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Proposed Framework for Integrating LCI's Learning Resources to Support Lean Education in Accredited Design and Construction Programs

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Lean is practiced by the design and construction industry for two decades, but it is not a part of the mainstream curriculum in US-based universities. This is the first gap. The Lean practitioner community affiliated with the Lean Construction Institute (LCI) produces many resources each year that can be used for Lean education and training. However, academia is not always aware of the resources produced by the LCI's practitioner community. This is the second gap. In this study, both gaps are addressed while fulfilling each other. This study identified potential integration points for Lean in the design and construction programs by providing examples of mapping between existing LCI's learning resources to their respective student learning outcomes (**SLOs**) and curriculum guidelines. By looking into different accreditations such as ACCE, ABET, and NCARB, we found that Lean can be integrated with design and construction curriculums in three ways. One addresses project-related Lean implementation areas; two addresses specific Lean Construction systems or methods; and three addresses Lean Construction courses. Selection of the most suitable approach will depend on the program at the US universities and how their classes are designed or structured towards graduation, both at the graduate and undergraduate levels.

Key Words: Lean, Education, Design, Construction, Accreditation, ABET, ACCE, NCARB

Introduction

In the last two decades, the design and construction industry has witnessed significant benefits resulting from Lean implementation to project delivery and performance (Aziz & Hafez, 2013), advanced technology adoption (Khan & Leicht, 2022), team culture and organizational dynamics (Asadian & Leicht, 2021), project quality (Bajjou & Chafi, 2018), customer satisfaction (McGraw Hill, 2013), worker productivity (Salem et al., 2005), job site safety (Gambatese et al., 2016), risk management (Issa, 2013), sustainability (Bajjou & Chafi, 2018), and profitability (McGraw Hill, 2013). Such benefits can only be guaranteed in the future by developing and maintaining new and

existing knowledge, skills, and abilities (**KSAs**) pertaining to Lean implementation within the design and construction workforce of the present and the future (Nofera et al., 2015); the future workforce is learners who are now in schools and colleges. Alves et al. (2010) emphasize that practitioner communities identified by the Lean Construction Institute (**LCI**) and International Group for Lean Construction (**IGLC**), which are two of the most prominent Lean communities, including academia and industry, contend that there is a serious need for formalizing Lean education as part of university education and research, in design and construction. Bhawani et al. (2021) further stress that doing so will strengthen the transfer of KSAs and best learning practices between academia and industry, simultaneously and potentially building consistency as we transition from theory to practice each time. Additionally, Rybkowski et al. (2020) noted that to keep fueling the industry and its workforce with the Lean KSAs, only a handful of university educators and educational consultants have continuously contributed to the dissemination of foundational theories and practical applications pertaining to Lean education over the last two decades. Only a few universities have acknowledged and responded to this need by formalizing Lean education through coursework and electives in their curriculums (Johnson & Gunderson, 2009; Nofera et al., 2015; Rybkowski et al., 2020; Tsao et al., 2012 and 2013). Still, Lean education is not yet mandated or consciously integrated into the accreditation's assessment process, Student Learning Outcomes (**SLOs**), or guidelines as the design and construction curriculum are continuously revamped. A quick Google search using the keywords Lean, ACCE, ABET, and NCARB shows that Lean has no direct reference on their websites. The lack of education, awareness, and understanding hinders Lean adoption. Therefore, setting the impetus for the work, this project was initiated to explore and understand how this challenge can be addressed and what potential integration points might be for Lean education in design and construction curricula aligned to the accreditation standards and guidelines for US-based universities. Considering the continuously evolving relationship between Lean implementation, sustainability, and advanced technology adoption as part of the design and construction workflows, it is crucial to ensure that we train our students, the future workforce, in the present so they are prepared for the real world challenges awaiting them (Hyatt, 2011; Rahman et al., 2013; Moradi & Sormunen, 2023); because without proper foundational education about the overlapping domains, i.e., Lean, Sustainability, and Technology, that make up the gamut of the design and construction domain in itself, professionals of the new generation would end up being confused and displaced by the disruptive evolution of knowledge bridging these domains.

This study recommends where university educators can start integrating Lean education, supporting existing SLOs and curricula guidelines. This would allow the graduating students, i.e., our future design and construction workforce, to be ready to integrate Lean Project Delivery into their professional practices. The scope of this paper is limited to the initial identification of integration points for US-based universities. Looking into the Student Learning Outcomes (**SLOs**) and Curriculum Guidelines specified by the American Council for Construction Education (**ACCE**), Accreditation Board for Engineering and Technology (**ABET**), and National Council of Architectural Registration Boards (**NCARB**), we found that Lean education can be integrated with the design and construction curriculums in three ways. One addresses project-related Lean implementation areas; two addresses specific Lean Construction systems or methods; and three addresses specific Lean Construction courses. However, selecting the most suitable approach or a combination of them will depend on the university's specific program and how their courses are designed or structured toward graduation, both at the graduate and undergraduate levels. The framework provided by this study will initiate a dialogue between Lean communities (academic and practitioner) and accreditation bodies guiding the future composition of design and construction curriculums at US-based universities. Owing to the scope defined for this project, the current exploration is limited to the program-level accreditation SLOs and curriculum guidelines only for US-based universities. Future research should focus on course-level mapping and integration of learning resources; further elevating the initiative to

a global context will bring forth the conversation towards standardization of KSAs related to Lean education and determine the best teaching and learning practices and benchmarking across different countries for continuous improvement.

Literature Review

Lean Project Delivery, i.e., Lean Design and Construction

Lean Project Delivery, commonly known as Lean Construction, is defined as respect and relationship-oriented holistic project design and delivery process with the overarching aim of maximizing value for all stakeholders; it emphasizes and realizes the customer's voice through systematic, synergistic, and continuous improvement in all aspects such as contractual arrangements, design development, construction process design, methods selection, supply chain, workflow reliability on the job-site, post-construction operations, and maintenance (Abdelhamid, 2009; LCI, 2010). While Lean implementation is a philosophy-based approach, various Lean Construction methods, such as Big Room Planning, Gemba Walk, Set-based Design, Visual Management, Value Stream Mapping, and Work Clusters, serve as a mechanism for instilling the affiliating Lean principles into the construction project's production process (Aziz & Hafez, 2013). From the review of several definitions consolidated by Mossman (2018), it can be said that implementing Lean methods, along with their interrelated components in design and construction projects and workflows, represent the domain of Lean Construction, i.e., Lean project delivery.

Project-level Lean Implementation Areas

The benefits from applying Lean methods are driven by the different functions they serve on a project. Bhawani (2021) suggests that the project functions served by Lean methods are essentially a set of actions that correspond to a common purpose associated with a knowledge area such as cost and schedule, a process such as monitoring and control, or a project phase such as design and construction, or a combination of them such as design development and cost monitoring and control. By gathering all such project functions enabled by Lean methods and grouping them based on close relationships, Bhawani (2021) provided a taxonomy of project functions organized by six project-level Lean implementation areas comprising project planning and organization, team culture and education, information and communication, design, production, and process improvement. Such areas were validated by expert Lean practitioners and compared to the knowledge areas, advanced areas, societal areas, and process groups listed in the Construction Extension of the Project Management Institute (PMI)'s Body of Knowledge (PMBOK Guide, 2013) to ensure comprehensiveness in the general context beyond Lean in the design and construction domain at a project level. For reference, in this paper, Lean implementation areas refer to those identified by Bhawani (2021).

Lean Education in the US Universities

It is being recognized that there is a need to better understand how Lean is being taught at universities (Leicht & Drevland, 2023). The latest study on the evolution of Lean education at US-based universities conducted by Rybkowski et al. (2020) reveals that 12 universities currently impart formal Lean education via curriculum in courses and electives. Two additional US universities also conduct formal Lean education and research in their graduate program (LCR at UW; P2SL at UC Berkeley). Several other US universities perform research on Lean design and construction but do not necessarily teach Lean principles and methods as a specific course or elective (LCI, 2023a). Another study conducted by Forbes et al. (2020) focused on Lean education or certifications provided by US-based Owner, Architect, Engineer, and Construction (OAEC) organizations. For example, the Associated

General Contractors of America (AGC) has a CM Lean Certification for professionals (AGC, 2023); the LCI released the Construction Professional Certification in 2023, and the Design Professional Certification is under development (LCI, 2023b).

Approaches to Teaching Lean Design and Construction at US-based Universities

Not necessarily as a curriculum standard, but Lean has been taught at US-based universities for over two decades since its inception in the AEC industry. In their study, Johnson and Gunderson (2009) recorded that only 12 ACCE-accredited programs taught about Lean at that time, with a partial focus on their courses. "Of the 12, 8 (66.7%) reported less than 10% of course content devoted to the topic, 3 (25%) reported from 10% to 25%, one reported from 25% to 50%, and none reported more than 50% average content focused on Lean construction per course." Tsao et al. (2012 and 2013) presented perspectives on teaching Lean based on the personal experiences of Lean instructors at six US-based universities: University of Cincinnati, San Diego State, Arizona State, University of Southern Illinois, Texas A&M, and Illinois Institute of Technology, alongside industry associations such as LCI and AGC. Rybkowski et al. (2020) further provided information about how five additional US-based universities were teaching Lean, i.e., North Carolina State, Virginia State, Colorado State, Michigan State, and Pittsburg State. Nofera et al. (2015) provided a deeper insight into how Lean was taught at Michigan State University (MSU) to graduate students; the course goal, objectives, content, and teaching-learning methods were also discussed to demonstrate how students use action learning to learn problem-solving. Lean has been taught at MSU as a standalone graduate elective course titled "Lean Construction Principles and Methods' that offers 3-credits toward graduation in the construction management program, which ACCE accredits.

Gaps in Approaches for Lean Education at US-based Universities

Based on the consolidated information presented by Rybkowski et al. (2020), it was noted that universities chose to offer custom Lean education as part of both graduate and undergraduate curriculum requirements or as an elective course, extending in duration from partial to an entire semester. The formative and summative assignments for Lean education comprised Readings, Discussion forums, Exams, Case studies, Term projects, Field trips, Reflection papers, Simulation/Lab activities, Guest presentations, Games, and Value stream (process) mapping. The list varies from lower-order thinking to higher-order thinking, as per Bloom's Taxonomy. However, it does not necessarily define a criterion for a subsequent alignment or a systematic selection of an approach. This creates a gap in adopting Lean in the mainstream design and construction curriculum.

LCI-based Learning Resources

While academia has been rigorously exploring ways to teach Lean effectively to university students, industry organizations such as AGC and LCI have also been working on sharing project and organizational knowledge and experiences from Lean implementations in different ways. Figure 1 shows the various LCI's Learning Offerings to date; this was provided by LCI's director of educational programs upon request from the authors of this study. It has been noted in discussions between various communities of practice that resources developed by the industry side of the Lean community have significant value but are continuously under-utilized and are being passed on to the academic side of the Lean community.

Figure 1: List of LCI's Key Learning Offerings (Provided by LCI for this study)

With increased collaboration between industry and academia and the sharing of learning resources, our future workforce, i.e., university students, can significantly benefit from real-life, example-based learning to support foundational understanding and practical application of Lean principles and methods in construction projects. Such resources, if made openly accessible, can eliminate most of the frequent educational barriers mentioned in Tsao et al. (2012 and 2013), Nofera et al. (2015), and Rybkowski et al., 2020. Such resources can also immensely relieve the stress on Lean educators to constantly develop the latest content aligned to the latest developments in the industry, which can be exhaustive alongside other responsibilities of grading and mentoring. For this study, we looked at some of the LCI's Learning Offerings, shown in Figure 1, to see how they can be mapped to Lean education approaches while aligned to accreditation needs. This would open doors for using industry-focused learning resources for classroom curriculum, which would address the gap in the workforce related to Lean KSAs and expedite adoption through enhanced collaborative learning between academia and industry.

Accreditations Guiding the Design and Construction Curriculums in the US

The American Council for Construction Education (ACCE) is a national, private, non-profit organization established in 1974, whose accreditation serves the interests of students, the construction industry, owners and users of constructed facilities, and the public. ACCE specifies a set of 20 SLOs to ensure that the accredited construction program has met the highest standards of content and quality, the graduates have been provided with a quality education that allows them to fulfill a variety of industry roles and responsibilities, and the program conducts periodic self-evaluations to keep the curriculum updated with latest developments in technology and best practices in the construction industry. (ACCE, 2023). ***The Accreditation Board for Engineering and Technology*** (ABET) is an international non-profit organization established in 1932, which provides voluntary accreditation to post-secondary programs such as applied and natural science, computing, engineering, and engineering technology within degree-granting institutions already recognized nationally and internationally (ABET, 2023). Under the applied sciences, 12 guidelines define the program criteria for accreditation. It assures the professional communities that the program fulfills the highest quality

standards in educating graduates from that profession. ABET is recognized globally across 40 countries, and over 200,000 students graduate each year from ABET-accredited programs. (ABET, 2023)**.** ***The National Council of Architectural Registration Boards*** (NCARB) is a national non-profit organization established in 1919 that comprises architectural licensing boards from all US states and territories and monitors all national programs for professional excellence. In collaboration with such licensing boards, NCARB protects the health, safety, and welfare of the public via licensing and credentialing (NCARB, 2023). NCARB provides a set of 13 standards across five subject areas: liberal arts, history theory and human behavior, design synthesis, building technology, and professional practice. (NCARB, 2023)

Methodology

This study used a three-step process. The details of each step are shown in Figure 2, with a literature review being one of the most predominant tasks to understand the existing scenario pertaining to the defined gaps and identify the solution space related to each gap.

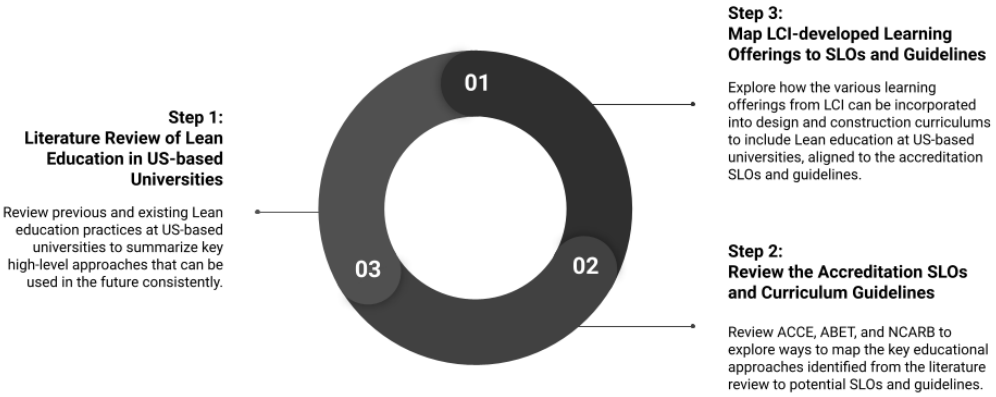

Figure 2: Methodology

Results and Discussion

Figures 3 and 4 summarize the key deliverables from this study, i.e., the existing Lean education approaches at US-based universities and a proposed framework for integrating Lean education holistically across the entire duration of an accredited design and construction degree program, respectively. Although there are three fundamental approaches evident in existing teaching and learning about Lean, as shown in Figure 3, the most holistic approach conducive to developing Lean KSAs in our future workforce, i.e., our students, is the proposed framework in Figure 4. Many studies have pointed out the different course learning outcomes (CLOs) and potential corresponding to Lean education no matter the level of integration, i.e., a module within a course, a course, multiple courses, and across the entire curriculum. A step further is needed to see how the CLOs can be mapped to the accreditation based SLOs and guidelines for design and construction. Figure 4 shows three integration points in the Lean education process: first, where the educator will need to introduce the Lean implementation areas as noted by Bhawani (2021); second, where the accreditation SLOs and guidelines need to be introduced; third, where the LCI's learning resources can be incorporated.

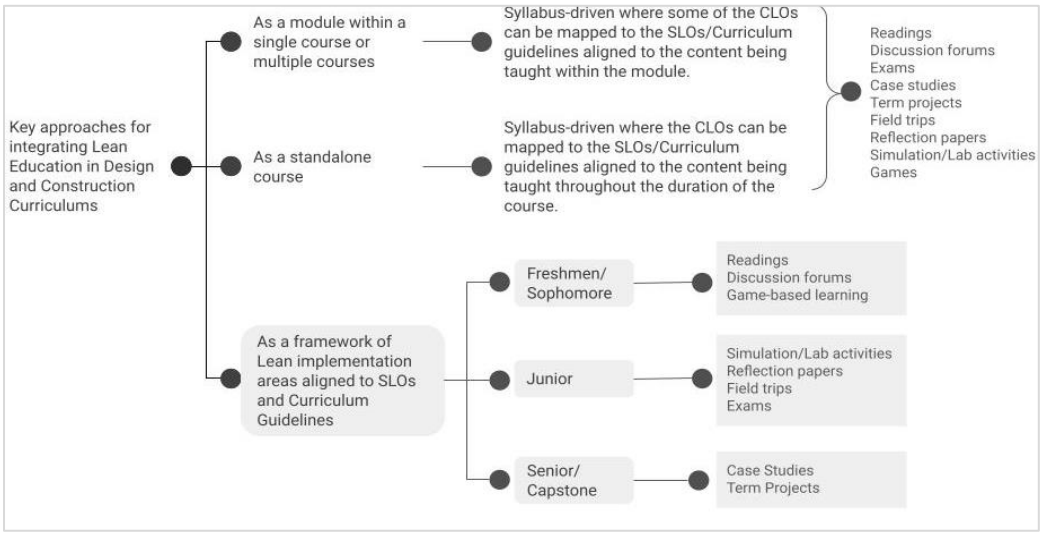

Figure 3: Three Key Approaches for Lean Education

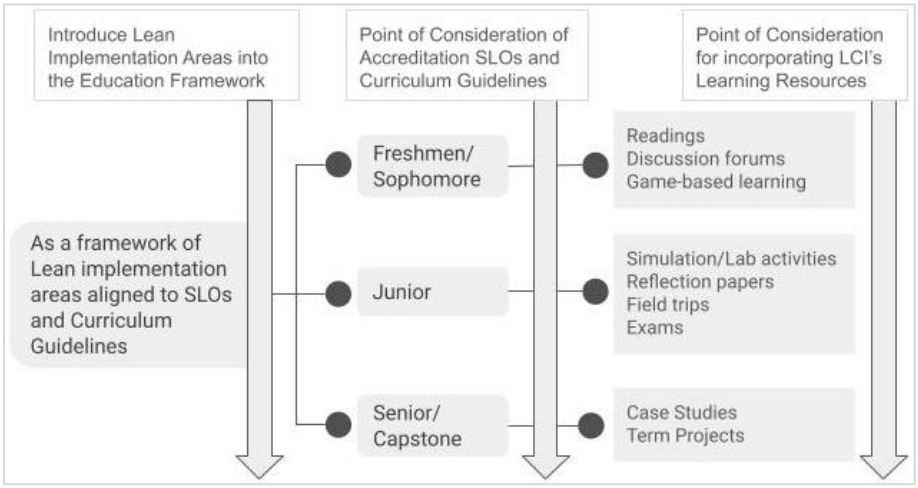

Figure 4: Framework for Integrating Lean Education

Conclusion

This study intends to elaborate the proposed framework using examples and concludes with two main propositions. One, LCI's Learning resources can promote collaborative learning between industry and academia, which will enhance and expedite Lean adoption that is effective and sustainable. Two, Lean education aligned to accreditation based SLOs and curriculum guidelines will enable a more holistic approach to teaching and learning about Lean.

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