

BOARD #118: LiDAR Technology in Construction/Engineering Education – Why, How, When?

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Sensing and Mapping Technologies in Construction/Engineering Education: Why, How, When?

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Abstract

As the construction industry increasingly adopts advanced sensing and mapping technologies, such as GPS, LiDAR, and 3D scanning, there is a growing imperative to integrate these tools into undergraduate Construction Management curricula. This study explores three key questions: (1) What are the justifications for incorporating these technologies? (2) What are the most effective methods for teaching them through experiential and virtual learning approaches? and (3) At what stage in undergraduate education is it optimal to introduce these technologies?

A survey conducted among 121 undergraduate students enrolled in Estimating and Plan Reading courses and insights gathered from industry professionals have contributed valuable insights to this study. The findings emphasize the urgent need for curriculum reforms incorporating sensing technologies to better align academic training with industry demands. Notably, 77% of industry professionals advocated for integrating these technologies during their junior year, which corresponds with the preferences of 50% of students who expressed interest in exposure to these technologies after completing their first co-op experience.

Additionally, industry stakeholders highlighted the importance of soft skills, such as problem-solving and teamwork, in conjunction with technical expertise. This study outlines the feasibility, logistics, and pedagogical strategies for effectively infusing advanced sensing technologies into construction education. By enhancing coursework to meet industry expectations, these curricular improvements aim to equip students with the technical proficiency and collaborative skills essential for success in modern construction management.

Background

The construction industry is experiencing a fast technological revolution by adopting advanced sensing and mapping technologies such as LiDAR (Light Detection and Ranging), GPS, 3D scanning, and thermal imaging. These tools are pivotal for enhancing project planning, site analysis, progress tracking, and safety management. While undergraduate construction curricula increasingly recognize the importance of cutting-edge technologies, there is still an opportunity to enhance their curricula with industry demands. This can help create a future workforce with the evolving technological landscape in the industry. This gap is particularly evident in core courses like Estimating and Plan Reading, which traditionally focus on manual and theoretical approaches. Integrating sensing technologies into these courses can provide students with practical skills that enhance their employability and readiness for real-world challenges. LiDAR, for instance, enables precise spatial mapping for 3D modeling, while GPS supports real-time location tracking and project coordination.

Sensing technologies are increasingly important in construction, prompting the need for workforce education in this area [1]. Academic literature underscores the value of exposing

students to these tools early in their education. For example, [5] highlights the role of LiDAR in improving spatial reasoning and 3D coordination, while [1] investigates the graduate's readiness to implement sensing technologies in the construction industry. Efforts to incorporate sensing technologies and Building Information Modeling (BIM) into construction engineering programs have been initiated, with courses introducing these tools at various levels of study [16]. [7] also discusses using LiDAR technology as an auxiliary visualizing tool for freshman and sophomore Construction Management students. [7] case study demonstrated that LiDAR technology improves student engagement and comprehension of 2D plans and their 3D aspects. However, cost, faculty expertise, and curriculum constraints hinder widespread adoption [4]. In addition, mixed reality environments have shown potential as practical learning tools for teaching sensing technologies, offering experiential learning opportunities despite constraints like weather or COVID-19 restrictions [1].

Sensing Technologies in Construction Education

Integrating LIDAR and BIM technologies into construction management education is increasingly vital due to their growing adoption in the industry. Several universities have developed courses and modules to introduce these technologies to students [12]-[14]. These courses typically use project-based, hands-on methods to involve students in real-world applications [13]; [11]. The technologies serve multiple purposes, such as documenting current conditions, tracking construction progress, and improving visualization [8]; [10]. Incorporating these technologies into curricula presents challenges, including high costs and a shortage of qualified instructors [14]. Their inclusion is essential for equipping students to meet future industry demands [9]. Industry professionals emphasize the importance of BIM education in graduate programs, highlighting the need for technological skills in construction management [9].

The research expands upon surveys conducted with students and industry professionals to address three critical factors regarding incorporating sensing technologies into undergraduate education. First, it explores the necessity of integrating these technologies into the curriculum and their impact on student learning. Second, it examines the effective strategies for implementing these technologies within education programs. Lastly, the study investigates the optimal timing of introducing these tools in the curriculum to ensure maximum engagement and knowledge retention. Overall, the study aims to address these three questions:

1. Why is it necessary to implement sensing technologies?
2. How should these technologies be implemented in the curriculum?
3. When is the best time to introduce these tools into the curriculum?

Methodology

The data collection for this research involved the distribution of survey questionnaires specifically designed for students and industry participants. These questionnaires were created using Google Forms to facilitate easy access and response. The collected data were fully anonymized, and no personal data were collected. After collecting the responses, the data was

analyzed to draw meaningful insights and conclusions. Two surveys were conducted to gather insights from key stakeholders:

1. **Student Survey:** Data were collected from 121 undergraduate Construction Management students enrolled in Estimating and Plan Reading courses. The survey captured:
 - Familiarity with sensing technologies (e.g., LiDAR, GPS, thermal imaging).
 - Preferences for teaching methods (e.g., workshops, integrated courses).
 - Views on the optimal timing for learning about these technologies.
2. **Industry Survey:** Responses from 21 professionals in construction-related roles (e.g., project managers, VDC/BIM engineers) addressed:
 - Current use of sensing technologies in projects.
 - Graduate readiness for technology-driven roles.
 - Recommendations for embedding these tools into undergraduate curricula.

The survey data were analyzed to identify trends and contextualized with findings from academic literature to develop actionable recommendations.

Results and Discussion

Importance of Introducing Sensing Technologies

Survey responses highlight the necessity of introducing sensing technologies into undergraduate education:

- **Student Responses**

89% of students agreed that advanced technologies like LiDAR and GPS should be included in their curriculum. Students emphasized that these tools provide practical insights into project planning and site management, enhancing their confidence in handling real-world construction challenges. The current cohort of students demonstrates an exceptional capacity for integrating technological innovations into their learning processes, underscoring the necessity of incorporating such digital tools within educational curricula. Their familiarity with digital tools and eagerness to explore innovations make them ideal candidates for mastering sensing technologies like LiDAR, GPS, and 3D scanning.

Moreover, these technologies can significantly enhance student engagement by providing interactive and hands-on learning experiences. Traditional course delivery methods can be supplemented with visual and experiential tools such as augmented reality, virtual site walkthroughs, and 3D scanning demonstrations. Such methods improve student interest and aid in better retention of course material, as students connect theoretical knowledge to practical applications. For instance, the ability to visualize 2D plans in 3D using LiDAR fosters a deeper understanding of spatial relationships, which is critical for construction management.

- **Industry Feedback**

58% of professionals consider these technologies essential for career preparation, while 28% view them as helpful but not critical. Industry participants noted that familiarity with tools like GPS and LiDAR significantly improves project accuracy and coordination. Additionally, industry experts have noted that graduates with strong technological skills are better equipped to succeed in roles that require technology integration, particularly in project management and virtual design coordination. Proficiency in relevant digital tools enhances efficiency and collaboration, which is critical for innovative problem-solving and teamwork in today's digital work environment.

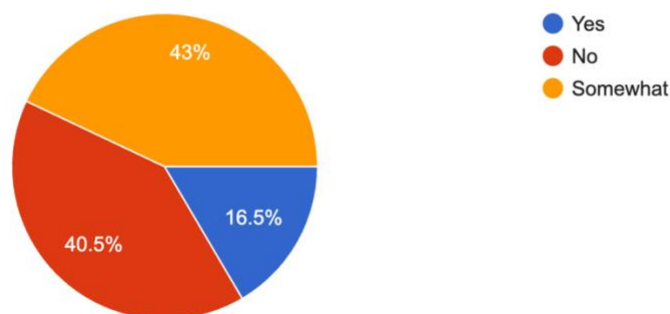
The industry's reliance on these tools reinforces their importance. For example, 72% of industry respondents reported using sensing technologies regularly or occasionally in their projects. This widespread adoption highlights the growing demand for proficient graduates in these tools. These findings align with [3], who demonstrated that tools like augmented reality enhance hazard detection and decision-making in construction. Moreover, professionals suggested that incorporating these technologies early in undergraduate programs could help bridge the skills gap between academia and industry expectations while capitalizing on students' natural adaptability to new technologies. By integrating these tools, educators can provide a more engaging, interactive, and practical learning environment that prepares students for the demands of modern construction practices.

Familiarity with Sensing technologies

The initial section of the survey assessed students' familiarity with sensing technologies. Only 16.5 percent of the students indicated that they were familiar with the sensing and scanning technologies used in the construction industry. In addition, 50 percent of the students indicated that they are somewhat familiar with the list of technologies available in the construction industry. Figure 1 illustrates the survey results regarding students' familiarity with these technologies.

Are you familiar with the existing sensing/scanning technologies in the industry?

121 responses



Which of the following technologies are you familiar with

114 responses

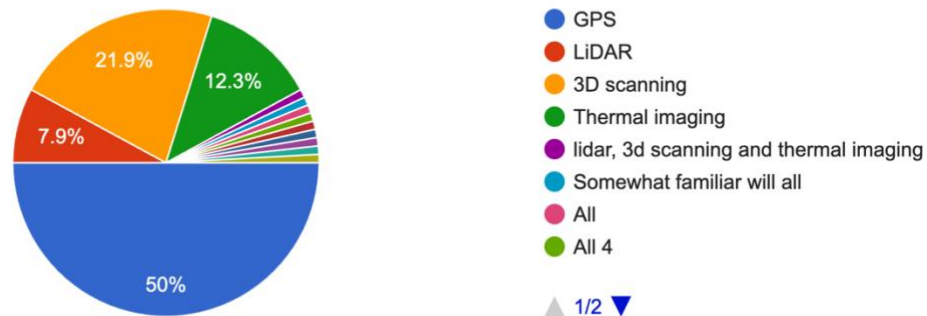


Figure 1: Familiarity with Sensing Technologies Among Students

Optimal Timing for Introducing Sensing Technologies

Timing preferences from industry and student surveys showed consistent and meaningful responses.

51% of the students believe these technologies should be introduced after their first co-op experience (junior year), with 44% favoring introduction in the sophomore year.

95% of industry professionals recommend introducing these tools during the sophomore or junior years, ensuring students have foundational knowledge before engaging with advanced tools.

The four-year undergraduate journey offers a natural progression for introducing and integrating sensing technologies. In the freshman year, students are typically introduced to fundamental concepts and basic skills, which serve as a foundation for advanced learning. During the sophomore year, students can begin exploring introductory aspects of sensing technologies such as GPS and 3D scanning, helping them build curiosity and awareness about their applications.

By the junior year, students have sufficient background knowledge to engage with more advanced topics, such as LiDAR and thermal imaging. They can connect these tools to practical use cases through co-op experiences or internships. These experiences play a pivotal role in allowing students to work with sensing technologies directly on job sites, gaining hands-on exposure to their applications in real-world settings. Co-ops and internships bridge the gap between classroom learning and industry practices, helping students solidify their technical skills and understand the operational challenges of implementing these tools in construction projects.

Finally, in the senior year, the curriculum can shift toward professional and real-world applications of sensing technologies. This stage allows students to engage with complex, real-world scenarios, applying their skills to capstone projects or industry collaborations. Table 1

details the students' and industry's responses to optimal timing in introducing the sensing technologies.

Table 1: Best Time to Introduce the Technology

Timing	Students' response (%) – # (out of 121)	Industry's response (%) - # (out of 21)
Freshman Year	2 - 3	4.8 - 1
Sophomore Year	44.2 - 53	19.0 - 4
Junior Year	50.8 - 61	76.2 - 16
Senior Year	3 - 4	0.0 – 0

Introducing more professional and application-based content toward the end of their academic journey ensures that students are technically equipped and understand the broader context of these tools in the industry, making their learning experience more impactful and relevant. These preferences align with [6] the competency-based learning model, which emphasizes experiential learning during internships or capstone projects.

Effective Methods for Introducing Sensing Technologies

The survey findings suggest that interactive and practical methods are most effective:

- **Student Responses**

62% preferred workshops, and 27% favored integrating technology modules into existing courses.

- **Industry Professionals**

73% emphasized the importance of hands-on training, and many recommended collaborating between academia and industry to develop in-house training programs.

Various methods are available to introduce sensing technologies in construction management education. Workshops and seminars offer an intensive, focused approach, allowing students to gain practical skills through direct interaction with technologies like LiDAR and GPS. Additionally, short presentations or modules embedded within existing courses ensure that these technologies are seamlessly integrated into the broader curriculum. For example, adding a LiDAR demonstration to a Plan Reading course or a GPS exercise to an Estimating course can provide students with context-specific applications of these tools.

Blending new material with traditional course delivery methods enhances student learning. As recommended by [1] and [3], Augmented and virtual reality tools simulate real-world scenarios,

providing students with experiential learning opportunities that reinforce theoretical concepts. These methods make learning more interactive and help students retain course material by linking abstract concepts to practical, visual experiences.

Capstone projects and independent studies represent another avenue for introducing advanced technologies. These projects allow students to work closely with industry partners or faculty mentors, applying sensing tools to solve complex, real-world problems. Industry collaborations can provide access to advanced equipment and datasets, further enriching the learning experience.

Moreover, offering elective courses focused on sensing and mapping technologies can give interested students a deeper dive into these tools. Such courses can cover advanced topics like data analysis, 3D modeling, and software applications, equipping students with specialized skills that enhance their employability. Table 2 details the responses regarding how these courses should be introduced to the students. By combining these approaches, from embedding technologies in existing courses to offering dedicated electives, educators can create a comprehensive framework that ensures students are well-prepared for the demands of modern construction practices.

Table 2: Preferred Methods for Introducing Sensing Technologies (Student and Industry Perspectives)

Delivery Method	Students' response (%) - # (out of 121)	Industry's response (%) - # (out of 21)
Separate Elective Course	41.8 - 51	28.6 - 6
Short Presentation within Course	32.8 - 40	38.1 - 8
Workshops/Seminars	25.4 - 31	33.3 - 7

Graduate Preparedness

Industry respondents expressed concerns about graduate readiness, as shown in Figure 2:

- 48% rated graduates as “somewhat prepared,” while 34% felt significant training was required post-graduation.
- 63% of companies provide in-house training, highlighting undergraduate education gaps.

While the survey size of 21 industry participants was small, the responses provided valuable insights into industry expectations. Employers expect recent graduates to have at least an introductory understanding of sensing technologies like LiDAR and GPS, enabling them to adapt quickly to the workplace and enhance their productivity during the critical first year of employment. Industry experts noted that employees with basic familiarity with these technologies require less training time and can contribute more effectively to mapping, data collection, and spatial analysis projects. However, future research with a larger participant sample could offer deeper insights into industry needs, revealing more nuanced trends and potential challenges in integrating sensing technologies into construction education. Expanding

the sample size would also improve the generalizability of findings, ensuring a more comprehensive understanding of employer expectations and workforce preparedness.

Furthermore, industry professionals emphasized the importance of soft skills such as problem-solving and teamwork in conjunction with technical expertise. Recent graduates who combine these skills with a working knowledge of sensing technologies are better positioned to take on responsibilities in project management, data analysis, and site coordination roles. Aligning educational content with these expectations ensures that students are well-prepared to meet industry demands while also reducing the training burden on employers. These findings underscore the need for curricular reforms incorporating technologies like GPS and LiDAR, better aligning academic preparation with industry requirements. Industry respondents also highlighted the stress new graduates may face when transitioning to roles that require working with unfamiliar and advanced technologies. This learning curve can be particularly challenging in the first year out of college, as recent graduates are expected to quickly adapt to workplace demands while managing the pressure to perform efficiently.

Introducing sensing technologies at the undergraduate level alleviates this stress by providing students with the foundational knowledge and hands-on experience they need to feel confident in their abilities. By the time they enter the workforce, they are better equipped to handle the complexities of real-world applications, reducing anxiety and enabling them to focus on refining their skills. Employers also benefit from this preparation, as graduates require less time to acclimate and can contribute to projects more effectively from the outset. Industry respondents also highlighted the cost implications of in-house training for new hires. Paid training programs, while necessary, often place a financial burden on companies and may not provide the depth and quality of education that a well-structured undergraduate curriculum can offer.

Undergraduate education provides students with a comprehensive understanding of sensing technologies through extensive exposure to theory, practice, and applications, unlike the condensed format of employer-sponsored training programs. Graduating with a foundational knowledge of these tools significantly lessens the need for extensive on-the-job training, allowing students to contribute productively from the start of their careers. This approach benefits employers and boosts the confidence and competence of new hires as they move into professional roles.

Do you believe recent graduates are ready to start positions involving new technologies?

21 responses

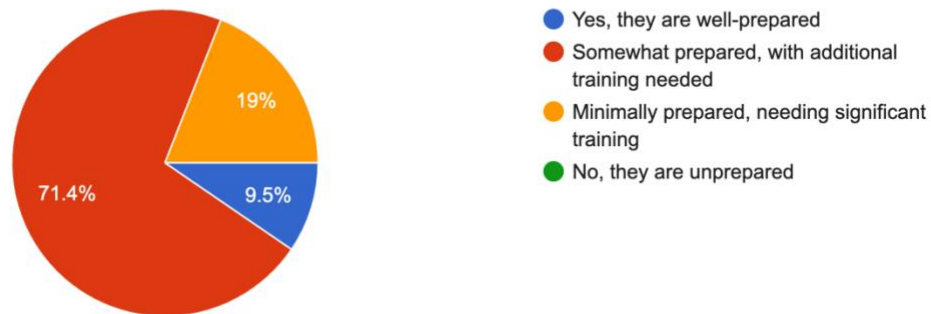


Figure 2: Perceived Graduate Preparedness for Sensing Technologies

Conclusion and Recommendations

This study underscores the transformative potential of integrating sensing technologies, such as LiDAR, GPS, and 3D scanning, into undergraduate construction and engineering education. The findings reveal that these tools enhance graduate readiness and significantly improve the learning experience's quality by fostering engagement, retention, and practical application.

Why? Adopting sensing technologies is essential to bridge the gap between academic preparation and industry demands. These tools equip students with the foundational skills needed to excel in a technology-driven construction environment, preparing them to address real-world challenges efficiently.

When? Introducing these technologies during the junior or senior years allows students to build on their foundational knowledge and apply their skills in professional contexts, such as internships and capstone projects. This progression ensures that students are theoretically informed and practically experienced when entering the workforce.

How? Effective integration strategies include blending new material into existing courses, offering dedicated workshops, and utilizing virtual and augmented reality for experiential learning. These methods ensure that students are exposed to both the theoretical and practical aspects of sensing technologies, preparing them for immediate career contributions.

Moreover, the study highlights the importance of reducing the stress associated with transitioning from academia to industry by ensuring students are adequately prepared. Introducing these tools in a structured academic setting diminishes the reliance on short, employer-provided training programs, which are often costly and lack the depth of a comprehensive undergraduate curriculum.

Therefore, introducing sensing technologies boosts graduates' readiness for their professional careers and enriches their overall college experience. This dual benefit ensures that students and employers derive maximum value from integrating these advanced tools into construction education. Collaboration with industry partners can further enhance training quality.

By addressing these key areas, educational institutions can better prepare students for the demands of a technology-driven construction industry. Therefore, introducing new technologies boosts graduates' readiness for their professional careers and fosters their learning experience during college by enhancing engagement, retention, and practical understanding.

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