

Undergraduate Construction Students' Likelihood of Attending Courses in Other AEC Disciplines

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Recent changes in the AEC industry have increased awareness within the field of the importance of multidisciplinary collaboration. Accreditation Procedures for architecture, civil engineering, construction and interior design related programs often prioritize teamwork and interdisciplinary collaboration. However, previous research indicates that few programs actually require students from different AEC disciplines to take classes together. The present study expands previous research by conducting a survey of construction related undergraduate programs to analyze the likelihood of construction students taking classes from architecture, civil engineering and interior design related programs and vice versa. This study also asks whether there are other opportunities for students from these disciplines to collaborate. Results showed that courses from architecture and civil engineering programs are more likely to attract construction students and vice versa than those from interior design programs. The study also revealed that estimating courses from construction related programs are most frequently cited as desirable for architecture, civil engineering and interior design students. Finally, the study found that several programs mentioned the existence of AEC collaboration opportunities unrelated to course work and that the most frequently cited ones were student competitions, clubs and organizations.

Keywords: undergraduate education; collaboration; curriculum; interdisciplinary

Introduction

In order to improve performance and provide more benefits for project stakeholders, the architecture, engineering and construction (AEC) industry is gradually moving from a siloed to an integrated approach (Clevenger, Valdes-Vasquez & Abdallah, 2016). The integrated approach is based on collaborative work. It requires AEC professionals to work with multidisciplinary teams and develop a holistic view of projects while relying on a high degree of specialization and knowledge of design and construction processes (Forgues & Koskela, 2009).

Previous studies in the AEC industry already have identified collaboration and interdisciplinary teamwork as key to the success of a project (Cheng, Li, Peter, Love & Irani, 2001; Cheung, Yiu & Lam, 2013). Recently, there has been an increasing interest in Building Information Modeling (BIM) and Integrated Project Delivery (IPD), creating a greater need for collaboration in the AEC industry. This need is reflected in discussions regarding AEC undergraduate education and shows the importance of teaching students so-called “soft” skills such as team work, collaborative decision-making and communication. In addition, accreditation bodies of AEC disciplines regularly include multidisciplinary teamwork and collaboration as requirements of undergraduate programs (ABET, 2017; ACCE, 2016; NAAB, 2015). Yet, research suggest that current educational approaches are insufficiently developing students' skills for industry practice (Maclaren, Wilson, Simmonds, Hamilton-Pryde, Mccarthy & Milligan, 2017) and it is becoming clear that students from diverse AEC disciplines have little exposure to each other in academic environments (de Cresce El Debs, Shaurette & Wilder, 2017). In addition, a recent study indicates that “It is not sufficient to teach ‘teamworking’ in intra-disciplinary groups. Effective learning can only take place in larger, multidisciplinary team scenarios” (Maclaren et al., 2017, p.181). Therefore, more research on the current state of construction education, related to exposure to other AEC disciplines, would be helpful to guide future efforts.

Considering ways of enhancing collaborative work among diverse AEC disciplines in institutions of higher learning, this study assesses the likelihood of undergraduate construction students taking courses in other AEC disciplines and vice versa. In addition, it determines which courses and experiences within other AEC disciplines construction students are most likely to engage in during their undergraduate education. The results can provide an important step

toward improving the training of future AEC professionals, since "AEC education should be setting the pace rather than keeping the pace with the industry" (Becerik-Gerber, Gerber, & Ku, 2011, p. 412).

Background

In recent years, the worldwide AEC industry has increasingly moved toward collaborative practices. Due to this trend, the AEC companies are instituting substantial changes in their professional environment related to how collaboration within and between other AEC companies to adjust to new processes and demands in the construction industry such as BIM, IPD, lean construction and sustainability (Becerik-Gerber et al., 2011).

Working relationships between architects, engineers, and construction professionals often have been fragmented because professionals tend to focus exclusively on their own actions, which leads to conflicting goals. These conflicted relationships often start with formal university education, which most often divides schools and disciplines in a way that separates students, who "continue to be educated in separate departments, with little or no integration or collaboration between the disciplines." (Macdonald, 2012, p.223).

Studies suggest that academic institutions are lagging behind the AEC industry in terms of promoting collaborative working practices and even in terms of adopting and teaching new technologies and processes to students from AEC programs (Becerik-Gerber et al., 2011; Becerik-Gerber, Ku, & Jazizadeh, 2012; Macdonald, 2012). In addition, the traditional structure of construction curricula and siloed departments within academic institutions may hinder a greater level of collaboration among AEC students (de Cresce El Debs et al., 2017) and "pose significant impediments in attaining a holistic understanding of the broader issues as the pillar of innovation and effective problem solving" (Vassigh, 2016, p. 1).

Some universities are adapting the curricula of their AEC programs, but in many cases these efforts are insufficiently preparing students for industry practice (Maclaren et al., 2017). Many challenges still need to be overcome, such as negotiating departmental boundaries of AEC disciplines, particularly when there are disputes related to responsibilities for cross-disciplinary courses (Macdonald, 2012; Mills & Macdonald, 2013). Once disciplinary boundaries are opened, it may be easier to complete the process of preparing students for the industry, which involves promoting connections between theoretical classroom activities and real-world practices (Becerik-Gerber et al., 2012). Such measures enhance the personal and professional skills that undergraduate students must achieve to be best placed and drive the AEC industry forward: teamworking; collaborative decision-making; communication; and knowledge of co-professionals (Maclaren et al., 2017).

Currently, the AEC industry requires that educational institutions offer courses that help undergraduate students develop a full "understanding of the complexity of implementing construction projects, interdependencies among participants, what type of information is needed from interrelated disciplines, and when and how this information could be exchanged and shared between tools and processes" (Becerik-Gerber et al., 2012, p.236). This requirement aligns with the requirements of multiple accrediting bodies within AEC education (ABET, 2017; ACCE, 2016; NAAB, 2015). In an effort to provide more integrated experiences to their students, some academic institutions also engage in academic competitions involving multiple AEC areas, such as competitions sponsored by industry or professional bodies. Previous research has shown that student competitions are an effective tool for student engagement and collaboration, and both defeats and challenges can benefit competition participants (Bigelow, Glick & Aragon, 2013; Herrmann, Gregory, Miller & Powney, 2016).

Undoubtedly, education is changing to reflect these new demands in the AEC industry, but not fast enough to meet the industry's needs. This becomes clear in light of two important rising concepts within the AEC industry: Building Information Modeling (BIM) and Integrated Project Delivery (IPD). Both concepts require the collaboration of multiple AEC industry stakeholders and may help push for change in construction undergraduate education, as described below:

- **Building information modeling (BIM).** BIM allows the development of a holistic design represented as a virtual information model that can be shared by a multidisciplinary team. This model can be used throughout the life cycle of the building, facilitating the collaboration of several industry stakeholders. In

view of the necessity of collaborative work, educational institutions need to envision BIM as a resource to engage students more effectively in interdisciplinary collaborative work which can help them to understand how structures are built (Becerik-Gerber et al., 2012; Macdonald, 2012).

- **Integrated Project Delivery (IPD).** IPD is a collaborative delivery method that requires stakeholders to collaborate throughout the project, including coming to an agreement about shared risks and rewards. This early collaboration reduces adversarial relations in the process and encourages a true inter- and multidisciplinary collaboration. An IPD approach in AEC education would help undergraduate students more fully comprehend what collaboration in AEC projects looks like by introducing them to important IPD principles related to collaboration, information sharing and trust (Kent & Becerik-Gerber, 2010; MacDonald & Mills, 2013).

Methodology

This study is part of a larger study on the current state of cross-disciplinary opportunities for AEC students in the United States. The original study was initiated in 2016, encompassing the 107 schools within the United States that have bachelor-level construction programs and are affiliated with the Associated Schools of Construction (i.e. Construction Management, Construction Engineering and other construction related programs, here referred to collectively as construction management - CM). Twenty-one of the 107 institutions evaluated are standalone construction programs, which, for the purposes of this study, means that they come from academic institutions that do not have architecture, civil engineering, and interior design related programs and were not included in the present study. Previous findings from this larger research effort also showed that there are few shared courses between construction related and architecture, civil engineering and interior design related programs, with the median courses being zero (de Cresce El Debs et al., 2017).

The present study expands on previous findings with the following research questions:

1. How likely are CM students to take courses within ID, CE, or ARCH programs?
2. How likely are ID, CE, and/or ARCH students to take CM courses?
3. Are there other extra-curricular opportunities for collaboration between ARCH, ID, CE, and CM students?

Prior exemption was obtained from the Institutional Review Board (IRB) (#1611018429) to survey CM faculty and/or academic advisors regarding undergraduate opportunities and actual cross-disciplinary participation of construction management programs in the United States. The survey was sent electronically to the primary contact of construction management programs listed on the Associated Schools of Construction (ASC) website. The academic institutions selected to participate in the study were those with undergraduate (bachelor's) construction related programs and at least one of the following programs: architecture (ARCH), interior design (ID), and civil engineering (CE), as well as related programs (programs such as Interior Architecture was considered to be Interior Design related programs). A total of 86 institutions in the United States were included in the survey. The survey contained a total of 21 questions which mainly questioned the institutions about: (a) AEC programs offered in addition to the CM program; (b) the likelihood of CM undergraduates to take courses from other AEC programs; (c) the likelihood of ARCH, ID, and CE undergraduates to take courses and vice-versa; (c) the AEC programs that offered more interesting courses for CM students; (d) the more interesting CM courses for AEC students; (e) and the institution's actions aimed at encouraging AEC-student collaboration. The survey was sent during the summer and fall of 2017, and follow up phone calls also were made during the same period.

For analysis, survey responses were evaluated, tabulated, quantified, and grouped by topic. Descriptive statistics were used to describe the data that answered the first two research questions and to provide a demographic for the responding institutions. Qualitative analysis was performed on the responses to the third research question, and the themes that most frequently emerged are presented in what follows.

Results

Although sixty-five responses were obtained, only 54 were considered (63% response rate). Eleven survey responses were eliminated from the results because seven were returned without answers and four were returned with only

University and/or course information identified by the participants. Respondents came from all six ASC regions covering the United States, with a balanced distribution between regions: the South Central Region had seven respondents; the Northeast Region had eight; both the North Central and the Southeast Regions had nine; the Far West Region provided ten respondents; and the Great Lakes Region had 11 institutions responding to the questionnaire.

The sizes of the construction related (CM) undergraduate programs from the 53 responding institutions (one of the 54 original institutions considered did not report the size of its program) ranged from 20 students to 1,000 students, resulting in a mean size of 212 undergraduate students per CM program. Only thirteen of the 54 institutions had construction related programs (CM) and all three of the following programs: architecture (Arch), civil engineering (CE) and interior design (ID) related programs. The researchers also note that only two institutions have CM and ARCH programs, with no CE and no ID, which may skew results for this group. The other 41 institutions had different combinations of CM and other AEC related programs, as presented in Figure 1.

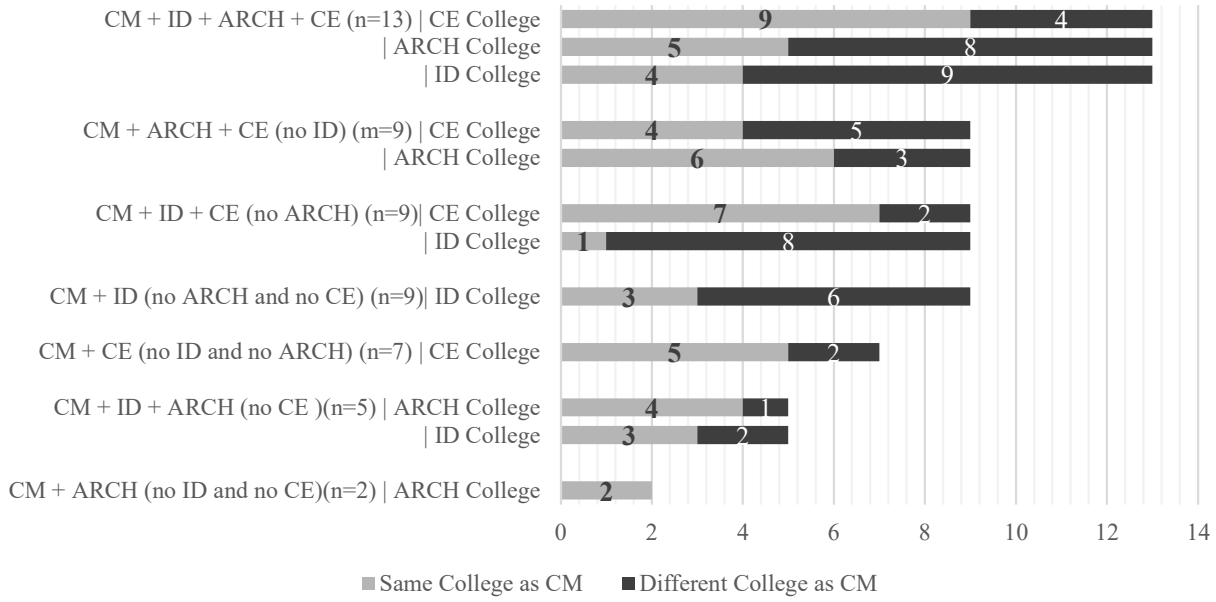

Figure 1: Construction management programs in academic institutions with architecture (ARCH), civil engineering (CE), and/or interior design (ID) programs (n=54)

Likelihood of CM students to take courses within ID, CE, or ARCH programs

Regarding the 54 institutions that participated in the study, Table 1 presents how likely CM undergraduate students are to take courses from other AEC programs. The results, shown in number of institutions, indicate a slightly positive likelihood of CM students to take other AEC courses (57%). In institutions with only CM and ID (44% of responses showing slightly, moderately, and extremely unlikely) or only CM and CE (43% of responses showing slightly, moderately, and extremely unlikely), CM students appear to be less likely to take courses in ID or CE related programs.

To the question of which AEC related programs would interest CM students, participants indicated civil engineering (n=13) and architecture (n=10) as the AEC programs most would choose to take as non-CM courses. Three responding institutions also mentioned that their CM students are positively likely to take courses in electrical engineering related programs and five mentioned that their students are positively likely to take courses in mechanical engineering related programs. The other courses most frequently cited by respondents as courses CM students were positively likely to take were from business (n=3), real estate (n=2), and architectural engineering (n=2). Figure 2 shows which AEC-related programs are more likely to interest CM undergraduate students,

according to the 43 participants who responded to this question (institutions could indicate more than one program). It is significant that some respondents, even if they had CE, ARCH, and/or ID programs in their institutions, did not provide an answer for the likelihood of their CM students to take courses in those programs. The authors of the present study identified that 38 CM programs in institutions that also had CE programs, 36 CM programs in institutions that also had ID programs, and 29 CM programs in institutions that also had ARCH programs did not respond to this question; therefore, they cannot fully interpret the results for this question.

Table 1

Likelihood of CM students to take courses from other AEC programs per institution (n=54)

Answer	CM with ARCH, CE and ID (n=13)	CM with ARCH and CE, no ID (n=9)	CM with CE and ID, no ARCH (n=9)	CM with ARCH and ID, no CE (n=5)	CM with ARCH, no CE no ID (n=2)	CM with CE, no ARCH, no ID (n=7)	CM with ID, no CE, no ARCH (n=9)	Total (n=54)
Extremely likely	46%	56%	33%	40%	50%	29%	11%	37%
Moderately likely	15%	0%	33%	20%	50%	14%	0%	15%
Slightly likely	0%	11%	11%	0%	0%	0%	11%	6%
Neither likely nor unlikely	0%	0%	0%	20%	0%	14%	11%	6%
Slightly unlikely	8%	11%	11%	0%	0%	14%	22%	11%
Moderately unlikely	15%	11%	0%	0%	0%	0%	11%	7%
Extremely unlikely	15%	11%	11%	20%	0%	29%	11%	19%

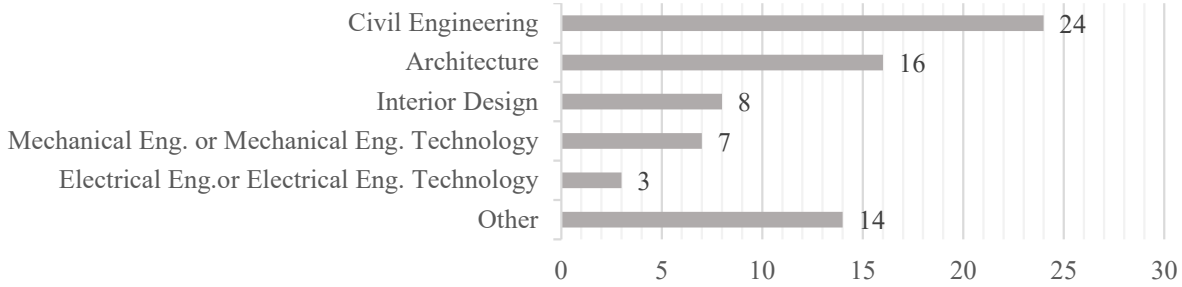

Figure 2: AEC programs CM students are more likely to take courses from (n=43)

Twenty-six respondents reported that their CM students are likely to take CE courses. They listed the number of CM students taking CE courses as ranging from a minimum of 2 to a maximum of 235 students on average per year (Mean = 50, Median = 28, SD = 62). Fifteen respondents indicated that their CM students are likely to take ARCH courses, ranging from a minimum of 2 CM students taking ARCH courses to a maximum 360 students on average per year (Mean = 78, Median = 40, SD = 88). Seven respondents reported that their CM students are likely to take ID courses, varying from a minimum of 2 CM students taking ID courses to a maximum of 10 students on average per year (Mean = 4, Median = 3, SD = 3). The results indicate high variability in answers, which could be a result of differences in program size.

The authors also evaluate the percentage of students, taking into consideration the size of the CM program, as reported by each of the responding institutions. The results indicate the percentage of CM students taking CE courses ranges from a minimum of 0.91% to a maximum of 100% of the total CM students in each program (n=24) per year (Mean = 33.01%, Median = 20.71%, SD = 0.36); the percentage of students taking ARCH courses ranges from a minimum of 2.92% to a maximum of 100% of the total CM students in each program (n=15- one respondent did not report the number of CM students taking ARCH courses) per year (Mean = 49.89%, Median = 37.50%, SD = 0.39); and the percentage of CM students taking ID courses ranges from a minimum of 0.47% to a maximum of 10.42% of the total CM students in each program (n=7) per year (Mean = 3.13%, Median = 1.67%, SD = 0.03). Assuming a balanced distribution of students per year in a four year program, the researchers would consider a

number close to 25% or higher to suggest a positive likelihood of CM students to take courses in other AEC programs.

Likelihood of ID, CE, and ARCH students to take CM courses

The 54 participants affiliated with institutions having CM and ARCH, CE and/or ID programs, varied greatly in responses to the question of how likely other AEC students were to attend construction related courses. Table 2 presents, in number of institutions, how likely ID, CE, and ARCH undergraduate students are to take courses from CM programs. The results show that there is a more positive likelihood that students from CE (70%) and ARCH (70%) programs will take CM courses than those from ID programs (53%). Two institutions explained that they do not have ID programs (even though the authors initially had identified interior design related programs in those institutions), and one institution responded that it does not have a CE program (again, even though initially the authors had identified civil engineering related program in that institution).

The researchers also asked participants for an estimated average number of ID, CE, and ARCH students who take CM courses per year. The results show a lower average number of students from ID than from CE and ARCH programs, though the researchers understand that the number of students can vary greatly due to the program size of the other AEC related programs. Not all respondents included the total number of students in those non CM programs (ID, CE and ARCH), so researchers could not obtain a reliable results to present in terms of percentage over the total number of students from those programs. What follows is a summary of the number of ID, ARCH, and CE students taking CM courses:

- 25 respondents reported a total of 245 ID undergraduate students taking courses from CM programs on average per year (Mean = 10, Median = 5 and SD = 13.35). An additional six respondents answered the question, but reported zero ID students taking courses from their CM program.
- 30 respondents reported a total of 956 CE undergraduate students taking courses from CM programs on average per year (Mean = 32, Median = 20 and SD = 44.51). An additional five respondents answered the question, but reported zero CE students taking courses from their CM program.
- 29 respondents reported a total of 907 ARCH undergraduate students taking courses from CM programs on average per year (Mean = 31, Median = 15 and SD = 33.45). One additional respondent answered the question, but reported zero ARCH students taking courses from their CM program.

Table 2

Likelihood of ARCH, CE and ID students to take courses from CM programs per institution

Answer	ID Programs (n=34)	CE Programs (n=37)	ARCH Programs (n=27)
Extremely likely	15%	32%	33%
Moderately likely	15%	16%	19%
Slightly likely	24%	22%	19%
Neither likely nor unlikely	6%	0%	4%
Slightly unlikely	6%	3%	7%
Moderately unlikely	12%	5%	0%
Extremely unlikely	24%	22%	19%

Participants also indicated that CM courses related to estimating and scheduling /planning are more likely to be chosen by CE student (10 responses each). ARCH undergraduate students are more likely to take CM courses related to construction documents and contracts (11 responses) and estimating (10 responses). Finally, ID students who take CM course are more likely to take classes related to estimating and project/construction management (six responses each).

In addition to regular courses, the researchers asked participants if there were courses listed by different departments, but that met during the same time and place (what we call here "cross-listed") between CM and CE, ARCH or ID. Survey respondents from eleven universities (seven institutions mentioned cross-listed courses with ARCH and six mentioned with CE – respondents may have indicated more than one program) confirmed that their construction related programs had such courses. There were no cross-listed courses with ID mentioned by the participants. Topics for courses that were cross-listed between CM and ARCH included: structures; materials and methods; building systems; building information modeling; and estimating/scheduling. Topics for courses that were cross-listed between CM and CE included: surveying; capstone; project management; structures; and estimating/scheduling. One course (cross listed with CE) could not be coded into a topic by the researchers due to the lack of information given by the respondent.

Other collaboration opportunities

When questioned about other activities and opportunities within their institutions that encourage AEC students to collaborate, 44 of 54 interviewees confirmed that there were other opportunities for collaboration among the AEC undergraduate students of their institutions. Table 3 presents all the additional activities cited by the respondents, grouped into six topics. The researchers decided that if a respondent reported more than one opportunity or activity within the same group, these were considered only once, but each program could report more than one opportunity. For example, the opportunity reported as: "Student clubs, ASC student competition, DBIA student competition, DBIA core courses, study tours and LEED prep course, to name a few" were counted as (1) for student groups, clubs and organizations, (1) for student competitions and (1) for workshops, field trips and, site tours.

Table 3

Opportunities for collaboration between ARCH, ID, CE, and CM students (n=44)

Ranking	Opportunity	Frequency
1	Student competitions	23
2	Student groups, clubs and organizations	20
3	Workshops, social activities, field trips and site tours	8
4	Career events, interactions with industry	4
5	Service projects (such as Habitat for Humanity)	3
6	Others (certification/ preparation courses, construction)	3

Discussion

The results of the present study suggest that, if an academic institution offers interdisciplinary opportunities, there is a positive likelihood that construction undergraduate students will take courses from the CE and ARCH disciplines. Similarly, CE and ARCH undergraduates seem likely to take CM courses. However, this study also indicates that there is a high variability of the percentage of students in CM programs that actually do take those CE and ARCH courses. This suggests that more students could benefit from an increase of interactions between CM and other AEC courses, in order to better prepare undergraduates for the AEC industry (Becerik-Gerber et al., 2012; Maclaren et al., 2017). The results also suggest that CM students' interest in ID program courses and vice versa does not seem to be very expressive. However, it is important to emphasize that these interactions must be closely analyzed because the researchers found big variations in the numbers provided by the institutions.

Among other collaborative opportunities for AEC undergraduates, the study suggests that student competitions are the most commonly used means by academic institutions to foster interdisciplinary collaboration at the undergraduate level. This finding is important and consistent with previous research demonstrating that student competitions are an effective way to enhance students' preparation for the AEC industry (Schuster, Davol & Mello, 2006; Bigelow, Glick & Aragon, 2013).

Findings presented here are limited to the information provided by the survey participants (the survey was sent electronically to the primary contact of construction management programs listed on the Associated Schools of Construction (ASC) website). The researchers acknowledge the possibility that participants' responses to research may not perfectly represent students' interests in the programs analyzed.

Conclusions

Collaboration and interdisciplinary teamwork are desirable according to the AEC industry and accreditation bodies of AEC related programs. This research shows that most institutions indicated a positive likelihood of students from construction related programs (CM) to take courses in architecture and civil engineering related programs, and vice versa and that, when given the opportunity, the percentage of CM students that actually do take those courses vary greatly, but is encouraging (about 20% of CM students take CE courses, and about 38% of CM students take ARCH courses, on average, per year). In addition, this research identifies topics of interest that students from other AEC disciplines (such as architecture, civil engineering, and interior design) want to take from construction related programs (for example estimating, scheduling, project/construction management, and construction documents and contracts). Estimating seems to be the most frequent topic cited by respondents as a topic taught regularly by construction related programs that is of interest to architecture, civil engineering, and interior design students. Finally, even though having taking courses together may not equate to increased collaboration between AEC students, co-locating students in classes may provide a common ground to create collaborative experiences. The results of this study can be used as a starting point for improving collaboration among undergraduate AEC students.

Future research may include: (1) further examination of the perceptions of construction students engaging in courses from other AEC disciplines and vice versa; (2) analysis of the adjustments to the CM course structure needed to accommodate students from other AEC disciplines and vice versa; (3) evaluation of the views of construction program instructors and program heads regarding reasons and issues related to having other AEC related students in their construction classes; and (4) study on how integration in AEC courses affects high school students' decision about considering a CM major.

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