Offsite Construction education adoption in Civil Engineering undergraduate curriculum: Analysis and proposal

Filipe Gonçalves Barros e SILVA[1] and Reymard Savio Sampaio de MELO[2*]

[1] *Civil Engineer, Federal University of Bahia, Brazil*
[2] *Assistant Professor, Department of Construction and Structures, Federal University of Bahia, Brazil*
[*] *Corresponding author's e-mail: reymard.savio@ufba.br*

ABSTRACT
Offsite construction (OSC) is not new globally yet is still not widespread in Civil Engineering (CE) programs. This study proposes strategies for implementing OSC education in a CE undergraduate program curriculum. The research method used was the exploratory field study. Data were collected from three online questionnaires sent to interested parties: OSC industry professionals, faculty members, and final-year students. Each questionnaire sought to answer a specific objective of this study: to identify the design and onsite assembly competencies demanded by the industry, identify the interfaces between OSC and the CE program curriculum and determine the level of confidence of final-year students in applying OSC competencies. The collected data analysis was qualitative and generated from a crossing of the data from the three questionnaires, which supported the proposition of hypotheses for the insertion of OSC teaching by identifying the needs, deficiencies, and difficulties the three interested parties presented. Findings suggest that the OSC competencies most demanded by the industry are about knowing how to detail the interfaces between the components and the parts of the construction site, guarantee the assembly of elements within the deadlines, or learning how to take safety measures against accidents during the construction site. Data also suggest that students are interested in the subject but graduate with little confidence in applying most of the design and onsite assembly competencies demanded by the industry. One of the few exceptions is the knowledge to take safety measures against accidents on the job site. As a result, two hypotheses were generated to adopt OSC teaching in a CE program.

KEYWORDS
Offsite construction; Higher Education; Undergraduate; Civil Engineering

INTRODUCTION
Offsite Construction (OSC) education in architecture, engineering, and construction (AEC) programs is limited and does not meet the industry demand for competency. OSC education is a research area that remains largely unexplored in the literature. Previous studies are few and often much more focused on training than education. Assaad et al. (2022) showed that 20 primary skills are needed for the OSC engineering and design workforce, 24 for the construction and fabrication workforce involved in OSC operations, and 22 for the OSC administrative workforce.

Smith et al. (2017) surveyed the state of teaching and research on offsite prefabrication in the design and construction sector five years ago. The educational survey was limited to Architecture and Construction Management programs in the United States and concluded that there are significant disconnects between what academia is researching and teaching and what industry professionals are currently practising and requiring in the future.

Although Choi (2018) has focused on a graduate-level course on Modular Construction, far too little attention has been paid to OSC education at the undergraduate level. Furthermore, previous studies have not targeted a civil engineering audience. To the author's knowledge, very little is known regarding when to incorporate OSC into current AEC programs curricula. This paper aims to advance the current body of OSC education knowledge by proposing two hypotheses for implementing OSC education in a Civil Engineering (CE) undergraduate program.

RESEARCH METHOD

The research method of this paper is classified as exploratory field research, combining exploratory and descriptive studies (Marconi & Lakatos, 2007) with the triple purpose of developing hypotheses, increasing the researcher's familiarity with the fact, or clarifying concepts. The selected CE program has a minimum duration of 10 semesters and a maximum of 18. The student will have a workload of at least 4080 hours divided into mandatory courses (3808 hours) and elective courses (at least 272 hours).

Data were collected from three online questionnaires sent to interested parties: OSC industry professionals, faculty members, and final-year students. Participants were selected from non-probabilistic convenience sampling. This type of sampling can be applied when one does not want to "make generalizations about any population from a convenience sample" (Malhotra, 2004) but when one wants to generate ideas in exploratory research.

Table 1 shows the "OSC individual competencies demanded by the industry" questionnaire. Nine OSC designs and 17 onsite assembly competencies were built on previous studies (Dziekonski,2017; Jabar et al., 2019). The form was sent to Brazilian industry professionals from OSC organizations in September and October 2020, reaching 15 respondents. The second questionnaire focused on the CE program curriculum at the Federal University of Bahia (UFBA, by its Portuguese acronym). Table 2 shows the questionnaire "Faculty perception of OSC teaching in the CE curriculum" answered by eleven faculty members of UFBA's Civil Engineering program. This questionnaire was adapted and adjusted from the study of Checcucci and Amorim (2014) to collect data from educators about their OSC knowledge and investigate the OSC competencies they could teach. The authors read the CE courses syllabus and included in the questionnaire those related to the OSC. Afterwards, a more detailed analysis of these courses was carried out to relate the course syllabus with the competencies desired by the industry.

Table 1. OSC individual competencies demanded by the industry.

Section 1: Organization profile		
Questions		Answers options
1	At what level of offsite construction does your organization operate?	Prefab components
		Panelized construction
		Pods
		Modular construction
2	What's your organization size?	Startup
		Micro organization - up to 19 employees
		Small organization - 20 to 99 employees
		Medium organization - 100 to 499 employees
		Large organization - 500 or more employees
3	In which regions does the organization operate?	North
		Northeast
		Central-West
		Southeast
		South
		Overseas
Section 2: Respondent Profile		
1	What position do you currently hold in the organization?	
2	How long have you been working in the area?	
3	Does your organization work in the design phase?	
Section 3: Design Competencies		
Rate how important you think the competencies below are for the development of OSC design. 0 > not important 1 >little important 2 > important 3 > very important		
D1	Know how to detail the interface between modules and components, as well as the interface between modules/components and elements in the construction site.	
D2	Know different types of connections (e.g.: screwing, welding...).	
D3	Know how to handle late design changes and/or field changes	
D4	Know how to introduce a degree of standardization into the design	
D5	Know or master the use of BIM software	
D6	Know or master the DFMA methodology - Design for Manufacturing and Assembly	
D7	Knowing how to "freeze" a part of the design to prevent any possible future changes that the client may request in subsequent phases of the project.	
D8	Know or master Brazilian Standard ABNT NBR 15873: Modular coordination for building construction	
D9	Knowing how to introduce a degree of repetition into the design.	

Table 2. OSC individual competencies demanded by the industry (continued)

Section 2: Respondent Profile	
	Does your organization work in the onsite assembly?
Section 4: Onsite Assembly Competencies	
Rate how important you think the competencies below are for the management of onsite assembly. 0 > not important 1 >little important 2 > important 3 > very important	
A1	Ensure the assembly of components/modules within the deadlines.
A2	Take safety measures against accidents during the construction site.
A3	Ensure all machinery/tools are on-site for the installation of components.
A4	Check the dimensional tolerances at the interface between modules/components and elements on site.
A5	Monitor the assembly of components ensuring the correct sequence of execution according to the manufacturers' instructions.
A6	Read and interpret off-site design plans.
A7	Prepare the site for receiving and assembling the components/modules.
A8	Monitor the execution of connections (e.g.: screwing, welding...).
A9	Integrate the assembly execution schedules with the general construction schedule.
A10	Manage the sequence of assembly activities and conventional activities.
A11	Negotiate the cost of components and machinery with suppliers.
A12	Check the quality of components before assembly in the service position.
A13	Correct or adapt discrepancies between actual and design conditions.
A14	Issue guarantees and certificates to customers.

Table 3. Faculty perception of OSC teaching in the CE curriculum.

Section 1: Organization profile		
Questions		Answers options
1	How do you rate your current knowledge of offsite construction?	0 to 10 scale
2	What barriers do you understand that exist for the implementation of teaching OSC in the Civil Engineering program at UFBA?	The size of the curriculum (workload) is excessive
		The need to create new courses to teach OSC
		Lack of OSC knowledge by faculty
		Cultural resistance to the paradigm shift
		Low market demand
		Absence/little regulation
		Other

Table 4. Faculty perception of OSC teaching in the CE curriculum (continued)

Section 2: Assessment of mandatory courses		
In this section, the respondent marks ONE course he/she taught, being directed to its respective assessment. Afterwards, you will be asked if you have taught any other courses. If you have taught another course, you will return to this section to be able to evaluate another course and repeat the loop until you have evaluated all the mandatory courses taught at UFBA.		
Section 3: Course assessment		
	What is the relationship between this course and OSC?	There is no interface with OSC.
		There may be an interface, depending on the focus the teacher gives to the course.
		There is a clear interface with OSC
	What stages of the building life cycle can be discussed in this course?	Feasibility study
		Design
		Construction Planning
		Construction
		Operation and Maintenance
		Demolition
		Not applicable
	What onsite assembly competencies can be developed in your course?	A1 to A14
	What OSC design competencies can be developed in your course?	D1 to D9
	How do you think you could develop the competencies marked above in the course?	OSC design development
		Simulation of processes
		Technical visits at OSC projects or factories
		Experimental laboratory development
		Games

FINDINGS AND DISCUSSION

OSC design and onsite assembly competences

Figure 1 shows the importance level of OSC design competencies demanded by the industry and Figure 2 shows how confident students are to apply OSC design competencies. A detailed discussion is not included in this paper due to space limitations.

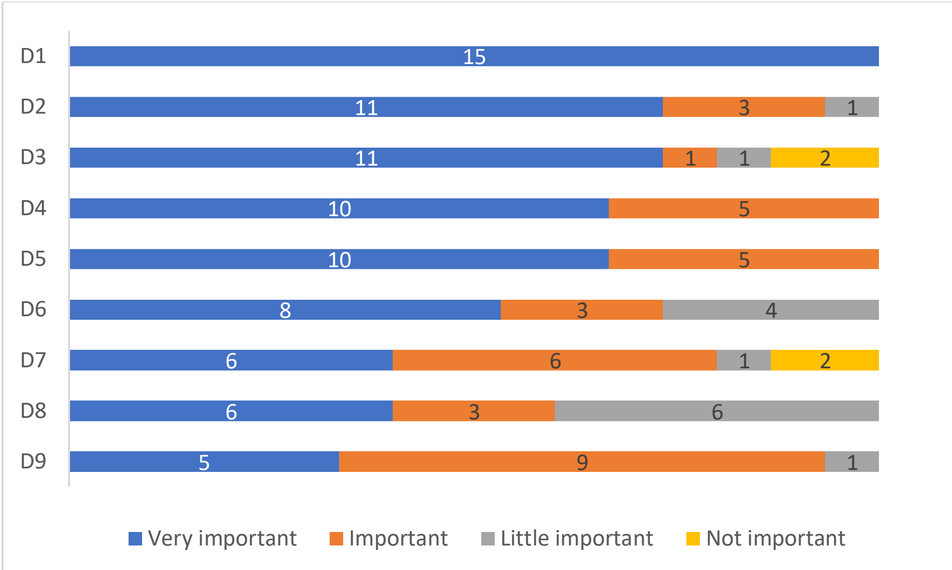

Figure 1. OSC design competencies demanded by the industry.

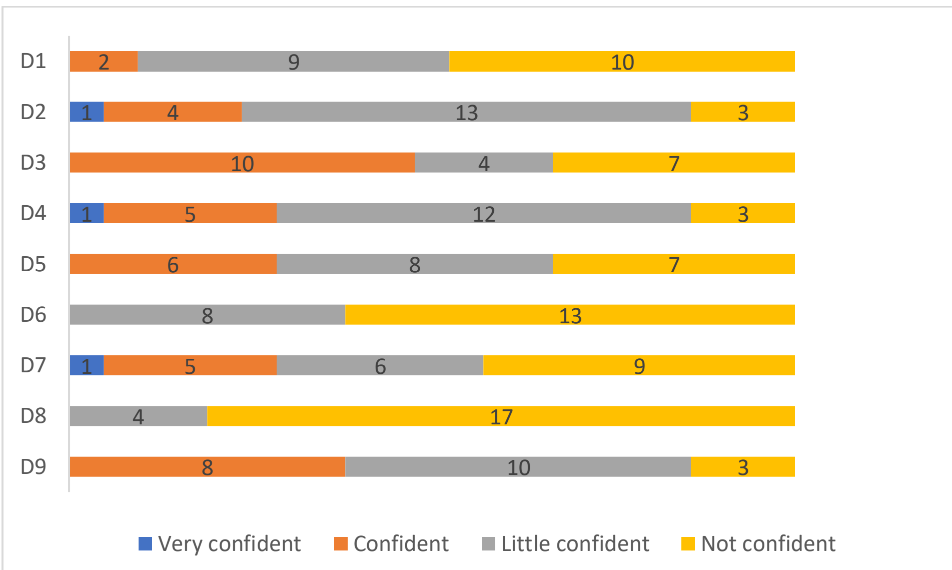

Figure 2. Students' confidence in OSC design competencies.

Only competencies D3 and D9 have a significant amount (10 and 8 respectively) of students who consider themselves confident in applying them, and all other competencies have many students "not confident" or "little confident" to apply them.

Competencies A2 and A9 stand out as "confident" or "very confident" by students. However, all other competencies have most of their answers as "not confident" or "little confident".

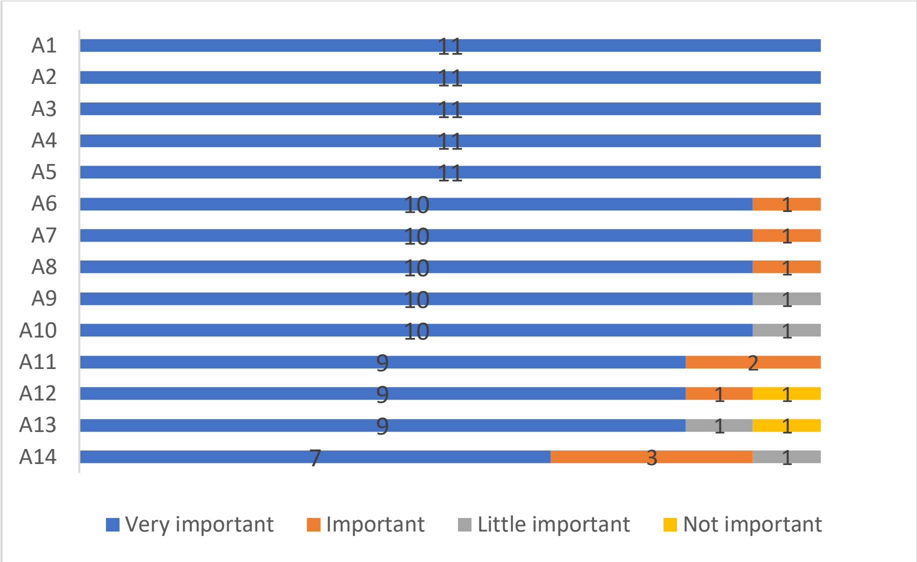

Figure 3. OSC assembly competencies demanded by the industry.

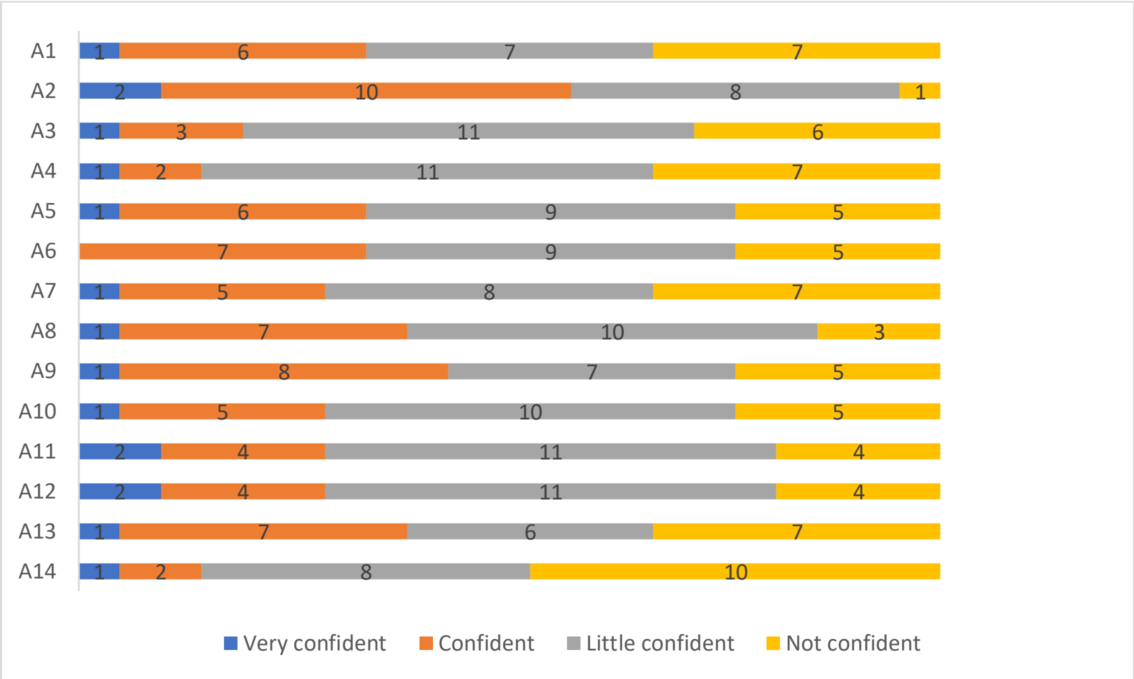

Figure 4. Students' confidence in OSC assembly competencies.

Barriers to OSC education at UFBA

45% of faculty are not familiar with OSC and only 36% consider they have a satisfactory knowledge of OSC. “The need to create new courses to teach OSC” and “Lack of OSC knowledge by faculty” were the barriers most cited by faculty.

CONCLUSION

As a result, two hypotheses for OSC adoption in the curriculum of the CE program at UFBA. The first hypothesis is the development of two new elective courses. Each of these courses would be responsible for one stage of offsite construction (design and onsite assembly). The design course would be developed in BIM software and focused on the specifics of offsite construction, such as standardizing projects, detailing connections, and detailing interfaces. Students would learn these skills through a single project throughout the semester, where they would design a small prefab building in the BIM software. The onsite assembly course would be developed with an experimental laboratory, where the student could visualize and understand the main assembly processes. In addition, there would also be a project where the student would learn about planning, equipment management, and preparation of the site for receiving OSC components.

The second hypothesis is the OSC adoption in two existing courses. The first course could address onsite assembly competencies, such as reading and interpreting projects, monitoring connections, checking tolerances, and correcting discrepancies. The second course could focus on execution schedules, assembly stages, and site preparation competencies.

This study must be interpreted considering its limitations due to its exploratory nature. First, the industry professionals, faculty and students' samples may not be representative to make statistical inferences. Second, the data were collected only at one higher education institution in Brazil. Further studies with a larger sample are needed to confirm and extend our hypotheses. Future studies may use the probability-sampling approach to support the current study findings.

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