Somewhat necessary, and 10 = Absolutely critical. For items about importance, those labels were 0 = Not at all important, 5 = Somewhat important, and 10 = Critically important. For most items, respondents also had the option to check a box labeled "Unsure/not my area" rather than provide a rating.

Results

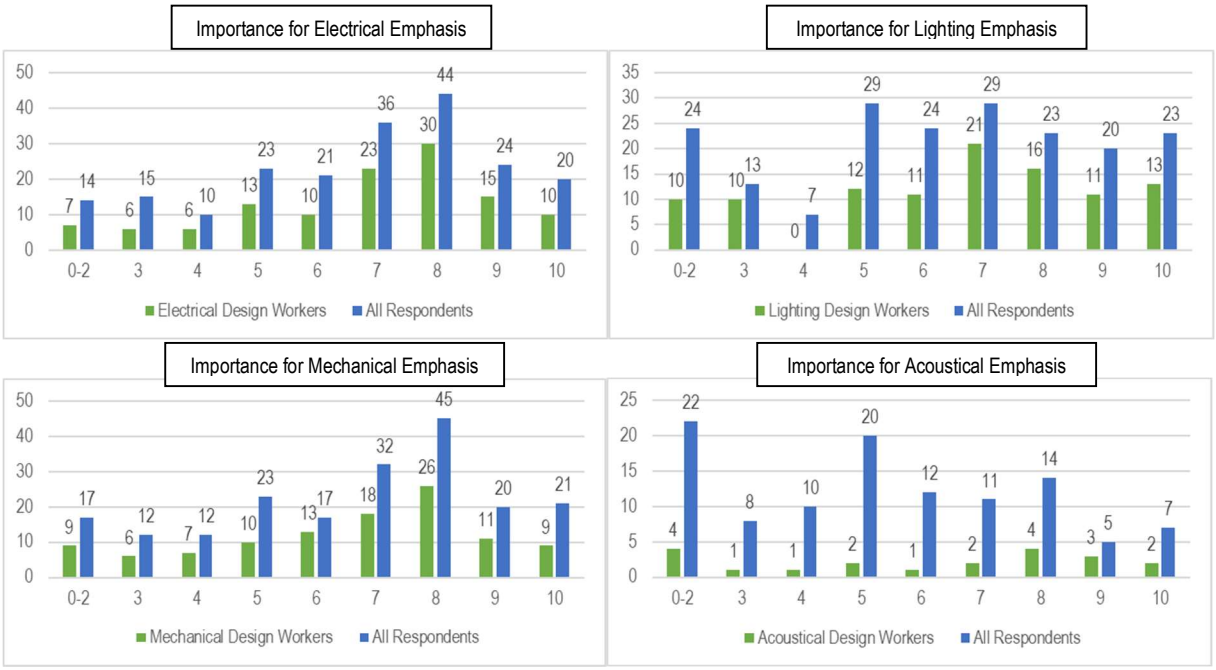
A total of 384 complete responses and 61 incomplete responses to the online survey were received. Results are reported for key items that influenced curriculum decisions.

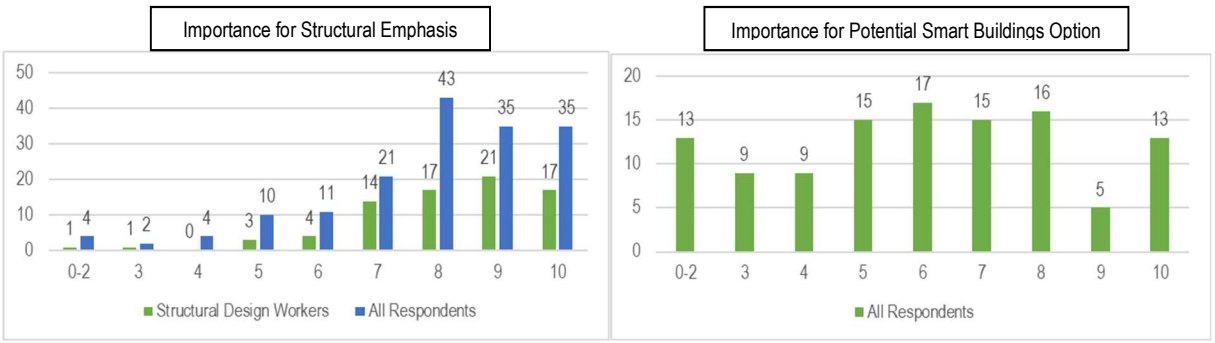
Importance of the fifth-year Master's degree

The fifth-year master's degree was rated most essential by respondents in the structural option (69% giving a rating of ≥8), followed by electrical (43% ≥ 8), mechanical (42% ≥ 8), lighting (33% ≥ 8), smart buildings (30% ≥ 8), and acoustical (24% ≥ 8).

Figure 1

Rated importance of the fifth-year Master's degree across area of expertise

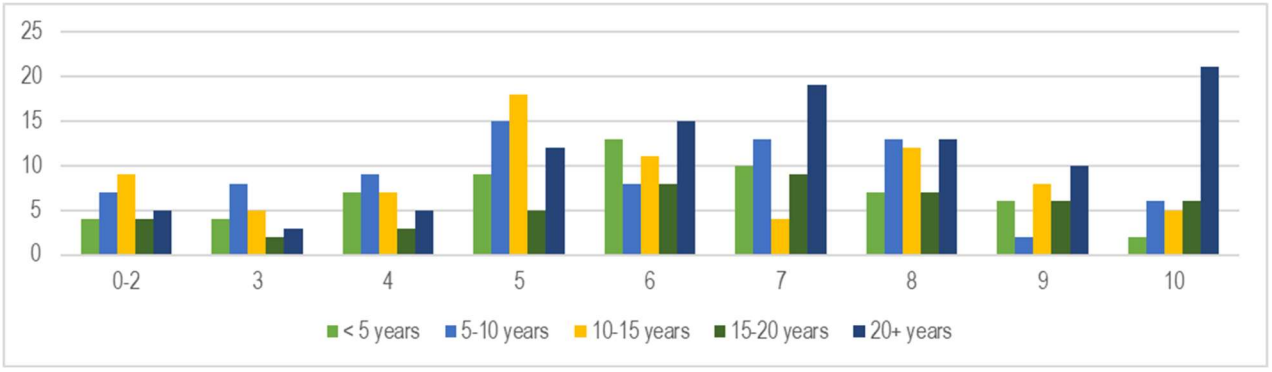




Adding a Smart Building Option

Overall, respondents felt that it is "somewhat important" to add a Smart Buildings degree option (53% gave rating of 4 - 7), but the most experienced respondents were more likely to rate it as "critically important" (62% gave rating of 7 or higher). In open-ended response items, participants commonly suggested that course topics in a potential smart building specialization should include integrated control systems, cybersecurity, data science, machine learning, fault detection, and sustainability standards. Some respondents noted concern regarding an unclear path to Professional Engineer (PE) licensure in a potential Smart Buildings option and suggested that smart building topics could instead be addressed through technical electives or integrated into other AE courses.

Figure 2 - Rated importance of adding a smart building option across years of experience



General Coursework and Curriculum

The interdisciplinary team design capstone course was rated as a "critically important" course (88% gave rating of 7 or higher; 36% rated it 10 of 10). The individual graduate project was rated between "somewhat important" and "critically important." On average, respondents felt that the individual graduate project should only be one semester while the interdisciplinary team design course should be two semesters. There was less consensus about the importance of other courses, but the internship class [5] and professional practice were generally seen as highly important. The graduate level statistics course was generally rated to be between "not important" and "less important" (as indicated in Figure 5).

Incorporation of Construction-Related Coursework

Respondents were asked to rate the importance for graduates of the fifth-year Master's program to have learning experiences or courses related to construction. The most highly related topics were preparation to be on a team with construction professionals, project delivery methods, and a combined estimating, scheduling, and project management course. There was less of a consensus regarding other construction-related topics, including preparation to be a specialty construction professional, preparation to be a general construction professional, prefabrication and manufacturing, and separate courses for estimating, scheduling, and project management.

Figure 3 - Rated importance of the individual graduate project course across years of experience and discipline

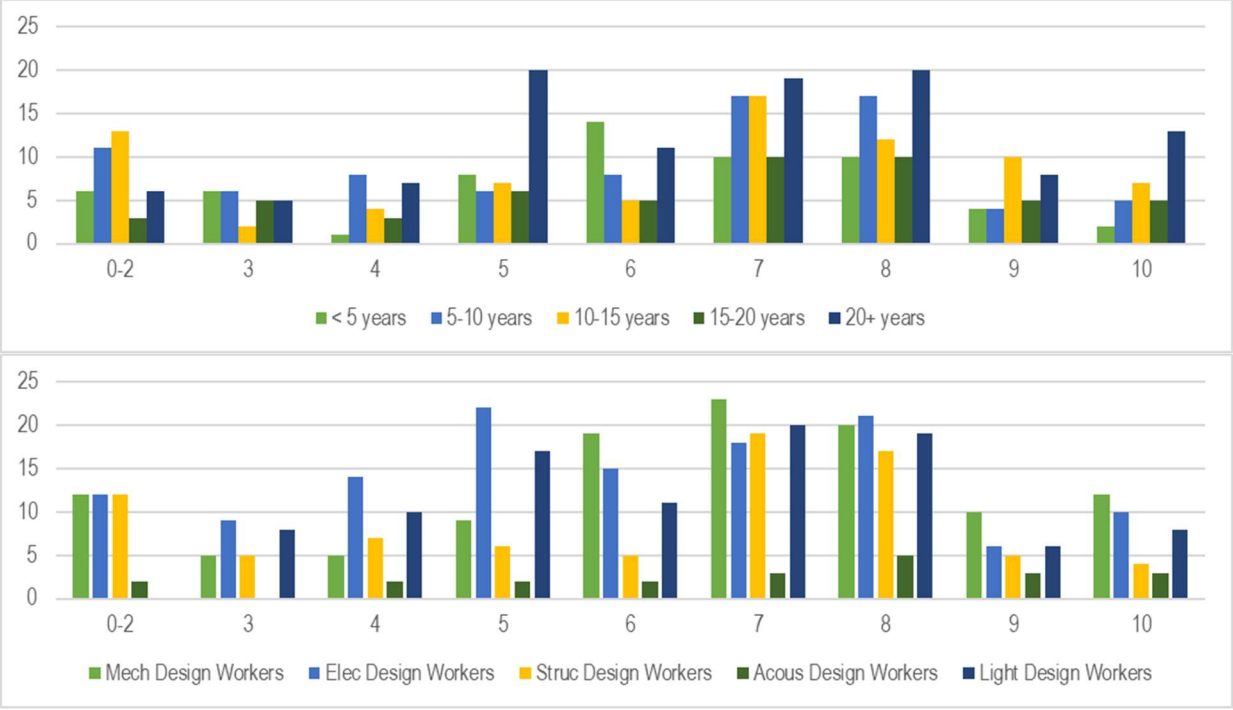
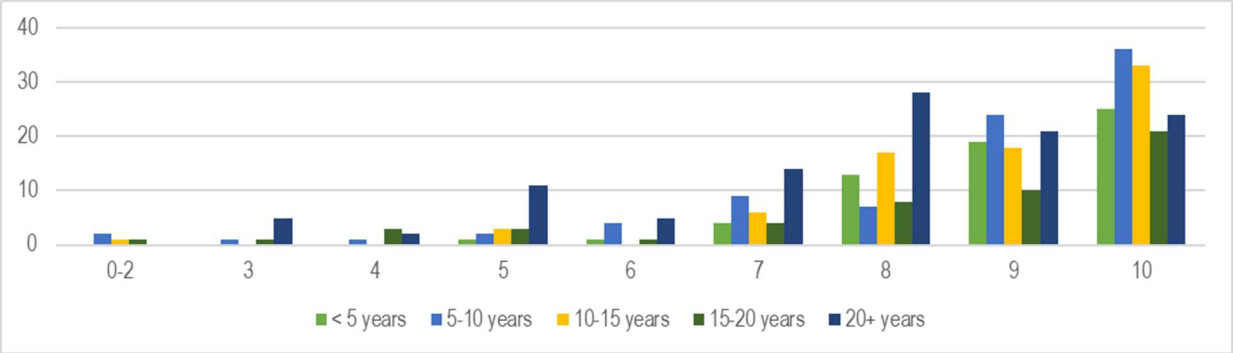


Figure 4 - Rated importance of the interdisciplinary team design course across years of experience and discipline



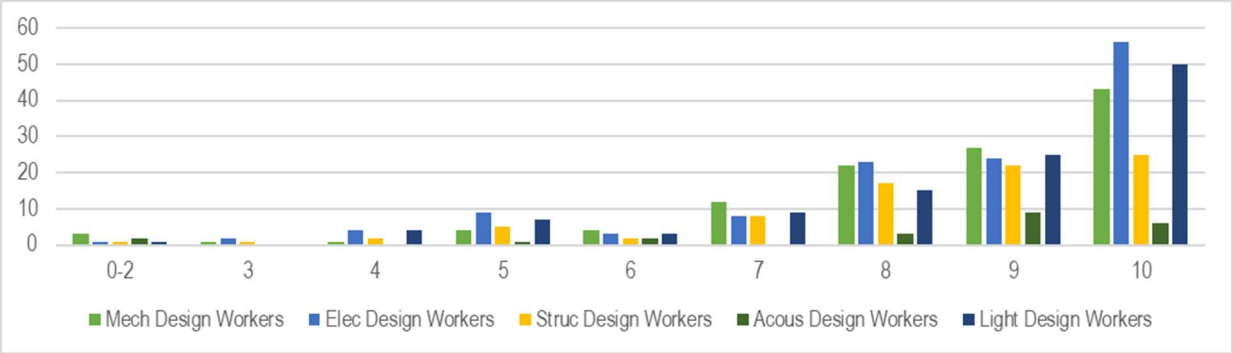
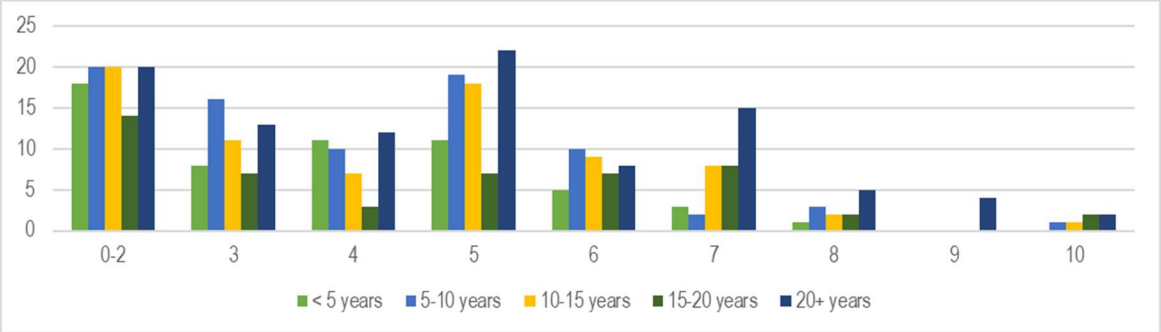


Figure 5 - Rated importance of a graduate level course in statistics across years of experience



Courses Specific to Degree Concentration

In open-ended responses, participants seemed to see value in having some training across disciplines, but that advanced coursework in other specialties was perceived as taking away opportunities to gain deeper training in one's own degree concentration.

New Courses to add to fifth-year Master's program

When asked to report new courses or topics to be covered in the fifth-year Master's program, responses tended to vary across discipline. A large proportion of respondents from the mechanical specialization noted plumbing as an important topic that was missing from the curriculum. Other topics included fire safety, building codes (especially among Electrical and Structural respondents), specialty systems, construction-related topics, and business-related topics such as management, administration, technical sales, contracts, legal liability, real estate economics, and finance.

Alumni Response Items

When alumni were asked to report the parts or experiences of the fifth-year Master's program that best prepared them to be a professional in the field, they were most likely to identify the interdisciplinary team capstone project, followed by internships, the individual graduate project, and advanced technical design courses in their respective disciplines. In the open-ended

responses, many respondents suggested that the rigor of the coursework in fifth-year Master's program served to prepare them for their professional career.

When alumni were asked to report the parts or experience of the fifth-year Master's program that were the least important to their work in their professional field, they were most likely to identify the graduate-level statistics course, the individual graduate project, and technical courses outside of their respective disciplines. In the open-ended responses, respondents that identified the individual graduate project to be least important tended to mention the topic of their project in their response. Conversely, of the alumni that identified the individual graduate project to be among the most important experiences, respondents tended to highlight non-topic related reasons (e.g., allowed in-depth consideration of a technical concept, independent investigation, development of written communication skills).

Non-Alumni Response Items

Many non-alumni named "soft skills" like communication, teamwork, and willingness to work and learn as being important when hiring recent graduates, as well as industry-relevant experience such as internships. Software proficiency in building information modeling (BIM) software or other discipline-specific design tools were also noted.

Non-alumni participants were also asked to report the skills or experiences that are most important in their decision making to hire experienced employees. Respondents again emphasized "soft skills" like communication and teamwork, but also noted relevant experience, leadership or project management experience, and technical knowledge.

Discussion

In response to the survey results obtained from industry professionals, a number of curricular changes were implemented. First, the fifth-year master's degree was restructured to include an individual graduate project requirement once again. However, rather than strictly requiring the development of a novel research effort, students were also permitted to select a topic extending from the interdisciplinary team design project. For example, a student might choose to deeply study an alternative building system that was not ultimately selected by their project team. Students are still required to present an oral presentation and written deliverable associated with their graduate project, but the scale of the project has decreased to three credit hours of work spread over both semesters of the fifth year. Second, the credit-hour total associated with the interdisciplinary team design project was decreased from eight to five credit hours spread across both semesters of the fifth year to accommodate the additional workload imposed by the individual graduate project. Third, the graduate level statistics course requirement was removed. Students had already received exposure to statistics topics in an undergraduate statistics course. Elsewhere in the fifth-year master's curriculum, minor adjustments were made to the credit-hours associated with the required AE Internship course and the AE Professional Practice course. No substantial changes were made to the content or structure of these courses. The net result of these changes was the successful reduction of the fifth-year Master's program from 36 credit hours to 30 credit hours.

Interestingly, results from the survey portray a disagreement between industry professionals regarding the usefulness of an individual graduate project in a fifth-year Master's program. Respondents were more likely to identify the graduate project as not useful and cite the irrelevance or novelty of their research topic while doing so. A different philosophy was expressed by those that found the graduate project to be useful—such respondents pointed toward value in the process and skill development. Moving forward, some negative sentiments toward the graduate project may be mitigated by emphasizing the skills that students may develop through their project rather than concentrating on the novelty of their project topic.

The architectural engineering program is still considering other points of feedback expressed through the survey regarding course topics and the incorporation of a Smart Buildings option.

Among non-alumni that were surveyed, the most important factors in hiring decisions (both recent graduates and experienced hires) were non-technical in nature. Technical skills may be seen as naturally expected from graduates, whereas communication skills, teamwork, and personality characteristics were reported to be the differentiator in hiring decisions.

Conclusion

Results from an online survey of working professionals in the AE&C industry were successfully used to inform curriculum changes to the University of Nebraska-Lincoln's fifth-year Master's degree program in architectural engineering in the process of reducing the degree from 36 credit hours to 30 credit hours. When added together, industry professionals donated more than 90 hours of their valuable time toward providing survey responses. This represents a substantial industry stake in curricular design.

The most significant changes to the program included reinstatement of an individual graduate project, and the removal of a graduate level statistics course. Responses indicating conflicting opinions toward the utility of the individual graduate project illustrated a need to focus the graduate project on developing skills (e.g., information gathering, task management, technical writing) rather than emphasizing the generation of a novel research effort. Opinions regarding the potential development of a Smart Buildings degree concentration were mixed, but more experienced respondents tended to attribute value to this topic. Interdisciplinary team design experiences, internships, and rigorous coursework consistently ranked highly among factors that professionals reported as preparing them for their careers. Industry professionals also tended to see value in having introductory level training across disciplines, but desired to see more advanced technical coursework within their own discipline. Non-technical skills were commonly identified as the differentiator in hiring decisions for both recent graduates and experienced employees.

Other programs and institutions are strongly encouraged to survey alumni and non-alumni professionals to obtain industry perspectives on curricular matters. Future work may include the inclusion of members of professional organizations as a group to be surveyed—it is unknown if ongoing continuing education activities would affect industry responses. Through such a process, engineering curricula may be aligned to better prepare graduates for success in their professional careers according to expectations or needs communicated by industry.

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