# Surveying Education in Construction Programs: A Systematic Review

**Srijesh Pradhan**
Colorado State University
Fort Collins, Colorado

**Deniz Besiktepe, Ph.D.**
Purdue University
West Lafayette, Indiana

Construction surveying is part of the core curriculum in construction degree programs. Focusing on teaching the surveying fundamentals, instrument use and practice, and more importantly, the interpretation and communication of surveying outcomes in different stages of construction projects, these programs have a critical mission to train the future workforce of construction professionals competent in surveying. As a preliminary effort to explore the status of surveying education in construction programs, this systematic review aims to scrutinize the existing literature on construction surveying education, highlighting trends and developments in pedagogical approaches, technological integration, industry demands, and academic standards. First, a set of qualifying criteria is developed, articles are searched from scholarly databases, and then the articles are screened using a machine learning tool. In the final step, the articles are reviewed to determine their fit into the topic. The findings highlight key themes: blended learning, emerging technology, evolving industry needs, and learning advancements, where most of the scholarly works direct their efforts. This study adds to the body of knowledge of surveying education literature by providing a comprehensive analysis of evolving skillsets and pedagogical strategies that are shaping the future of construction surveying education.

**Key Words:** Surveying education, Construction surveying, Literature, Systematic review

## Introduction

The surveying applications are a crucial element of construction practices, with professional surveying carrying educational and licensing requisites alongside notable professional liabilities. The interpretation of surveying measurements and outcomes is at the core of construction programs' curriculum. American Council for Construction Education (ACCE)'s student learning outcomes include an outcome focusing on surveying: *"Apply basic surveying techniques for construction layout and control"* (ACCE, 2024). This outcome anchors the fundamentals of surveying within construction programs, encompassing both theoretical knowledge and practical application. The construction surveying principles include but are not limited to distance measurements, angle measurements, traverse survey, differential leveling, horizontal and vertical curve layout, building and construction

layout, contour lines and earthwork, and legal aspects (Arumala, 2000). These principles are delivered both in theoretical aspects and with hands-on applications.

In an era marked by rapid technological advancements and with the increasing scale and complexity of construction projects, the education of construction surveyors has never been more critical. However, it equally brings challenges in adapting the existing education system to meet these evolving needs. The construction industry has witnessed an unprecedented technological surge, with advanced tools such as unmanned aerial vehicles (UAV), robotic total stations, laser scanners, hand-held collectors, and digital photogrammetry becoming staples in modern surveying practices (Williamson III & Gage, 2019; Dib & Adamo-Villani, 2014). These advancements offer considerable benefits, saving cost and time through enhanced efficiency and accuracy, leading to widespread industry adoption. In addition to the technological revolution, the construction industry's expectations are also changing, needing an adaptive educational framework that can swiftly respond to new standards, innovative applications, and industry needs (Masum Fahria et al., 2019). Amidst this backdrop of innovation and evolving industry needs, uncertainties like the COVID-19 pandemic have further accelerated the need for curriculum adaptation, challenging traditional methods and prompting a swift transition to remote and hybrid learning models (Tingerthal & Kaoni, 2021). As educators and institutions strive to align curricula with these evolving needs, support from instrument manufacturers, software developers, and contractors has become even more instrumental. Contributions such as complimentary educational access, instrument discounts, and the creation of dedicated labs for teaching and research (Trimble, 2023) are pivotal in equipping the next generation of construction surveyors with the knowledge and skills to navigate a rapidly changing and increasing digital professional landscape.

In order to guide construction educators to improve construction surveying curricula that align with the industry's current state of practice, evolving technologies, and future uncertainties, it is essential to understand the present status, challenges, and future needs of construction surveying education. With that, the goal of this systematic review is to scrutinize the existing literature in construction surveying education, particularly focusing on the trends and developments in pedagogical approaches, technological integration, and industry needs, in the context of journal and conference publications. This study is essential to help educators, instructional designers, and industry stakeholders with the insights needed to cultivate a future-ready workforce from construction management graduates.

## Background

Most of the literature on surveying education has focused its attention on the geomatics education field (i.e., related to the study of collection and analysis of geographic data), mostly catering to the geomatics and land surveyor profession (Chan et al., 2023). Construction surveying education places significant emphasis on the layout of horizontal elements (e.g., roads and pipelines) and vertical elements (e.g., buildings and bridges), including earthwork, excavation, and the determination of grades and elevations (Arumala, 2000). From a pedagogical standpoint, construction surveying requires theoretical and practical coursework that increases students' cognitive and spatial abilities (Williamson & Anderson, 2019). Challenges in the construction surveying education lay in a wide range, including (i) limited access to instruments, (ii) availability of proper outdoor working, (iii) limited one-on-one instructor and student interaction, (iv) lack of immediate feedback on students' progress, (v) restricted assessment of student's performance due to lack of limited interaction, and (vi) weather conditions (Dib & Adamo-Villani, 2014).

The rapid advancements in technology shifted trends in construction from traditional applications to more technology-based innovative ones. With that, surveying instruments are evolving into automated technologies, improving productivity and efficiency. However, utilizing these instruments requires

extensive training and continuous professional development for practitioners with significant investment costs (Dib & Adamo-Villani, 2014). Moreover, curriculum development and educational efforts need strong alignment with technological advancements. Studies in the literature had attempts at technology integration and utilizing non-traditional teaching (e.g., virtual learning) in construction surveying education (Bolkas et al., 2021; El-Mowafy et al., 2013; Kuo et al., 2011). However, the current literature lacks a review study in construction surveying education, which is crucial for both curriculum development and technology integration. Considering the non-existence of a systematic literature review in construction surveying education, this study synthesizes key findings from various scholarly studies. Finally, this study addresses the gap in the body of knowledge with a comprehensive and up-to-date analysis of the current status, challenges, and future needs of construction surveying education with a systematic literature review.

## Research Methodology

A multi-step process was followed for the systematic review, including 1) Qualifying criteria, 2) Article search, 3) Machine learning-assisted screening, and 4) Final review.

### *Qualifying Criteria*

The authors established a set of qualifying criteria to ensure a relevant and focused analysis in the systematic review. The criteria included: (i) Scope of Research, (ii) Subject Matter, and (iii) Publication Status.

First, the scope of research should encompass preliminary records that are directly associated with the surveying education domain. This domain broadly encompasses two distinct fields: surveying education and construction surveying education. The authors define *surveying education* as broadly related to the field of geomatics, covering a comprehensive curriculum that includes surveying methods and technologies, focusing on teaching topics related to the collection, analysis, and interpretation of geographical and spatial data. In contrast, the educational focus in *construction surveying* is more centered on providing knowledge and skills related to applications in the construction industry. Including both domains allowed a comprehensive understanding of the general and specialized training that forms the foundation of construction surveying.

Second, the subject matter should include the following aspects: curriculum content (e.g., exploring topics, courses, and modules should constitute surveying education), teaching methodologies (e.g., exploring various teaching methods employed in surveying education from classroom learning to fieldwork and online/hybrid methods), technological integration (e.g., focus on how emerging surveying technologies are integrated into the curriculum), industry expectations (e.g., explore how surveying education aligns with industry needs), and student learning (e.g., methods that improve educational experience of students). Finally, published peer-reviewed journal and conference articles are considered for further analysis.

### *Article Search*

To identify scholarly works on construction surveying education, the authors employed a multifaceted search strategy using several scholarly databases. The primary search was conducted on two major international repositories: Web of Science and Scopus. In both databases, the keywords "surveying", "education", "construction surveying", and "geomatics" were utilized within several combinations. In addition to these primary sources, the search was expanded to include the Associated Schools of Construction (ASC) Proceedings and the International Journal of Construction Education and Research (IJCER), specifically targeting the intersection of construction education and practice.

Finally, Google Scholar was utilized to search records, including various combinations of keywords that helped to identify additional records. It is important to note that the ASC proceedings were explored within Scopus, Web of Science, and Google Scholar databases, while the IJCER publications were delved into the journal's webpage.

### Machine Learning-assisted Screening

The search lists from the databases were imported to ASReview, an open-source software that integrates machine learning models with active learning techniques to streamline the screening process in systematic reviews (van de Schoot et al., 2021). The initial step involved feeding the software with a dataset of records previously identified from scholarly databases, aligning with the qualification criteria. At least two sample articles were selected from this set as relevant benchmarks, providing the software with a foundational understanding of the research focus. ASReview uses these selected articles as a starting point to present the most closely related articles next. During the screening process, the software displays the abstract of each potentially relevant article. Based on these abstracts, the authors made decisions about whether to include each new record in the review. Each decision influenced the subsequent suggestions, as the software recalibrated and presented the next most related article based on the authors' choices. This iterative process was continued until a series of consecutive articles were detected that did not align with the research interest. At this point, it was concluded the remaining articles were likely to be irrelevant.

### Final Review

Following the systematic search and screening process, a detailed final review was conducted with the compiled list of studies. This crucial phase involved an extensive evaluation of each selected record so that it was aligned with the relevance and contribution to construction surveying education. The articles were assessed based on the methodological soundness, subject relevance, and quality of insights provided by these studies into the subject matter (e.g., teaching methodologies, technological integration, industry expectations, and student learning).

## Results and Discussion

The results present a quantitative analysis of reviewed publications and their thematic synthesis.

### Descriptive Statistics

The article search process yielded 305 articles which were fed to the ASReview tool. The ASReview tool provided 37 articles, out of which 10 of them were identified as not related to surveying education, and they were excluded from further review. Hence, the final list comprised 27 articles for further analysis. Figure 1a shows the yearly frequency of the articles under analysis over three decades. The percentages provided above each bar indicate the proportion of total publications represented by each year. There was a general trend of increasing publication frequency over time with some fluctuations. Notably, the peaks were observed in certain years (e.g., 2013, 2017, and 2019). The years 1992-2007 displayed lower publication frequencies, which could indicate less focus on the subject matter or fewer researchers publishing in the field during these periods. The most recent years (e.g., 2013-2021) showed a major increase in publications, with percentages peaking at 14.80%, suggesting a growing interest or a surge in research and development in the field. The study's analysis of 27 articles revealed that 18 were journal articles, and nine were conference articles (Figure 1b), while 19 were focused on surveying education, and eight were on construction surveying (Figure 1c).
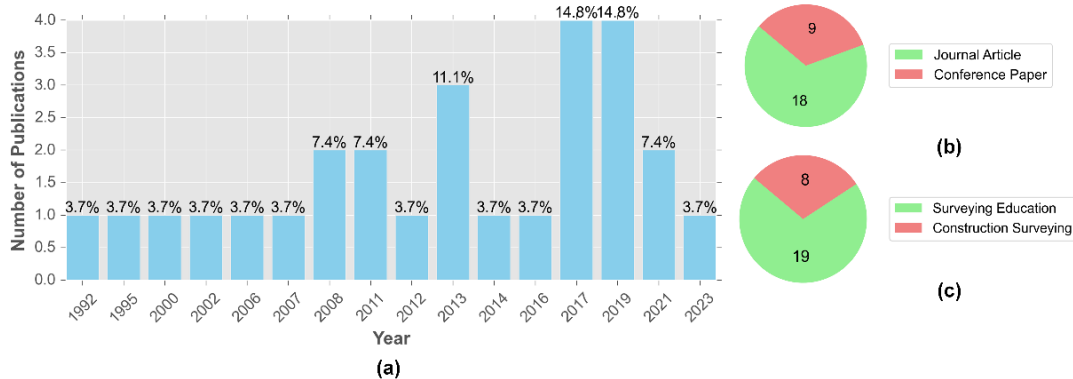
Figure 1. (a) Yearly distribution of articles; (b) Distribution of articles based on publication type; and (c) Distribution of articles based on education domain

## *Thematic Synthesis*

The articles were synthesized from the final list to find different themes in the literature that align with adapting surveying curricula to a better learning environment, current industry practices, technological advancements, and broader learning challenges. Thematic synthesis was conducted using qualitative analysis software; however, due to the page limitations, the details of the analysis were not presented. The broad themes that were discovered included (i) blended learning, (ii) emerging technology, (iii) evolving industry needs, and (iv) learning advancements. While these four themes were distinct, their diversity was a strength and provided a comprehensive view of the multifaceted nature of the surveying education field. The key findings were grouped according to their focus areas based on the identified themes from the articles.

## *Blended Learning*

Blended learning integrates face-to-face classroom instruction with digital learning components or virtual tools in surveying education (El-Mowafy et al., 2013). Table 1 shows the key focus areas discovered under this theme. For example, the Virtual Learning Environment encompasses a broader digital platform (e.g., interactive simulations, video tools) that enhances understanding of surveying concepts (Dib et al., 2013; El-Mowafy et al., 2013; Dib & Adamo, 2011). Virtual Labs enable students to engage in practical exercises remotely, ensuring accessibility and continuity of learning (Tingerthal & Kaoni, 2021; Kist & Basnet, 2013). Virtual Survey Instruments are digital tools that simulate actual surveying instruments and provide hands-on experience in surveying without the need for physical equipment (Bolkas et al., 2021; Kuo et al., 2011). Lastly, Digital Textbooks are electronic versions of traditional textbooks, often enhanced with interactive features such as multimedia and self-assessment quizzes (Holley, 2006). Studies, however, revealed intriguing variations in assessment outcomes in various blended learning approaches. For instance, Tingerthal & Kaoni (2021) observed that students in virtual labs reported enhanced learning benefits. However, in Dib & Adamo's (2011) study, the grades generated by the e-assessment tool (i.e., a digital tool to track student assessment in a virtual learning context) were significantly lower compared to those obtained through traditional manual grading. These findings collectively suggest that while blended learning tools are innovative, they also bring forth challenges in uniformly assessing student learning.

Table 1

*Focus areas under the blended learning category.*

| Focus area | Authors |
|---|---|
| Virtual Learning Environment | Dib et al., 2013; El-Mowafy et al., 2013; Dib & Adamo, 2011 |
| Virtual Labs | Tingerthal & Kaoni, 2021; Kist & Basnet, 2013 |
| Virtual Survey Instruments | Bolkas et al., 2021; Kuo et al., 2011 |
| Digital textbooks | Holley, 2006 |

## Emerging Technology

The focus areas discovered under this theme are shown in Table 2. Surveying instruments like chains, auto levels, theodolites, and total stations are traditional tools taught in almost every construction surveying course. Adding improvements and enhancements to these conventional tools (e.g., use of the robotic total stations and Global Positioning System (GPS) enabled data collecting devices) can help students gain practical experience and familiarity with the technology they will encounter in the professional world (Arumala, 2000). New technologies refer to non-traditional surveying tools such as drones, laser scanning, and robots that offer enhanced data collection capabilities and operational efficiencies. However, incorporating emerging technologies in construction surveying education may present financial, logistical, and regulatory challenges. For example, the substantial cost of advanced surveying instruments, even with educational discounts, poses significant budgetary considerations for academic programs (Arumala, 2000). Additionally, integrating cutting-edge technologies like drones into the curriculum can involve navigating complex approval processes and regulatory requirements (Williamson III & Gage, 2019).

Table 2

*Focus areas under the emerging technology category.*

| Focus area | Authors |
|---|---|
| Advancements in traditional tools | Arumala, 2000 |
| Incorporating new technologies | Williamson III & Gage, 2019 |

## Evolving Industry Needs

The focus areas of this theme are shown in Table 3. Adapting surveying curricula based on professional feedback ensures that graduates possess the technical skills and knowledge demanded by the industry (Masum Fahria et al., 2019; Wong et al., 2007). Complementing this technical training with managerial and problem-solving skills in interdisciplinary fields prepares students for the multifaceted challenges of contemporary surveying, thus blending practical abilities with critical managerial competencies (Enemark, 2002). However, merely focusing on academic preparation may not be enough. The evolving technological and professional landscape demands that surveying education also prioritizes practical application and real-world readiness. This includes adapting teaching methods and course content to reflect the latest technological advancements and industry practices, ensuring that graduates are equipped not just with theoretical knowledge but with the ability

to apply these skills effectively in their profession (Chan et al., 2023; Wong et al., 2007; Currin & Troemel, 1992). Finally, collaboration between surveying academia and industry is essential to ensure educational programs are directly relevant and responsive to professional demands (Young et al., 2012).

Table 3

*Focus areas under the evolving industry needs category.*

| Focus area | Authors |
|---|---|
| Curriculum adaptation and development | Masum Fahria et al., 2019; Wong et al., 2007 |
| Managerial and interdisciplinary approach | Enemark, 2002 |
| Adaptation to the changing landscape of technology and professional practices | Chan et al., 2023; Wong et al., 2007; Currin & Troemel, 1992 |
| Collaboration between education and industry | Young et al., 2012 |

## *Learning Advancements*

Learning advancement refers to progressive developments and innovations in education that enhance the effectiveness, efficiency, and accessibility of learning as shown in Table 4. Studies have revealed that adopting strategies like creative learning, hands-on training, and logical thinking contribute to learning enhancement in surveying education. For instance, creative learning methods (e.g., use of 3D models) have been shown to enhance spatial reasoning (Carbonell et al., 2017). Hands-on training and workshops can improve critical thinking and problem-solving skills (Awange et al., 2017). Logical reasoning abilities have been shown to foster academic success in construction surveying courses (Williamson & Anderson, 2019). Lastly, course formats (e.g., traditional vs. mini-mester formats) can also influence student's academic performance in construction surveying (Williamson III, 2017).

Table 4

*Focus areas under the learning advancements category.*

| Focus area | Authors |
|---|---|
| Creative learning | Carbonell et al., 2017 |
| Hands-on training | Awange et al., 2017 |
| Reasoning abilities | Williamson & Anderson, 2019 |
| Course format | Williamson III, 2017 |

## Conclusion

This research intended to scrutinize the existing literature in surveying education, highlighting trends and developments in pedagogical approaches, technological integration, and industry needs. Four major themes were discovered during the synthesis: (i) blended learning, (ii) emerging technology, (iii) evolving industry needs, and (iv) learning advancements.

The findings from these themes and their respective focus areas offer actionable insights for educators and industry professionals to help construction surveying education adapt to the changing times, while

also acknowledging the challenges associated with integrating new methodologies. A debate exists among educators and students regarding whether a virtual or online learning environment can completely replace traditional face-to-face instruction in surveying. However, the COVID-19 pandemic forced many construction surveying programs to transition to online and hybrid formats, necessitating the importance of integrating virtual learning methods side-by-side with traditional formats. Incorporating digital textbooks can be a starting point for universities in blending traditional and virtual learning methods. While adding new technologies is beneficial, it should not come at the expense of students not grasping the fundamental concepts of traditional surveying tools. Industry needs in construction surveying are often not clearly defined and differ from professional surveying. There is also a lack of clarity among students about their role at the construction job site related to surveying, given their role overlaps with those of professional surveyors. Workshops engaging students with construction companies on the scope of construction surveying applications at the job site can be beneficial to students. Lastly, as many students enrolled in construction surveying courses may lack sufficient background in trigonometry and technology, it is crucial to adopt strategies that can enhance the learning experience and problem-solving skills of construction surveying students.

## *Limitations and Future Research*

The study's limitations stem from the utilized machine learning-assisted tool as well as the number of papers (i.e., N=27) reviewed. Despite the tool's time-saving benefits, human review and judgment are essential to further refine the article selection process. In addition, the review solely focused on journal and conference publications, whereas future research studies could include textbooks and syllabus reviews within a more comprehensive effort to identify the educational perspective. Case studies, debatable disagreements, and interesting facts could be discussed in future research. Moreover, a comprehensive review could be performed with a broader perspective of surveying education with more robust methods, such as scientometric analysis or Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), in future studies.

## **References**

ACCE. (2024). *Degree Programs Accreditation*. https://www.acce-hq.org/accredited-degree-programs

Arumala, J. O. (2000). The impact of new surveying instruments on the construction surveying course of study. *Journal of Construction Education*, *5*(3), 227–243.

Awange, J. L., Anwar, A. H. M. F., Forootan, E., Nikraz, H., Khandu, K., & Walker, J. (2017). Enhancing Civil Engineering Surveying Learning through Workshops. *Journal of Surveying Engineering*, *143*(3), 05017001. https://doi.org/10.1061/(ASCE)SU.1943-5428.0000211

Bolkas, D., Chiampi, J., Fioti, J., & Gaffney, D. (2021). Surveying Reality (SurReal): Software to Simulate Surveying in Virtual Reality. *ISPRS International Journal of Geo-Information*, *10*(5). https://doi.org/10.3390/ijgi10050296

Carbonell, C., Saorín, J., Melian, D., Cantero, J., & Cantero, T. (2017). 3D Creative Teaching-Learning Strategy in Surveying Engineering Education. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*, 1–14. https://doi.org/10.12973/ejmste/78757

Chan, B. S.-B., Leung, S.-C., & Ding, X. (2023). Nurturing Talents Of Geomatics Surveyors To Meet The Challenges Of Land Supply, Works Projects And Smart City Of Hong Kong. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *X-5/W1-2023*, 1–9. https://doi.org/10.5194/isprs-annals-X-5-W1-2023-1-2023

Currin, T., & Troemel, H. (1992). Surveying Education: The Surveyor's Perspective. *Proceedings. Twenty-Second Annual Conference Frontiers in Education*, 590–594.

Dib, H., & Adamo, N. (2011). An e-tool for undergraduate surveying education: Design and evaluation. *ICST Trans. e-Education e-Learning*, *11*, e5. https://doi.org/10.4108/icst.trans.eeel.2011.e5

Dib, H., Adamo, N., & Garver, S. (2013). An Interactive Virtual Environment for Teaching "Triangulations and Coordinates Calculations" to Surveying Students. *Proceedings of the International Conference on Information Visualisation*, 445–450. https://doi.org/10.1109/IV.2013.58

Dib, H., & Adamo-Villani, N. (2014). An innovative software application for surveying education. *Computer Applications in Engineering Education*, *22*(3), 551–562. https://doi.org/10.1002/cae.20580

El-Mowafy, A., Kuhn, M., & Snow, T. (2013). Blended learning in higher education: Current and future challenges in surveying education. *Issues in Educational Research*, *23*, 132–150.

Enemark, S. (2002). Innovation in surveying education. *Global J. of Engng. Educ*, *6*(2), 153–159.

Holley, P. W. (2006). Effectiveness of IT-based Course Material: A Case Study in Publishing and Using a Digital Textbook for Construction Surveying. *International Journal of Construction Education and Research*, *2*(1), 29–41. https://doi.org/10.1080/15503980500519593

Kist, A. A., & Basnet, B. (2013). Providing equivalent learning activities with software-based remote access laboratories. *International Journal of Online Engineering*, *9*(S3), 14–19.

Kuo, H.-L., Kang, S.-C., Lu, C.-C., Hsieh, S.-H., & Lin, Y.-H. (2011). Using virtual instruments to teach surveying courses: Application and assessment. *Computer Applications in Engineering Education*, *19*(3), 411–420. https://doi.org/10.1002/cae.20291

Masum Fahria, Mansberger Reinfried, Martin Audrey, Navratil Gerhard, & Mushinge Anthony. (2019). Adapting the Surveying Curriculum to New Dimensions of the Profession. *Journal of Professional Issues in Engineering Education and Practice*, *145*(2), 04019003. https://doi.org/10.1061/(ASCE)EI.1943-5541.0000408

Tingerthal, J., & Kaoni, K. (2021). Implementing a Virtual Surveying Lab. *2021 ASEE Virtual Annual Conference Content Access*.

Trimble. (2023). *Trimble Technology Labs*. https://www.trimble.com/en/our-commitment/education-and-outreach/technology-labs

van de Schoot, R., de Bruin, J., Schram, R., Zahedi, P., de Boer, J., Weijdema, F., Kramer, B., Huijts, M., Hoogerwerf, M., Ferdinands, G., Harkema, A., Willemsen, J., Ma, Y., Fang, Q., Hindriks, S., Tummers, L., & Oberski, D. L. (2021). An open source machine learning framework for efficient and transparent systematic reviews. *Nature Machine Intelligence*, *3*(2), 125–133. https://doi.org/10.1038/s42256-020-00287-7

Williamson III, K. C. (2017). A comparison between mini-mester and full semester achievement in a construction surveying course. *Proceedings of the Associated Schools of Construction, 53rd Annual International Conference, Seattle, Washington*, 5–7.

Williamson III, K. C., & Gage, G. (2019). Important considerations for implementing a drone-based activity within a construction surveying course. *55th ASC Annual International Conference Proceedings*.

Williamson, K. C., & Anderson, A. J. (2019). Reasoning Ability as a Predictor of Success in a Construction Surveying Course. *International Journal of Construction Education and Research*, *15*(1), 42–61. https://doi.org/10.1080/15578771.2017.1380733

Wong, J. M. W., Wong, F. K. W., & Hui, E. C. M. (2007). A Study to Improve Higher Education for Surveying Professionals in Hong Kong. *Journal for Education in the Built Environment*, *2*(1), 76–89. https://doi.org/10.11120/jebe.2007.02010076

Young, G. O., Smith, M. J., & Murphy, R. (2012). Contemporary surveying education changing with the times. *Survey Review*, *44*(326), 223–229. https://doi.org/10.1179/1752270611Y.0000000026