Undergraduate Opportunities for Construction Students' Multidisciplinary AEC Collaboration and Awareness

Dr. Luciana de Cresce El Debs, Purdue University, West Lafayette

Luciana Debs, is an Assistant Professor of Construction Management in the School Construction Management Technology at Purdue University. She received her PhD from Purdue University Main Campus. Her previous degrees include a MS from the Technical Research Institute of Sao Paulo (IPT-SP), and BArch from the University of São Paulo (USP), in Sao Paulo, Brazil. Prior to her current position she worked in design coordination in construction and real estate development companies in Brazil. Her research interests include team work and collaboration in construction, effective communication in spatial problem solving, and design - field team interaction.

Mr. Mark Shaurette, Purdue Polytechnic Institute

Mark Shaurette has a MS in Civil Engineering from the Massachusetts Institute of Technology and a PhD in Technology from Purdue University. He is currently an associate professor at Purdue University, was a 2012 Fulbright Scholar in Ireland, and has work experience that includes 30+ years of senior construction management practice as well as work as a research engineer for the National Association of Home Builders Research Foundation. He is active in research, education, and community outreach in the areas of building retrofit for energy conservation, sustainable construction practices, management of the demolition process, material reuse and recycling, as well as instructional design in technology education.

Denise McAllister Wilder NCIDQ, Purdue Polytechnic Institute

Denise McAllister Wilder, NCIDQ is a doctoral student at the Purdue Polytechnic Institute in the School of Construction Management Technology. She has taught and practiced in the architecture, engineering, and construction community for over twenty-five years and is a registered interior designer in Indiana. Her areas of research focus include aging in place, studio learning in a transdisciplinary technology environment, BIM and lighting simulations, smart home technology and aging in place, and retrofitting existing homes to create net zero homes for aging in place.

Undergraduate opportunities for construction students' multidisciplinary AEC collaboration and awareness

Introduction

Construction is a fragmented industry[1-3] which relies on the abilities of several different professionals for successful completion of projects. The diversity of backgrounds involved in the construction process requires that professionals within the Architectural, Engineering, and Construction (AEC) industry be skilled when collaborating and communicating across several disciplines.[2] This is especially true when dealing with collaborative delivery methods such as design-build and integrated project delivery (IPD), or when using collaborative technologies such as building information modeling.[4, 5]

The need for increased multidisciplinary collaboration is recognized by all major AEC educational programs' accrediting bodies: the Accreditation Board for Engineering (ABET), the American Council for Construction Education (ACCE), the National Architecture Accrediting Board (NAAB), and the Council for Interior Design Accreditation (CIDA). This recognition is indicated in the language of learning outcomes required by construction management (CM), civil engineering (CE), architecture (Arch), and interior design (ID) programs as can be seen in table 1.

Table 1 – Requirements for collaboration and multidisciplinary interaction in AEC accrediting bodies

AEC related field	Accrediting Organization	Requirement Student Outcomes and Program Requirements
Construction Management (CM)	ACCE[6]	• Apply construction management skills as a member of a multidisciplinary team.
Civil Engineering (CE)	ABET[7]	• An ability to function on multidisciplinary teams
Architecture (Arch)	NAAB[8]	• *Understanding* of the relationship between the client, contractor, architect and other key stakeholders such as user groups and the community, in the design of the built environment. Understanding the responsibilities of the architect to reconcile the needs of those stakeholders • The program must describe its culture for successful individual and team dynamics, collaborative experiences and opportunities for leadership roles. Architects serve clients and the public, engage allied disciplines and professional colleagues, and rely on a spectrum of collaborative skills to work successfully across diverse groups and stakeholders.
Interior Design (ID)	CIDA[9]	• Interior designers collaborate and also participate in interdisciplinary teams.

However, even though multidisciplinary collaboration is expected in professional settings and academic programs, most academic structures for AEC undergraduate education are siloed and thus have little student collaboration between them.[4, 10, 11] Reasons for this lack of collaboration may vary, but are also influenced by each program's curriculum structure, such as programs that encourage interdisciplinary classes, and others that prefer to work with classes designed for a single major.[12] This lack of exposure contributes to construction management (CM) students experiencing very little collaboration with other related AEC undergraduate students. Efforts are being made to bring together AEC disciplines in undergraduate education, with the hopes of improving interdisciplinary collaboration, communication and understanding of diverse values and needs. However, experiences such as those reported at Mississippi State University[13] and Auburn University[11] are still uncommon or limited to the duration of a specific course or experience.[11]

Even though these collaboration projects are limited, Herrmann, Gregory, Miller, and Powney[14], while analyzing five years of collaborative initiatives at the Mississippi State University, indicated a positive change in the perspective of students from diverse disciplines (architecture, construction, interior design, and graphic design) for at least half of the students who responded to the survey. Students who participated in the experience also reported the opportunity to "prepare [themselves] for collaboration that will take place in practice"[14] (p. 4) as the most important goal for the collaboration experience. This suggests that students are aware of the importance of working in multidisciplinary groups within the AEC industry. Leathem, McGlohn, Gregory, Herrmann, and Carson[13] mention that "…initial successes of these programs suggest a cross-disciplinary collaborative model improves the potential for project success within the architecture and construction disciplines." (pp. 1-2).

Previous studies have shown benefits of students from various AEC disciplines working together, and have identified that curricular limitations and siloed structures may hinder more extensive collaboration. These siloed structures may also contribute to the duplication of efforts in similar courses, but taught to different AEC programs. Based on these studies, we have identified a need to survey AEC programs' curricula to verify opportunities already embedded within them and to discover how many programs exist within universities and colleges that could foster student interaction. This information can provide a basic panorama of cross disciplinary AEC education in the United States.

Methodology

Given this scenario, this study analyzes the core curricula of CM programs affiliated with the Associated Schools of Construction (ASC) in an effort to determine overlaps and potential overlaps between required courses in the plans of study of CM and other AEC disciplines. This research involves curriculum analysis of construction management, architecture, and civil engineering programs of American universities that have CM affiliated programs. Researchers focus only on bachelor's degrees within those academic institutions.

In order to provide a survey of the current state of cross-disciplinary opportunities for AEC students in the US, we pose the following research questions:

1) How many CM programs reside at institutions that also host ID, CE, and/or Architecture programs?
2) How many of the CM programs located at institutions that have ID, CE and/or Architecture programs have overlapping courses indicated in their plan of study?
3) How likely are CM students to take courses within ID, CE or Architectural programs?
4) How likely are ID, CE, and/or Architecture students to take CM courses?

The research focuses on actual and potential overlaps. An actual overlap is defined here as a course with the same name and number in both CM and another AEC program. Overlaps between interior design and architecture, interior design and civil engineering, as well as architecture and civil engineering were not taken into consideration. It is an assumption of the researchers that if two programs share the same course name and number, students from both programs would have a possibility of taking the course together. However, we anticipate data collection limitations for courses with the same name and number, but which have separate sections for each program because this information is not openly available on university websites. Also, our methodology cannot identify cross listed courses, which are courses with same meeting time, but with different numbers in different programs.

A potential overlap is defined as courses with similar content coverage as determined by their name and / or course description (when available). For example, the following two courses can be found in Alfred State College: CIVL 3553 – Commercial Building Construction and Practice, within the Construction Management program, and ARCH 4103 – Construction Technology 2, within the architectural program. In this case, course descriptions were available to researchers and are transcribed below. Similarities between courses descriptions indicate that both cover commercial buildings materials and methods and are highlighted in italic lettering below.

- CIVL 3553 (Commercial Building Construction Methods and Practices): This course is a study of *materials and methods of construction* employed in *commercial building construction*. This course will be used to extend the students' *graphics skills using BIM/3D software* as well as their knowledge of the *building construction process.* Topics include: foundation, steel frame and *reinforced concrete* construction. Throughout the course, attention will be given to sustainability of construction materials and methods;[15]
- ARCH 4014 (Construction Technology 2): This course builds on the construction topics begun in Construction Technology 1. The course is focused on *construction techniques for commercial buildings*. Topics covered include steel frame, *reinforced concrete*, precast concrete and building envelope systems. Emphasis is placed on *contemporary details and methods of construction*. Student evaluations are based on *Building Information Modeling (BIM) computer generated projects* and periodic tests.[16]

The description of CIVL 3553 and ARCH 4103 indicate potential overlap of the course topic (materials and methods), as well as similar content in both courses (commercial construction, BIM software), even though they are presented as separate in the college's catalog of undergraduate courses. The researchers classify this as a 'potential overlap,' which indicates courses that could perhaps benefit from some student collaboration.

On the other hand, the two courses presented below, from New York University's civil engineering and construction management programs were not classified as a potential overlap in the area of site design. This was due to the content emphasis of 4812 as being a part of a broader capstone experience, while 3553 emphasis seems to be strictly in surveying calculations. CE-UY 3553 is also offered to Civil Engineering students as a possible elective, and as part of the major curriculum for CM students. Even though CE students can take the course as an elective, researchers cannot assess if that is actually the case. Students in NYU may choose only one elective course from a list of 25 pre-approved courses, of which 13 are in CM, 7 in CE, and 5 is in transportation engineering.

- CE-UY 4812 (Civil Engineering Design I: Site Planning and Design): This is the first part of a two-semester capstone design project course for Civil Engineers. Each year a specific project will [be] created. Student groups will be formed, and each group will develop its plan and design for the assigned project. Formal progress reports will be required, and a full design report will have to be prepared, submitted, and orally defended each semester. The first semester focuses on site planning and design issues. The main facility will be located on the site, and all site issues addressed: grading and earthwork, traffic access and parking, water supply and sewage disposal, power supply and related issues;[17]
- CE-UY 3553 (Construction Site Layout & Surveying): This course studies the practical applications of surveying and its relationship to site planning and design. The first portion of the course concentrates on land surveying concepts, including mathematics, horizontal and vertical control, and angle measurement. The second portion of the course applies surveying data to site layout using traverses, area computations, property surveys, topography, and construction layout for highway and building applications. This course also includes a field laboratory which introduces students to basic surveying practice, including the use of surveying equipment (wheels, tapes, levels, and theodolites), measurements theory and computation, data accuracy and precision, and the use of the field book to properly record data.[18]

Research phasing

This is a working paper of a broader study, which is organized in three phases: (1) survey of programs and actual overlaps; (2), review of plans of study and analysis of potential overlaps; and (3) survey of academic advisors of CM programs to answer research questions 3 and 4. Information for plans of study and courses used in this research are publicly available online.

IRB exemption (#1611018429) was obtained to survey academic advisors regarding undergraduate opportunities and actual cross disciplinary participation.

Descriptive statistics will be used to describe the data for all four questions, and a correlation analysis will be performed to verify if there is a relation between the likelihood of CM students taking other AEC courses or AEC students taking CM courses. Potential overlaps will be determined through qualitative analysis of course names and descriptions.

This study has currently finished phase 1 (online data collection). Phase 2 will be completed during the first semester of 2017, and phase 3 during the summer of 2017. The results in this paper reflect findings for phase 1 and are aimed at helping CM educators evaluate the present level of collaboration between AEC undergraduate programs in the United States.

Partial Results

Sample Demographics

There are 129 ASC affiliated schools in regions 1 through 7 in the association's website. Region eight was excluded from the analysis as it encompasses only schools from outside of the United States. Other exclusions were made and are presented below. Finally, this research was conducted using data from 107 schools.

- Two other schools that were included in region 1, but were located outside of the US were also excluded from the analysis;
- Twelve schools were excluded because their CM related program was not at the bachelor's level (associate or graduate levels only);
- Eight programs were excluded because construction management was not a standalone degree, but rather embedded into a civil engineering or civil technology degree.

The distribution of schools per ASC region is presented in figure 1 which indicates a reasonably balanced distribution of schools per region.

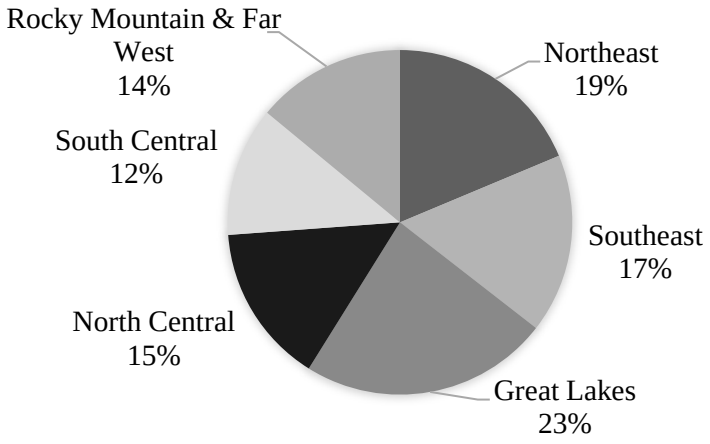

Figure 1. Distribution of schools per ASC region (n=107)

Researchers also registered the variety of names in which ASC construction management programs were affiliated. Researchers found 78 programs named construction management, construction science and management, or construction management technology; twelve named construction engineering or construction engineering technology; eleven named building sciences or construction sciences, and do not include the words ‘engineering’ or ‘management’ in their program title; and, six programs were found under other names (engineering technology, technical management, engineering technology management, applied engineering technology, project management, and technology management). Figure 2 presents the percentage breakdown for construction management programs related names.

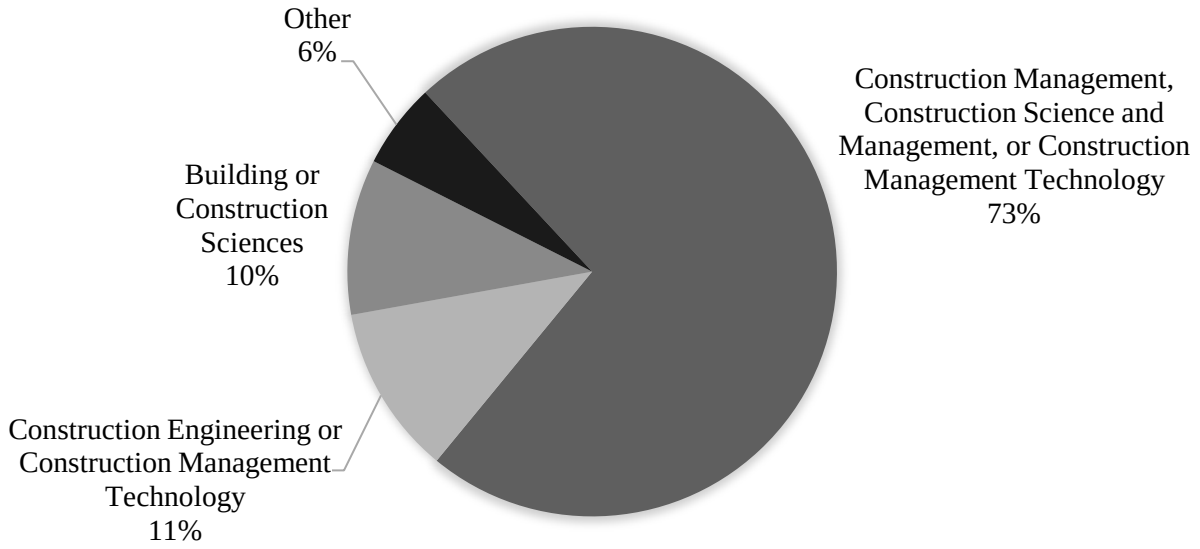

Figure 2. Classification of the name of the CM related program (n=107)

School and college affiliation within academic institutions was also recorded as it was expected to influence the existence of actual overlaps between plans of study. Colleges or departments were classified in 13 categories, which are presented in table 2. Four schools were not organized in academic subunits such as colleges and were not included in this analysis, and one program was considered a collaboration between two separate colleges. Names of the units were classified using major AEC disciplines, such as engineering, or architecture. Other names frequently mentioned were also included, such as business, and technology. It was found that 33% of the 103 programs analyzed were affiliated with engineering, followed by 21% with colleges or schools of technology, and 12% with other non-related AEC disciplines, such as environmental sciences, education, and arts. Table 2 presents the results of the classification, as well as examples of names of colleges classified in each category.

Table 2 – Classification of academic units within universities with an ASC affiliated bachelor's program (n=103)

College or school name	Quantity	Examples
Engineering	34	College of Engineering; College of Engineering and Computer Science
Technology	22	College of Technology; College of Science and Technology; College of Applied Sciences and Technology; Purdue Polytechnic Institute
Other, non AEC related	12	College of Education and Professional Studies; College of Arts & Sciences; College of Food, Agricultural and Environmental Sciences; College of Environmental Science and Forestry
Business	8	School of Business and Justice, College of Business
Engineering and Technology	8	College of Engineering and Technology; School of Engineering, Science, & Technology
Architecture	7	School of Architecture; College of Architecture, Art, & Design; College of Architecture
Architecture and Construction	4	College of Architecture and Construction Management; College of Architecture, Design and Construction Management
Other, AEC related	8	College of Built Environment; College of Engineering and Architecture; College of Engineering, Architecture and Technology

Construction Management Programs in Academic Institutions with other AEC related programs

Results indicated an almost equal number of CM programs in institutions that also have architecture, civil engineering and interior design, as the ones who only have construction management, and not architecture, civil engineering and interior design. For that analysis, it is important to note that only bachelor's in architecture (or architectural experience) were considered; only bachelors of civil engineering, or civil and environmental engineering, or engineering with emphasis on civil were considered as civil engineering degrees; and interior design and interior architecture were considered as interior design degrees. Architectural engineering and civil engineering technology were not included in the analysis.

Twenty one of the 107 institutions evaluated which have construction management related bachelor's program are standalone AEC programs, which for this study means they are in academic institutions that do not have other AEC related programs, specifically architecture, civil engineering, and interior design. Twenty programs are in academic institutions that have architecture, civil engineering, and interior design programs. Figure 3 shows the distribution of CM related programs as pertains to the existence of architecture, civil engineering, and interior design programs within the same academic institutions.

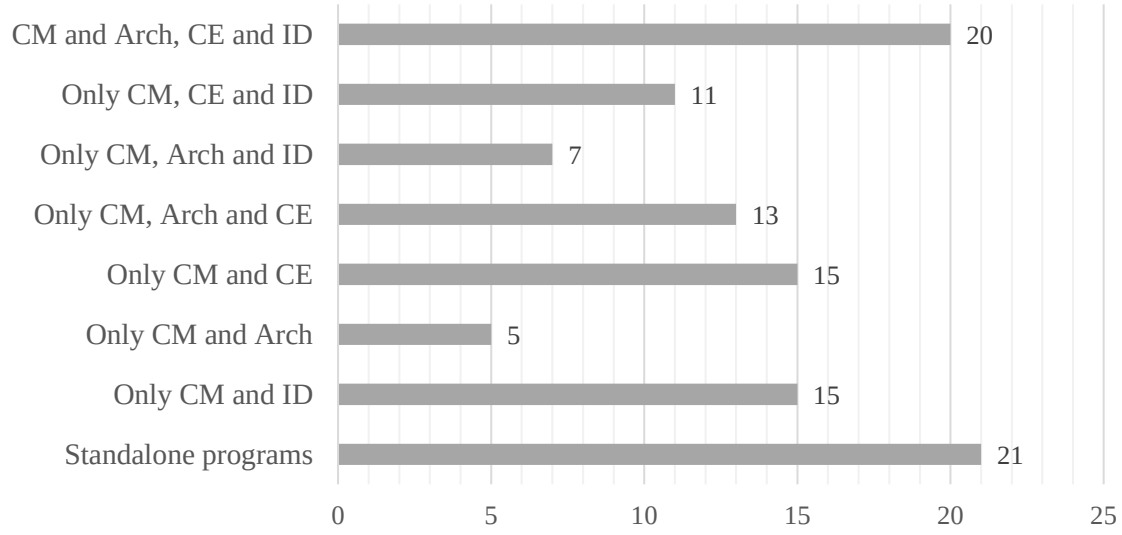

Figure 3. Construction management programs in academic institutions with architecture, civil engineering, and interior design (n=107)

The researchers then evaluated how many of those AEC related programs are located within the same academic subunit (college or school, depending on how the academic institution is organized) as the construction management ASC affiliated program. Most CM programs within academic institutions which also host civil engineering programs are also located in the same subunit as the civil engineering programs (63%). Slightly more than half of the CM programs in academic institutions that have Architecture are also located within the same subunit (56%). A little less than one third (32%) of CM programs that are in academic institutions which also host Interior Design are located in the same academic subunit. The breakdown for the location of architecture, civil engineering, and interior design programs is presented by figure 4.

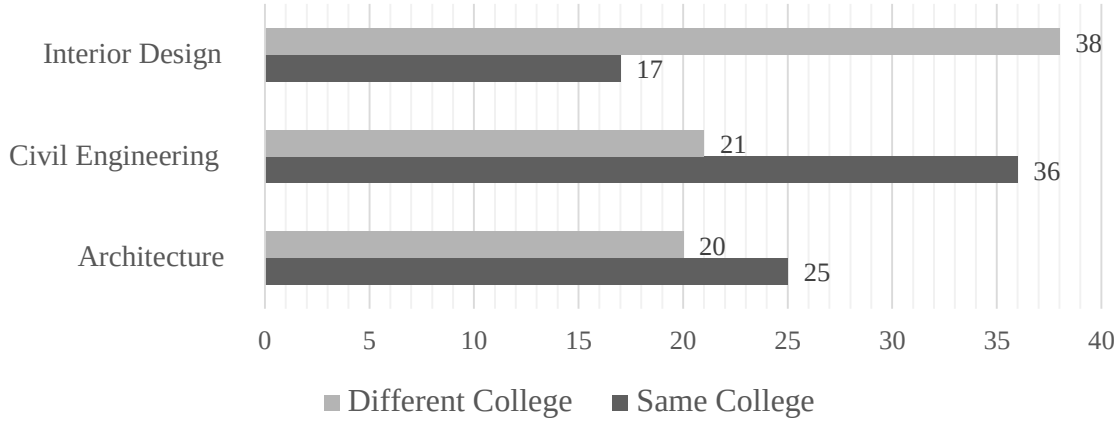

Figure 4. Construction management programs in relation to academic subunits that also host architecture, civil engineering, and interior design programs (n=86)

Actual overlap of construction management courses with architectural, civil engineering and interior design programs

In order to analyze actual overlaps, researchers have verified 240 plans of study and major requirements of CM, Arch, CE, and ID programs based on information available at each academic institution's website. Researchers have recorded General Education requirements as well as major requirements. General education requirements include, for example, subjects in: English and communication, literature, history, globalization, culture, general economics, and general physics. Some courses which are support courses for CM students, but might be taught in other colleges such as mechanics, management, and accounting were included as major requirements.

Construction Management overlap with Architecture

Forty-five Construction Management programs are located in academic institutions offering architectural degrees. Of these:

- Twenty-nine institutions have no actual overlap in AEC related courses;
- Sixteen institutions have 71 overlapping AEC related courses between CM and Arch students;
    - Within those 16 institutions, there is a median of 2 overlapping AEC courses per school, with a median of 6 overlapping AEC credit-hours per school.
- The State University of New York Delhi (SUNY) has the highest number of overlapping AEC courses between Building Construction Management and Architectural Design, with a total of fourteen courses (41 credit hours) taught to both CM and Arch students;

The researchers also categorized experiences by the title of the courses. Table 3 presents the results which indicate a higher overlap in mechanics and structure, as well as materials and methods courses.

Table 3 – Classification of overlapping courses between CM and Arch programs (n=71)

Topic Area	Number of overlapping courses	Example of course titles
Mechanics and Structures	23	Structures I; Statics and Mechanics of Materials
Materials and Methods	18	Construction Materials; Building Science
Mechanical, Electrical, and Plumbing systems	8	Active Building Systems I; Building Environmental Design II
Graphics	5	Commercial Detailing; Architectural drafting
Design Studio[a]	3	Design Studio I, Design Studio II

Management	4	Project Management; Construction Management
Introductory courses	3	Fundamentals of Architecture; World of Design and Construction
Building Codes or Law	2	Building Codes
Estimating	2	Cost Estimating; Cost Estimating Lab
Other (safety, quality & scheduling)	3	Construction Planning & Scheduling; Intro to Occupational Safety

[a] – three studio coursework, all in the NewSchool of Architecture and Design

Construction Management overlap with Civil Engineering

Fifty-nine CM programs located in academic institutions also offer undergraduate degree (bachelor's) of civil engineering. Of those:

- Thirty-two institutions do not have overlapping course work in AEC related disciplines;
- Twenty-seven academic institutions have 134 actual overlapping courses related to AEC between CE and CM programs;
    - Within those 29 institutions, the medium number of overlapping courses is 4, and the medium number of overlapping credit hours is 9 per institution.
- The Milwaukee School of Engineering has the highest number of AEC overlapping courses between CE and CM programs, with a total of 14 overlapping courses (48 credit-hours).

Table 4 presents categorized experiences according to the title of the courses indicating a higher overlap in mechanics and structure, followed by courses in the area of surveying, materials and methods, graphics and soils.

Table 4 – Classification of overlapping courses between CM and CE programs (n=134)

Topic Area	Number of overlapping courses	Example of course titles
Mechanics and Structures	30	Engineering Statics; Principles of Structural Engineering
Surveying	18	Surveying
Materials and Methods	17	Civil Engineering Materials; Building Construction Methods
Graphics	16	Engineering Graphics, CADD
Soils, Geology, or Geotechnical	14	Physical Geology; Geotechnical Engineering
Introductory courses	11	Introduction to Transportation Engineering; Introduction to Engineering and Design

Management	10	Construction Management; Project Management
Estimating	6	Specifications and Estimating; Project CostBenefit Analysis
Building Codes or Law	3	Construction Law;
Ethics	3	Introduction to Ethics; Engineering Ethics and its Impact on Society
Capstone	3	Civil Engineering Capstone Design; Capstone Design
Other (safety, mechanical, electrical, and plumbing systems, and scheduling	1	Construction Safety & Equipment; Mechanical, Electrical, and Plumbing (MEP) Systems

Construction Management overlap with Interior Design

Fifty-three CM programs are located within academic institutions that also hold ID programs. Of these programs:

- Thirty-eight institutions have no form of course overlap between CM and ID in AEC related disciplines;
- Fifteen institutions have 26 overlapping AEC related courses between CM and ID program curricula;
    - Within those 15 institutions, there is a median of 2 overlapping AEC coursework, with a median of 6 overlapping credit hours per institution.
- Both the Appalachian State University and the Southwestern Missouri State University have the most overlapping courses (3 courses and 9 credits of overlap) related to AEC disciplines between their Interior Design and CM programs.

The categorized actual overlap by content topic and results in table 5 shows that 46% (n=12) of the actual course overlaps between construction management and interior design courses are in construction graphics, which encompasses manual architectural drafting and computer aided design (two and three dimensional). The graphics area is clearly the most promising area of content overlap between Interior Design and CM curricula, with other topic areas presenting a significantly lower number of overlapping courses.

Table 5 – Classification of overlapping courses between CM and ID programs (n=26)

Topic Area	Number of overlapping courses	Example of course titles
Graphics	12	Construction Graphics; Computer Aided Design I

Management	3	Managing Organizations; Principles of Organization and Management
Materials and Methods	3	Light Construction Methods and Materials; Construction Design and Processes
Mechanical, Electrical, and Plumbing systems	2	Mechanical and Electrical Systems, Building Mechanical Systems
Introductory courses	2	World of Design and Construction, Intro to Construction
Accounting	2	Fundamentals of Accounting, Fundamental Financial Accounting
Mechanics and Structures	1	Structures of Buildings
Building Codes or Law	1	Building Codes

Summary of findings regarding actual overlaps

The results show a high number of overlapping courses between CM, Arch, CE, and ID. However, most of those courses are related to general education and usually taught to multiple programs, which might not lead to specific opportunities for students from AEC related disciplines to collaborate.

The summary of AEC related courses which overlap between CM, Arch, CE and ID indicate:

- Civil engineering programs have the most institutions with overlapping AEC courses (n=27) with CM programs. These 27 institutions have a mean of 4.96 courses and 13.59 credit-hours that overlap between CE and CM programs;
- There are sixteen architectural programs with overlapping AEC related coursework with CM programs. These sixteen institutions have a mean of 4.44 courses and 12.87 credit-hours that overlap between Arch and CM programs;
- Fifteen institutions were found to have interior design and CM overlapping courses that are AEC related. These fifteen institutions have a mean of 1.73 courses and 5.33 credit-hours that overlap between ID and CM programs.

Content areas of overlap also vary by program, with graphics being the most recurring overlap between ID and CM, and mechanics and structures the most recurring between construction management and architectural and civil engineering programs.

Table 6 summarizes the median and mean overlap for AEC courses for all institutions analyzed in this study, separated by program. This includes information about AEC related (Arch, CE, and ID) programs that exist within institutions that hold CM programs and do not have any overlapping courses. Table 5 shows that, when taking all programs into consideration, there are still many programs which have no overlap for AEC related disciplines, resulting in a median of overlapping courses and credit hours to be 0 for all three AEC related disciplines and CM programs analyzed. The mean of overlapping courses varies between a low of 0.49 courses

between CM and ID, and a high of 2.25 courses between CM and CE programs. Overlapping credit hours reflect that difference, with a mean of 1.35 credit hours of overlap between CM and ID students, 3.93 credit hours between CM and Arch students, and 6.20 credit hours between CM and CE students.

Table 6 – Descriptive statistics for quantity of courses and credit hours overlaps between all CM in institutions with Arch, CE and/or ID programs (n=05)

Total programs (n=105)	Overlapping Courses		Overlapping Credit Hours	
	Median (M)	Mean ($\bar{x}$)	Median (M)	Mean ($\bar{x}$)
Between CM and Arch (n=45)	0	1.15	0	3.93
Between CM and CE (n=59)	0	2.25	0	6.20
Between CM and ID (n=53)	0	0.49	0	1.35

The least number of total credit hours for the CM bachelor's programs analyzed in this study was 120 credit hours (with a mean of 123 for 105 CM programs with one program excluded due to lack of information available). The researchers have calculated the percentage of overlapping AEC related courses credit hours between CM degrees and other AEC courses analyzed in this study based on the minimum 120 credit hours necessary for degree completion. The results show a maximum of 5% overlap in credit hours in the case of overlaps between civil engineers and CM students; 3% between Arch and CM students; and 1% between CM and ID students.

Discussion

Our partial results of actual overlapping courses between construction programs and architecture, civil engineering, and interior design, confirms previous research that indicate the AEC undergraduate education continues to be siloed, even though current trends in industry are focusing on integrated delivery and cross disciplinary collaboration[4, 10, 11]. Despite the fact that accreditation bodies of AEC related programs indicate the need for multidisciplinary collaboration, actual practice does not appear to result in a higher amount of cross disciplinary courses between AEC programs at the undergraduate level.

Limitations

Findings presented here are limited to the information available in academic institution's websites, including information about plans of study as well as course descriptions and names. Researchers also acknowledge the possibility that certain courses, despite having different course code or numbers, might be taught together to more than one AEC related program. Because the academic institutions' websites do not indicate when courses include students from

multiple disciplines in the various programs' plans of study, the results presented here do not include overlaps of courses with different codes, numbers, or names.

Preliminary conclusions and next steps

Collaboration is desired by accreditation bodies of AEC related programs. The present research shows that even though the programs seek to prepare students for combined efforts of the AEC industry (such as with collaborative delivery methods), academic institutions with more than one AEC related program present low formal academic opportunities for collaboration. The median for overlapping construction management (CM) related courses with other AEC disciplines (architecture, civil engineering, and interior design) is zero for number of courses and number of credit-hours. Researchers have considered all construction management undergraduate programs associated with the Associated Schools of Construction (ASC) within the United States. If academic institutions want to produce graduates prepared to collaborating with other AEC related professionals, it would be beneficial for the students to have collaborative experiences during their undergraduate programs.

Limitations to the current study include the inability to track courses that are listed in two separate programs with different names and/or different codes, and other opportunities available to students within their academic institutions, which are not connected to a course. To minimize these limitations in phase 3 of the study, researchers are preparing to send surveys to academic advisors of CM programs to understand other possible collaboration opportunities that were not captured by the plan of study analysis during the summer of 2017. These could include the existence of students from other AEC majors in CM courses, cross listed courses (courses from different programs that meet and are taught together, but are presented in the plans of study with different codes, numbers and/or names), and other opportunities for collaboration that are outside of courses but within those academic institutions.

Future phasing of this research also includes the analysis of potential opportunities for collaboration of CM students with other AEC related disciplines. Researchers are evaluating courses names and description to compile a list of potential overlap courses, as indicated in the methodology section as phase 2. This list could help identify possible course duplication efforts between AEC related programs within the same academic institution. Evaluation of the content and delivery of those courses could help improve the discussion towards fostering more undergraduate opportunities for multidisciplinary AEC collaboration and students' awareness of the importance of this collaboration.

References

[1] Chan, C. T. W., & Sher, W. (2014). Exploring AEC education through collaborative learning. *Engineering, Construction and Architectural Management*, *21*(5), 532–550. https://doi.org/10.1108/ECAM-04-2013-0036
[2] Cheung, S. O., Yiu, T. W., & Lam, M. C. (2013). Interweaving Trust and Communication with Project Performance. *Journal of Construction Engineering and Management*, *139*(10), 941–950. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000681.
[3] Dave, B., & Koskela, L. (2009). Collaborative knowledge management—A construction case study. *Automation in Construction*, *18*(7), 894–902. https://doi.org/10.1016/j.autcon.2009.03.015
[4] Holley, P. & Emig, E., (2010) "Changing the Culture of Design and Construction Education in the U.S." In: *Architecture + construction alliance research initiatives.* Retrieved from: http://aplusca.org/documents/A+CA.Book.pdf
[5] Costa, A. A., & Tavares, L. V. (2012). Social e-business and the Satellite Network model: Innovative concepts to improve collaboration in construction. *Automation in Construction*, *22*, 387-397.
[6] American Council for Construction Education (ACCE) (2016). Document 103 – Standards and criteria for accreditation of postsecondary construction education degree programs. ACCE. Retrieved from: www.accehq.org/images/uploads/Doc_103_Updated_081116_final2.pdf
[7] Accreditation Board for Engineering and Technology (ABET) (2015). *Accreditation Policy and procedure manual – Effective for reviews during the 2016-17 Accreditation Cycle*. ABET. Baltimore, MD. Retrieved from: http://www.abet.org/wp-content/uploads/2015/10/A001-16-17-Accreditation-Policy-and-ProcedureManual-11-1-15.pdf
[8] National Architectural Accrediting Board (NAAB) (2015). Procedures for Accreditation. Professional Degree programs in Architecture 2015 Edition. Retrieved from: http://www.naab.org/wpcontent/uploads/2016/03/Full-Document.pdf
[9] Council for Interior Design Accreditation (CIDA) (2016). *Council for Interior Design Accreditation Professional Standards 2017*. Retrieved from: http://accredit-id.org/wpcontent/uploads/2016/06/Professional-Standards-2017-Jan_2016.pdf
[10] Hatipkarasulu, Y., Canizaro, V. B., & Murphy Jr, J. D. (2012). Multi-disciplinary Integration for design and construction freshman: Structual organization and challenges. In *American Society for Engineering Education* (p. 25.954.1-25.954.15).
[11] Holley, P. W., & Dagg, C. (2006). Development of expanded multidisciplinary collaborative experiences across construction and design curricula. *International Journal of Construction Education and Research*, *2*(2), 91111.
[12] Migliaccio, G., Sturts Dossick, C., & Golden, E. M. (2014). Enhancing Interdisciplinary Thinking, Teamwork and Collaboration across CM, Arch and CE Disciplines through a Design-Build Competition. In *50th ASC Annual International Conference Proceedings* (pp. 1–8).
[13] Leathem, T., McGlohn, E. M., Gregory, A., Herrmann, H., & Carson, L. (2015). A Case Study in Pedagogy for a Cross-Disciplinary Architecture/Construction Program. *51st ASC Annual International Conference Proceedings.* College Station, TX.
[14] Herrmann, M. M., Gregory, A. D., Miller, B., & Powney, S. (2016). A Retrospective of Five Years of a Collaborative Student Design Competition. In *52nd ASC Annual International Conference Proceedings* (pp. 1–8).
[15] Alfred State College (2017a). CIVL Course Descriptions. Alfred Sate College Catalog. Retrieved from: http://catalog.alfredstate.edu/current/courses/civl/index.php
[16] Alfred State College (2017b). ARCH Course Descriptions. Alfred Sate College Catalog. Retrieved from: http://catalog.alfredstate.edu/current/courses/arch/index.php
[17] New York University (2017a). BS Civil Engineering Curriculum. New York University Tandon Schools of Engineering. Retrieved from: http://engineering.nyu.edu/academics/programs/civil-engineering-bs/curriculum
[18] New York University (2017b). BS Construction Management Curriculum. New York University Tandon Schools of Engineering. Retrieved from: http://engineering.nyu.edu/academics/programs/constructionmanagement-bs/curriculum