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Board 65: Application of LiDAR Technology in Construction Education (Case Study: Estimating Course)

Dr. Farzam S. Maleki P.E., Wentworth Institute of Technology

Dr. Maleki is an Associate Professor of Construction Management in the Wentworth Institute of Technology (WIT). He has over ten years of experience in academia, teaching undergraduates and graduate students the basics of building construction. Prior to WIT, Dr. Maleki was an associate professor of Engineering at Massachusetts Maritime Academy.

Dr. Maleki is also a registered Professional Engineer (PE) in the state of Massachusetts. He has substantial experience in structural design, analysis, and construction processes. He also served in several construction legal litigations as an expert witness. Dr. Maleki's current research agenda is the application of new technologies to improve the undergraduate construction education. Dr. Maleki has published several technical and scientific papers in peer-reviewed journals and international conferences. He is a member of multiple scientific societies and serves as a peer reviewer for several journals.

Application of LiDAR Technology in Construction Education - Case study: Estimating Course

Abstract

This study explored the use of LiDAR technology as a supplementary tool for freshmen and sophomore Construction Management (CM) students who often struggle with understanding 2D plans and visualizing 3D projects. These skills are essential in the field of construction management. The study assessed LiDAR's effectiveness in enhancing students' learning outcomes in an "Estimating" course by comparing traditional plan-based learning with LiDAR-assisted learning. Students were tasked with reviewing a construction plan and then given access to a LiDAR scan of the same project for virtual exploration and measurement. A survey was developed with multiple questions about students' overall experience, their comfort level with working with either mode of data delivery, and some basic measurements.
Results indicated that while LiDAR offered strong visualization and measurement capabilities, issues such as data quality and the need for training could adversely impact the learning experience.

Introduction

The application of sensing and mapping technologies in the construction industry is growing rapidly. From handheld laser scanners to state-of-the-art mapping equipment, remote sensing technology is now a crucial part of the as-built condition assessment, progress report preparation, and quality control in the construction industry. Surveys from professional CMs and construction industry employers evidence the demand and expectations for levels of proficiency and familiarity with this technology [1].

Many researchers have studied the effect of construction monitoring and sensing techniques on project performance and risk mitigation [2], [3]. Many construction companies (such as BOND building construction) have established their in-house Realty Capture team and Virtual Design & Construction (VDC) department for laser scanning services and creating as-built models of existing systems. Such companies constantly seek qualified recent graduates to feed their workforce pipelines [4].

O. Ogunseiju et al. [1] have studied the incorporation of sensing technologies within the construction sector and the industry's viewpoints on the expertise and competencies essential for implementing these technologies in construction projects.

Some academic researchers studied the potential role of visualization and mapping technologies in construction and engineering education. P. Meadati and A. Akhnoukh [5] studied the effect of 3D scan models in facilitating students' visualization and better engagement.

J. Irizarry et al.'s [6] study showed enhanced student performance in solving problems when using the BIM (Building Information Modeling) based 3D views in engineering and construction concepts education.

Light Detection and Ranging (LiDAR), among others, is a sophisticated remote sensing technology that utilizes laser light for precise distance measurements. The process involves emitting laser pulses toward a target and measuring the time the light returns. The data obtained from these laser pulses can be leveraged to generate intricate three-dimensional maps of the targeted area.

In LiDAR systems, a laser scanner emits laser beams in various directions, and a sensor detects the reflected light. By calculating the time taken for the laser pulses to travel to the target and back, the LiDAR system can accurately ascertain distances to objects. This technology finds extensive applications in diverse fields such as topographic mapping, forestry, autonomous vehicles, geology, urban planning, and archaeology. LiDAR is pivotal in producing highly detailed and accurate elevation models and three-dimensional representations of landscapes or structures.

Although the technology is sophisticated, only a few smartphone manufacturers, primarily Apple Inc., have integrated it into their products. LiDAR scanners are crucial in measuring, mapping, and assessing projects' existing conditions. As handheld scanners become more prevalent on-site, it becomes imperative for students to acquire proficiency in their usage.

As the next generation of construction managers learn the required fundamental concepts through conventional course materials and delivery methods, more diverse teaching modalities can bridge the existing gap between academia and industry. Incorporation of new sensing technologies (such as LiDAR) into construction management education can be a crucial step toward preparing students for the challenges of the modern industry landscape. Additionally, students possessing knowledge and/or familiarity with sensing technology are more likely to secure employment upon graduation than their peers.
Freshmen and junior-level courses, like "Estimating," were found to be challenging for students to visualize using traditional two-dimensional course delivery approaches. Specifically, correlating the project's details presented in the plan and section views can be better comprehended with three-dimensional presentations. This research can further be expanded to understanding the feasibility of available LiDAR technology as an educational tool in an undergraduate-level "Estimating" course in the Construction Management program.

Research Methodology and Discussion

Plan reading and project visualization are indispensable skills for construction management students, serving as a cornerstone for future courses, effective project execution, and successful career development in the construction industry. Aspiring construction managers must adeptly interpret architectural and engineering drawings, blueprints, and schematics to comprehend the intricate details of a construction project. Proficient project visualization and plan reading enable students to grasp the spatial relationships, dimensions, and specifications critical to coordinating various construction activities. This skill is pivotal in ensuring the construction process aligns with design intent, regulations, and safety standards. Additionally, understanding and interpreting the construction plans are the foundation of accurate and reliable estimating and Quantity Take-Offs (QTOs).

Construction management students who master this skill have better academic performance in their education and obtain a competitive edge in their professional journey, as it enhances their ability to anticipate challenges, make informed decisions, and contribute to the overall success of construction projects.

To assess the readiness of the students to accept and adopt the mapping technology (e.g., LiDAR) as part of their curriculum, a sample LiDAR data along with the traditional two-dimensional floor plan was provided to four sections of sophomore Construction Management major students in the Estimating course. A total of 100 students were asked to participate in this case study, with a response rate of 37%. Among many available applications, An iOS-based smartphone application (PolyCam) was used to scan their classroom and capture the LiDAR data. The application was chosen mainly based on its user-friendly features and utilization simplicity. The built-in LiDAR technology in an iPhone 14 was used for scanning the target area. All participating students received a research package, including the 2D-floor plan of their course classroom, an AutoCAD version of the plan, scanned LiDAR data, and instructions on utilizing the given data within the app.

The following questions were submitted to all participants. For the first five questions, students were asked to rank their answers using the linear scale options as follows: (5) Strongly Disagree (4) Disagree, (3) Neither agree or disagree, (2) Agree, and (1) Strongly Agree.
The first question was related to students' opinions about the effectiveness of LiDAR technology as a tool in Estimating course. As Figure 1 shows, more than 51% of the participants strongly agree that the LiDAR technology can be a strong teaching tool for the Estimating course.

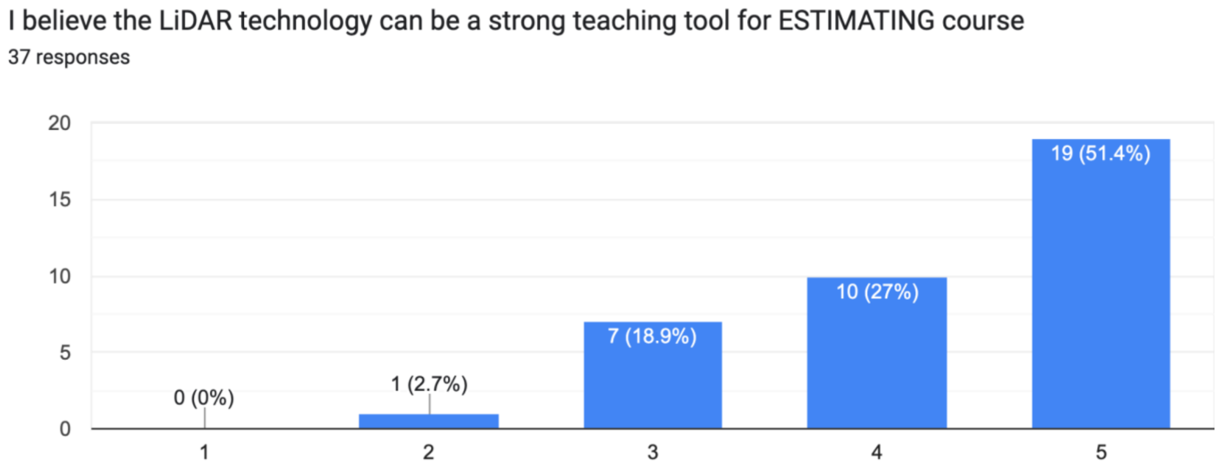

Figure 1. Outcomes regarding students' perspectives on the incorporation of LiDAR technology as an instructional instrument (linear scale)

Despite the provided instruction (written and video tutorial), Approximately 46% of the participants expressed difficulty importing the LiDAR data into their smartphone devices and navigating through the app. Considering the age range and apparent proficiency in working with iOS-based apps (all participants owned Apple smartphones and used iOS apps frequently in their daily lives), they still faced challenges importing the given data, interpreting the model, and utilizing the application effectively. This fact evidences the need for in-person training, preparing the students, and empowering them to apply basic tasks for using untraditional course material as part of their academic curriculum.

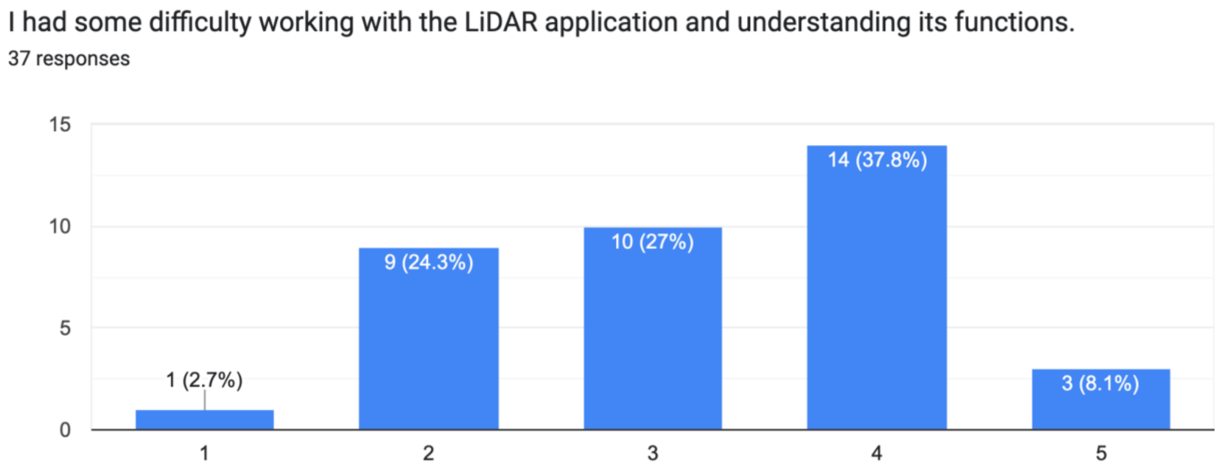

Figure 2. Results concerning students encountering challenges in utilizing LiDAR data and navigating the application.

Around 78% of the respondents either strongly agree or agree that incorporating LiDAR technology in the ESTIMATING course can enhance the visualization of 2D AS-BUILT plans. The corresponding survey findings are displayed in Figure 3. This robust level of positive response underscores the technology's potential to overcome the visualization challenges inherent in traditional plan reading, a crucial aspect for effective delivery of the Estimating course.

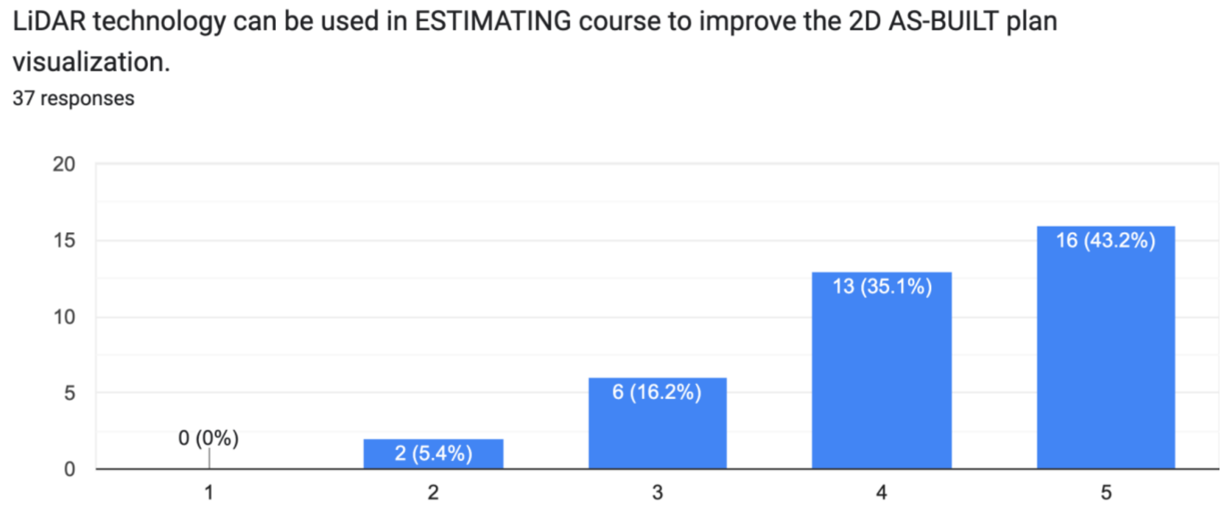

Figure 3. Survey findings regarding students' viewpoints on the capability of LiDAR technology to enhance the 2D AS-BUILT plan visualization.

Approximately 50% of the participants demonstrated competence in executing fundamental Quantity Takeoffs (QTOs) and measurements utilizing the application.

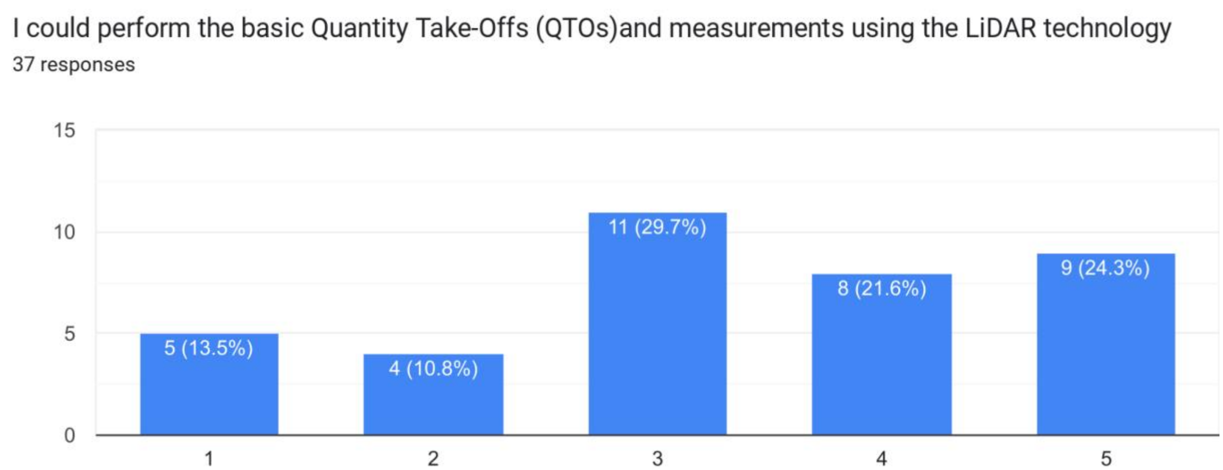

Figure 4. Students' self-evaluations in performing fundamental QTOs and utilizing the measuring tools provided by the application.

The students' feedback regarding the prospective application of the new technology in parallel with the traditional 2D plans for the basic estimating assignments was examined. Roughly 45% of the participants pointed to the data quality as the primary factor hindering their effective utilization of the application. The quality of data is directly influenced by the time invested in capturing it through the scanning device. Additionally, 36% of the participants expressed confidence in verifying QTOs using both LiDAR and 2D plans. Furthermore, 55% believed that the innovative LiDAR technology allowed them to explore the job site from diverse perspectives.

A subset of 33.3% acknowledged the potential of the technology in virtually visualizing proposed change orders.

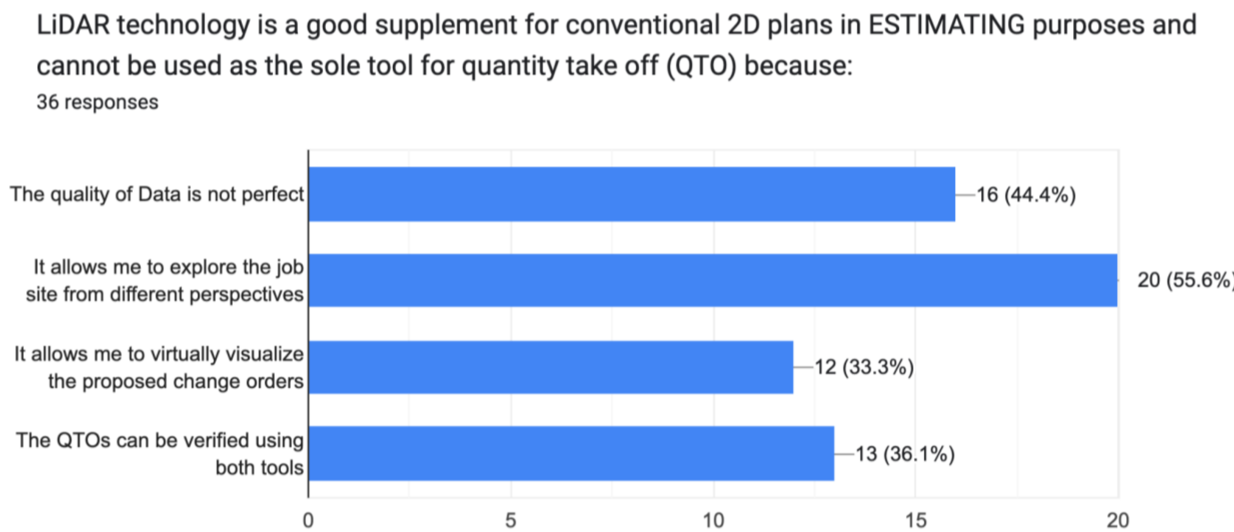

Figure 5. students' feedback regarding the prospective application of LiDAR technology compared to traditional 2D plans.

The survey then inquired about experiences, preferences, and views regarding integrating LiDAR in Construction Education, particularly in the ESTIMATING course, recognizing the active use of sensing and mapping equipment in the construction industry's daily operations.

Only 5.6% of the respondents expressed the belief that the application of LiDAR technology SHOULD be a mandatory inclusion in the course materials. This lower interest rate may be correlated with the difficulty of using new technology and students' reluctance to adopt it. Additionally, 19.4% opine that it is premature for the technology to be embraced in the educational context. Moreover, 50% view its inclusion as a positive aspect, describing it as a NICE addition to the course material. In other words, having LiDAR technology as a supplemental course delivery tool is more appealing to the students. Another 25% consider it suitable as an optional component within the curriculum. Figure 6 illustrates the survey results.

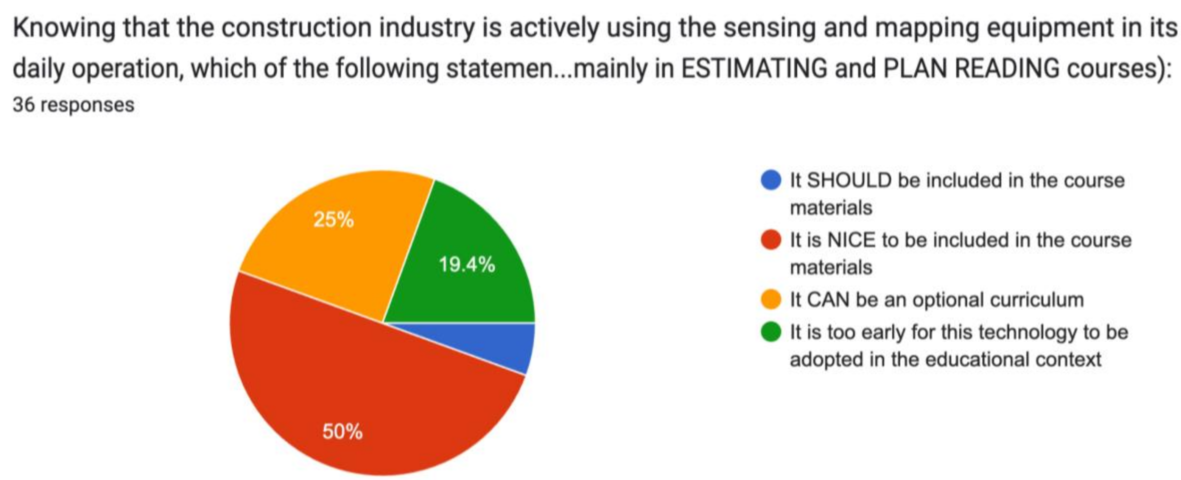

Figure 6. Students' perspective regarding the integration of LiDAR in Construction Education, ESTIMATING course.

To gain a more comprehensive understanding of students' performance with LiDAR data and their proficiency in using the application's features, students were instructed to install the application, import provided data, explore the project environment, and experiment with the available measuring tools. Figure 8 shows the LiDAR model of the classroom.

Figure 7. LiDAR model of the classroom for the example project in the ESTIMATING course.

Subsequently, they were tasked with quantifying the Net area (sqft) of interior walls for Paint and the floor area (sqft) for Carpet. The items were deliberately chosen to assess students' performance in quantifying items in both horizontal and vertical plans.

Results showed that 45.9% and 48.6% of the participants successfully quantified the interior wall surface and floor area, respectively. Approximately 19% encountered difficulty in performing both tasks, attributing it to data quality issues. Around 35% expressed discomfort using the application for quantification purposes. This underscores the importance of providing in-person training before introducing new technology. Figures 8 and 9 show the self-assessment results for both wall and floor area calculations.

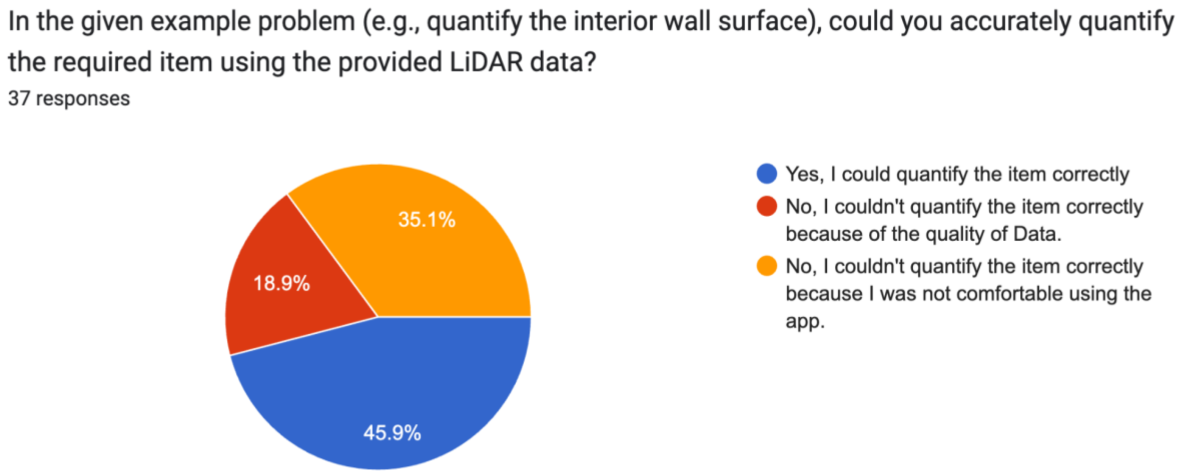

Figure 8. Students’ self-assessment on the QTO task for the square footage of the interior walls for the Paint.

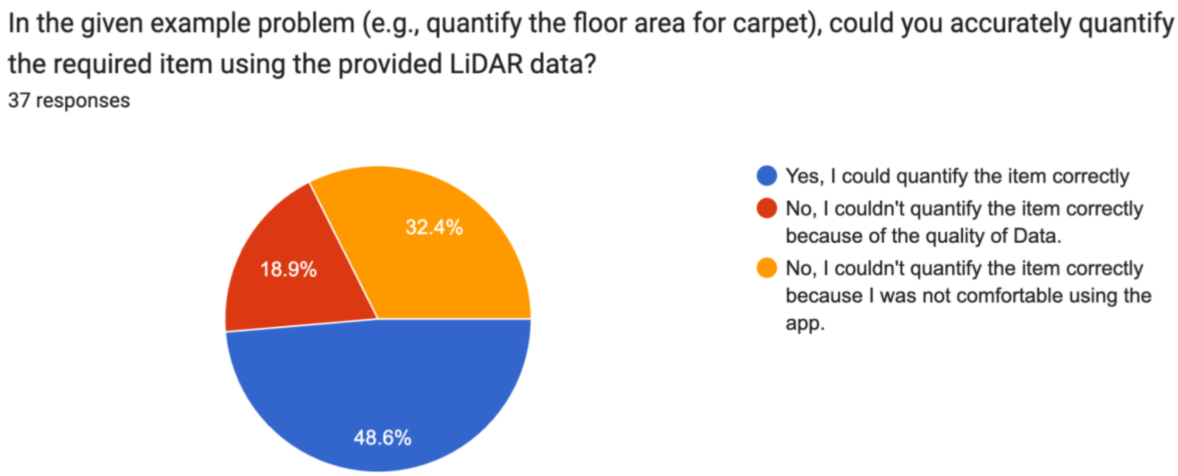

Figure 9. Students’ self-assessment on the QTO task for the square footage of the floor for the Carpet.

Barriers and Considerations:

Apart from students' feedback and readiness to accept new technologies (like LiDAR) in their standard coursework, educational institutions must consider several factors to ensure a smooth, effective, and sustainable integration.

A. Alignment with Student Learning Objectives (SLOs):

Ensure that the integration of mapping technology (e.g., LiDAR) aligns with the student learning objectives of the existing curriculum. The technology should enhance and support the educational goals rather than being introduced for novelty. Also, the technology should align with the Accreditation requirements and SLOs. The American Council for Construction Education (ACCE) is the accreditation agency for Construction Management programs. Based on ACCE's latest standards and criteria for the accreditation of construction management programs (Rev 2024.02.14) [7], students graduating from an accredited Bachelor's Degree Program shall have attained a set of knowledge, skills, and abilities (called Student Learning Objectives - SLOs) upon completion of their education. The list of SLOs for BSc in Construction Management is as follows

1. Create written communications appropriate to the construction discipline.
2. Create oral presentations appropriate to the construction discipline.
3. Create a construction project safety plan.
4. Create construction project cost estimates.
5. Create construction project schedules.
6. Analyze professional decisions based on ethical principles.
7. Analyze methods, materials, and equipment used to construct projects.
8. Apply electronic-based technology to manage the construction process.
9. Apply basic surveying techniques for construction layout and control.
10. Understand different methods of project delivery and the roles and responsibilities of all constituencies involved in the design and construction process.
11. Understand construction accounting and cost control.
12. Understand construction quality assurance and control.
13. Understand construction project control processes.
14. Understand the legal implications of contract, common, and regulatory law to manage a construction project.
15. Understand the basic principles of sustainable construction.
16. Understand the basic principles of structural behavior.
17. Understand the basic principles of HVAC, electrical, and plumbing systems.

Traditionally, the “Estimating Course” has been used to satisfy SLO 4, i.e., Create construction project cost estimates. As part of the course direct assessment, an estimating project of a real construction project is used. The assignment includes QTOs of the given construction project based on the MasterFormat organizational framework. Incorporating scanning and mapping tools (such as LiDAR data), data visualization tools, and other supporting information allows students to quantify specific items (such as paint and carpet square footage and number of doors/windows) on the pre-existing scanned structures.

This approach not only enriches students' learning experiences by facilitating a deeper understanding of the concepts but also aligns with the established SLOs for the program. To effectively evaluate SLOs, it is imperative to develop appropriate assessment tools and corresponding rubrics.

B. Faculty Training and Development

Provide adequate training and professional development opportunities for faculty members. Instructors must proficiently use the mapping/scanning technology to teach and support students effectively.

C. Infrastructure and Resources

Ensure that the institution has the necessary hardware, and software, resources to support the implementation of LiDAR technology.

D. Accessibility and Inclusivity

Consider the accessibility of LiDAR technology to all students. Ensure that the technology is inclusive and that students with diverse backgrounds and abilities can effectively engage with and benefit from its use.

E. Industry Collaboration

Foster collaboration with industry partners who are using LiDAR technology. This collaboration can provide valuable insights, real-world applications, and potential student internship opportunities. Wentworth successfully partnered with Bond Construction and guest speakers from Bond’s VDC department often present real-life applications of scanning and mapping technologies to our classroom.

F. Continuous Curriculum Review

Implement a process for continuous curriculum review and adaptation. Technology evolves rapidly, and regular updates to the curriculum ensure that students are exposed to the latest advancements in LiDAR and related fields.

Conclusion

Applying LiDAR technology in Construction Management Education presents a promising avenue for enhancing the learning experience and preparing students for the dynamic challenges of the construction industry. As technology evolves, educational institutions must adapt curricula to ensure graduates are well-equipped with the skills needed to excel in the modern construction landscape. In this case study, the comprehensive feedback of students regarding integrating LiDAR mapping technology into their Estimating course delivery methods was explored. A notable finding was that around 50% of the participants demonstrated proficiency in effectively utilizing assigned data to fulfill the specified Quantity Takeoff (QTO) tasks. The survey outcomes indicated an overall positive sentiment among students, affirming the valuable contribution of the new technology to enhancing their visualization experience.

Furthermore, students emphasized the significance of training sessions preceding the application of the technology, underlining its pivotal role in their successful engagement. Additionally, the study delved into various barriers and considerations associated with seamlessly incorporating this technology into the established course structure.

This research presents an opportunity for extension to other pertinent undergraduate courses, aiming to deepen our understanding of the technology's impact on students' learning outcomes across various academic domains.

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