EPiC Series in Built Environment

Volume 6, 2025, Pages 260–269

Proceedings of Associated Schools of Construction 61st Annual International Conference

Identifying Effective Tools for Teaching Construction Estimating Take-off Courses

Kishor Shrestha [1] and Bakari Bakari [2]
[1]Washington State University, [2]Turner Construction

Construction estimating courses are foundational in preparing students for careers in the construction industry. This study aims to identify effective teaching tools for construction estimating quantity take-off (QTO) courses through a survey with instructors. The survey, with 55 responses, examined the tools currently used, evaluated their effectiveness in enhancing student learning, and identified some challenges the instructors faced. The study results showed that 80 percent of respondents used visualization tools, and the four most effective tools were 3D objects, 3D SketchUp models, 3D Revit models, and YouTube videos. Respondents also stated that these tools helped visual learners and improved other students' understanding of complex drawings while also increasing their confidence and skills in planning. However, limitations and challenges such as lack of course-project-specific 3D models, reliance on the tools, and technological and licensing issues have been identified in some institutions. In the absence of visualization tools, some instructors frequently relied on traditional approaches. The study also emphasized the broader usefulness of visualization tools beyond QTO courses, indicating their potential use in construction safety, planning and scheduling, and site logistics courses. Augmented reality (AR) and virtual reality (VR) tools typically showed great promise for generating immersive, scenario-driven learning experiences.

Keywords: Construction, Quantity, Take-off, Teaching, Tools

Introduction

An estimating course is vital for construction-related BS degrees because it teaches how to accurately predict the costs of construction projects, which is a fundamental skill in the industry (Ryoo & An, 2021). This skill is essential for preparing bid documents and estimates, which rely heavily on QTO. All courses, including construction estimating QTO, always benefit from effective instruction. In this context, two primary teaching approaches are utilized: traditional and technology-enhanced teaching.

Traditional teaching is also called a pen and pencil approach (ASCEBC, 2023). This approach relies on printed drawings (2D) and manual calculation methods. This approach often falls short of providing adequate visualization. For example, traditional teaching approaches involve providing lecture notes, printed drawings, quantity take-off equations, and memorizing them (Hajirasouli & Banihashemi, 2022). In this approach, visual learners usually struggle to engage and comprehend the teaching material in QTO courses. Glick et al. (2015) showed that if students have not been exposed to construction sites, they typically had more challenges understanding the structural elements in QTO classes. Many students found it difficult to mentally convert a 2D plan into a 3D model (Deno, 1995). Collins & Redden (2020) found that students' estimating skills enhanced through a practical experiential learning activity. On the other hand, technology-enhanced teaching uses visualization tools as supplements to enhance the learning experience and provide dynamic and immersive learning environments that can fill the gap in traditional teaching methods. Various tools and applications are used including 3D models and VR.

Recent advances in technology have introduced novel tools and applications that improve student engagement, understanding, and accuracy in estimating QTO processes. These technologies offer immersive and interactive learning skills that can significantly improve students' understanding and retention of knowledge. One commonly used tool is 3D models. 3D models assist students to visualizing ideas, facilitating understanding, and speeding up the assimilation of concepts (Autodesk, 2007). According to Teply et al. (2022), 3D models benefit both instructors and students, and they highly recommended incorporating them into the curriculum. Ryoo and An (2021) used Revit 3D models to assist students become more skilled in QTO processes, improving visualization, and teaching fundamental ideas. Another study found that 3D models facilitate a deeper comprehension of structural components and their relationships within a project (Zolfagharian et al., 2013). Sampaio and Martins (2017) used 3D models of roofs and other structural elements of buildings and bridge projects to enhance students' understanding. Deno (1995) also showed that there were substantial benefits of including 3D models for improved student understanding. Batra et al. (2020) noted that teaching students to visualize construction elements in 3D can be challenging due to individual aptitudes. However, while technology helps students in multiple dimensions, it is advised that they traditionally become confident in reading plans before utilizing technology. 3D models can be created in various ways for different purposes with Sketch Up being a commonly used software due to its affordability and ease of use (Reyes et al., 2015).

Tools such as VR help students understand construction elements better (Gandhi et al., 2018). These tools address the student body's needs, which is why many institutions have introduced them worldwide (Kaminska et al., 2019; Valdez et al., 2015). It contributes significantly to the instructional process by offering an engaging method of learning (Kaminska et al., 2019). Research on the advantages of integrating these technologies into construction instruction has grown recently. These tools provide interactive, immersive experiences that can make complex spatial information more comprehensible for students (Hajirasouli & Banihashemi, 2022). For example, VR applications enable students to navigate through a virtual construction site, offering a more realistic context for learning QTO processes. VR applications also provided flexibility of accessing classes from a distance (Valdez et al., 2015). Such tools allow students to manipulate digital representations of objects, giving them hands-on experience that is otherwise difficult to achieve in a traditional classroom setting. According to Hajirasouli & Banihashemi (2022), students may experience and interact with project elements in a simulated setting using AR and VR technology, which improves their spatial awareness and comprehension of construction procedures. The ability to mentally twist, rotate, or manipulate graphically presented stimuli is known as spatial visualization (McGee, 1979).

Integrating these technologies into construction estimating QTO courses significantly advances in construction education. By using these resources, instructors can design more interesting and successful lessons that better equip students for the demands of the industry. Collins & Redden (2022) indicated that these technologies improve student engagement and enhance their ability to confidently perform complex QTO tasks. Additionally, by simulating real-world situations, these tools offer students practical experience. Moreover, employing advanced visualization tools will actively involve students in learning (McGee, 1979).

This study examines the tools/ applications currently used in teaching QTO courses in construction management, construction engineering, engineering technology, and civil engineering departments in US universities. It also assesses their effectiveness in overcoming traditional teaching limitations to identify the most effective teaching tools for construction QTO courses. Using effective tools may help instructors in academia effectively teach construction QTO courses. Such tools also help students to be more engaged in classroom activities and retain their knowledge.

Literature Review

The literature review section covers the evolution of QTO visualization tools in construction education. It also covers the cognitive benefits that can be used in classrooms. Important literature on the subject is presented below. Recent studies have highlighted the benefits of incorporating visualization tools into construction estimating QTO courses.

Hajirasouli & Banihashemi (2022) studied AR as a transformative tool in architecture and construction education. Traditional teaching methods were typically passive, where instructors were the primary knowledge transmitters, and students were passive recipients. The authors highlighted how AR could bridge this gap by offering a blended learning environment that supplemented traditional approaches with interactive and immersive experiences. Through AR, students could engage with virtual overlays that simulate real-world contexts. This enhanced students' comprehension of abstract concepts and fostered their ability to integrate virtual information into real-world applications. Furthermore, AR's accessibility made it a feasible tool for university curricula. The authors emphasized the potential use of AR to enhance student engagement, improve spatial understanding, and offer experiential learning opportunities that traditional methods lacked, positioning AR as a pivotal tool in preparing students for Industry demands. According to research, these tools increase student engagement and improve their capacity to carry out challenging activities like project scheduling and cost estimation. Additionally, these AR/VR systems can replicate real-world situations, giving students practical experience that is frequently hard to come by in a conventional classroom (Messer et al., 2003).

Ryoo & An (2021) carried out a study that explored an innovative method for teaching construction plan reading online courses, utilizing 3D modeling with Revit to overcome remote learning challenges. The course was designed to begin with basic cognitive tasks, such as understanding construction drawings and memorizing terminology, and gradually progress to the complex task of creating a 3D model. The flipped classroom model, typically used in traditional settings, was adapted for online instruction during the COVID-19 pandemic to improve learning outcomes. The course proved effective, as post-course surveys showed students had a strong grasp of interpreting construction drawings and could accurately prepare estimates.

Another study investigated the impact of using 3D models on student comprehension in construction materials and methods courses, focusing on challenging topics like masonry and metals (Glick & Porter, 2012). The survey responses of that study were positive, with students reporting enhanced skills in mentally rotating objects and visualizing spatial relationships, which Sorby & Baartmans (1996) had previously identified as difficult. The results also showed a substantial impact of using 3D models in high-impact curriculum areas like masonry. Factors such as instructor differences, family construction backgrounds, and geographical upbringing did not significantly affect student perceptions, suggesting that 3D models are broadly applicable across diverse student backgrounds.

Messner et al. (2003) studied integrating VR and 4D CAD modeling into construction education. To evaluate the educational benefits of these tools, two experiments were carried out i) creating 4D CAD models for building projects and ii) exploring immersive VR environments to develop construction plans. The results showed that advanced visualization tools significantly enhanced students' comprehension of construction planning, enabling them to quickly acquire practical skills and stay engaged. Additionally, VR environments simulate key aspects of real-world construction sites, offering virtual alternatives to physical site visits. These environments help students practice essential skills such as sequence planning, temporary facility placement, trade coordination, safety assessment, and constructability improvements.

Research Methods

The study employed a survey-based research methodology targeting construction QTO instructors across various institutions in the United States. The survey (developed in Google Forms) included both quantitative questions (e.g., tool effectiveness ratings) and qualitative feedback (e.g., challenges faced). It was conducted via email, sending a link to potential respondents. Figure 1 presents the overall research methods employed in this study.

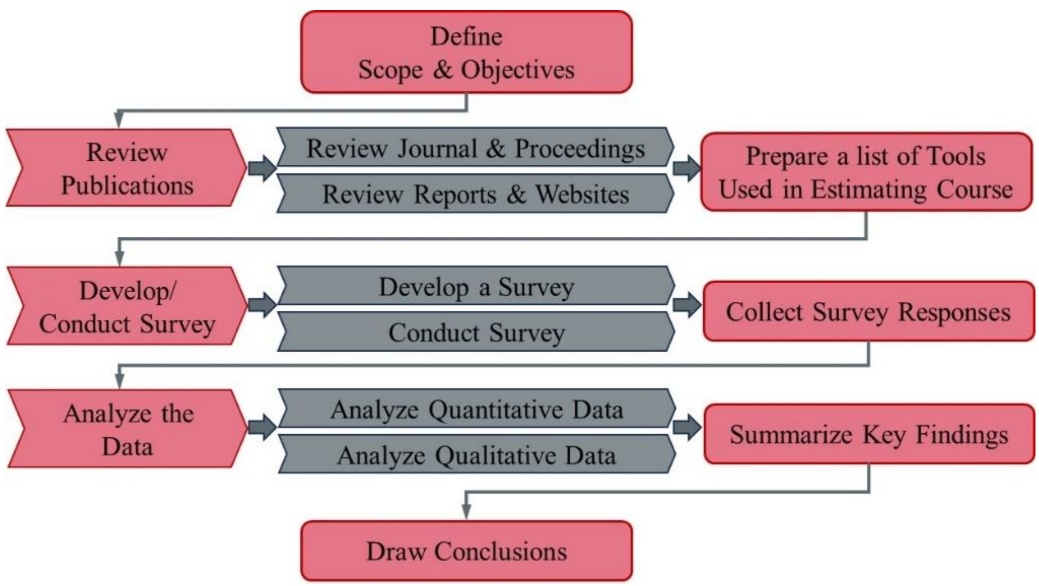

Figure 1. The research method adopted in this study

Data Collection

All the data were collected through the survey. The survey was dispatched to all the ASC Estimating Bootcamp participants held in Milwaukee, Wisconsin in 2023. The survey was also distributed to the American Society of Professional Estimators (ASPE) members who have taught or were potentially teaching the QTO courses. Google Forms was used to develop the survey, and the weblink was shared with an email invitation. Reminder emails were also sent to the individuals to improve the response rate. The main objective of the survey was to collect data focused on identifying commonly used tools/ applications, perceived benefits, and challenges faced in construction QTO courses. Since the survey weblink was distributed, their responses were collected immediately from the responses tab.

Data Analysis

The collected data can be categorized into two types: qualitative and quantitative. The qualitative data includes text information from the respondents, such as "What limitations/ challenges have you encountered with visualization tools/applications?" The quantitative data includes rating the given subjects on a Likert scale of 1-5, such as "To evaluate the effectiveness of these tools/ applications, please rate them on a scale of 1-5 based on your personal opinion." On the scale, 5 being exceptionally effective and 1 being neutral or ineffective. This study conducted descriptive data analysis for the data collected for each of the questions separately. The results of the study are presented in the result section.

Results

In this study, a survey was conducted to collect data. The first question asked to the respondents was "Have you taught or are you currently teaching a construction estimating QTO course?" Fifty-five responses were received. Out of these, 39 respondents (over 70 percent) were teaching or have taught the construction estimating QTO course. The second question was "If yes to the above question, what types of projects are included in your course?" Thirty-nine responses were collected for this question. The results showed that 29 (74 percent) respondents have included vertical projects (building construction projects) and 22 (56 percent) have included horizontal projects, such as highway and bridge projects. Figure 2 presents the details of their responses.

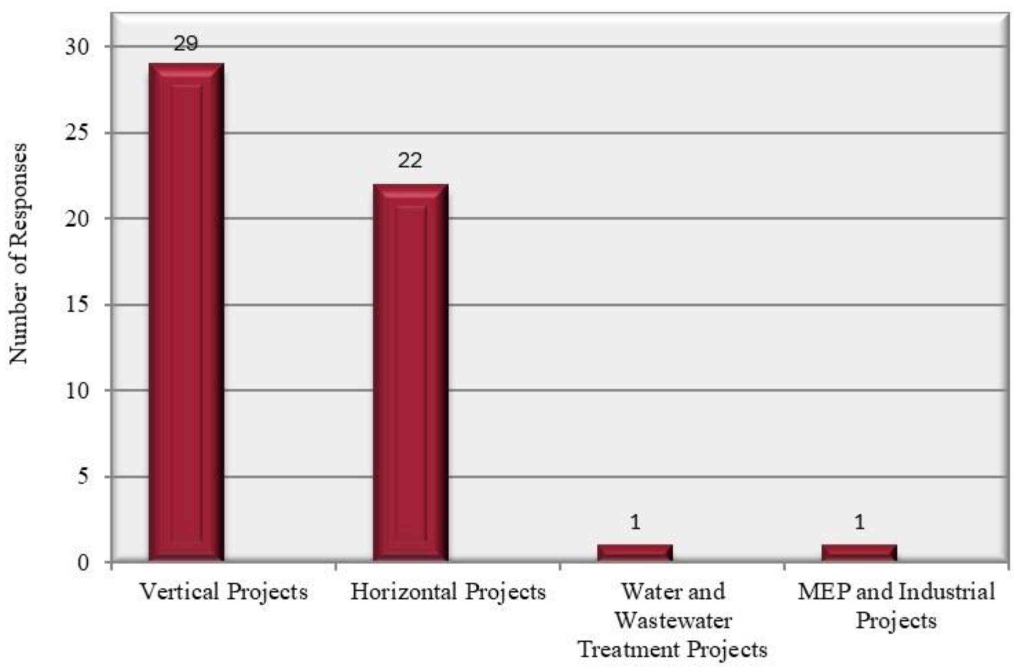

Figure 2. Type of projects used in construction estimating QTO courses

The third question asked was, "How many years have you taught construction estimating QTO course?" The range of experience was 2-23 years. The average years of experience was 6.7 years. There were 23 respondents with less than 5 years of experience, nine with 6-10 years of experience, one with 11-15 years of experience, and five with over 16 years of experience.

In another question, the respondents were asked “Have you used or are you currently using any tools/ applications (models, YouTube videos, objects, etc.) in your class to help students in interpreting/visualizing 2D plans/drawings?” The authors provided a list of common tools/ applications to choose from (collected from existing publications). The authors also provided ‘Others’ option if the respondents have used tools other than those listed in the survey. Thirty-six respondents completed this question, and their responses showed that 29 (80.6 percent) have used such tools in the estimating QTO course.

In the fifth question, the authors asked respondents to select the tools or applications they have used or are currently using in their construction QTO course. The survey results revealed that 36 percent used YouTube Videos, 27 percent used 3D Objects, 21 percent used 3D SketchUp models, and 11 percent used 3D Revit models, as detailed in Figure 3. As a follow-up, the sixth question asked respondents to rate the effectiveness of these tools on a scale of 1-5, with 5 being exceptionally effective and 1 being neutral or ineffective. The survey results revealed that the four effective tools based on mean rating (Shrestha et al. 2023; Shrestha & Shrestha 2022; Shrestha & Shrestha 2020) were 3D Objects, 3D SketchUp Models, 3D Revit models, and YouTube Videos. Figure 4 provides the average ratings for each tool used in the construction QTO course.

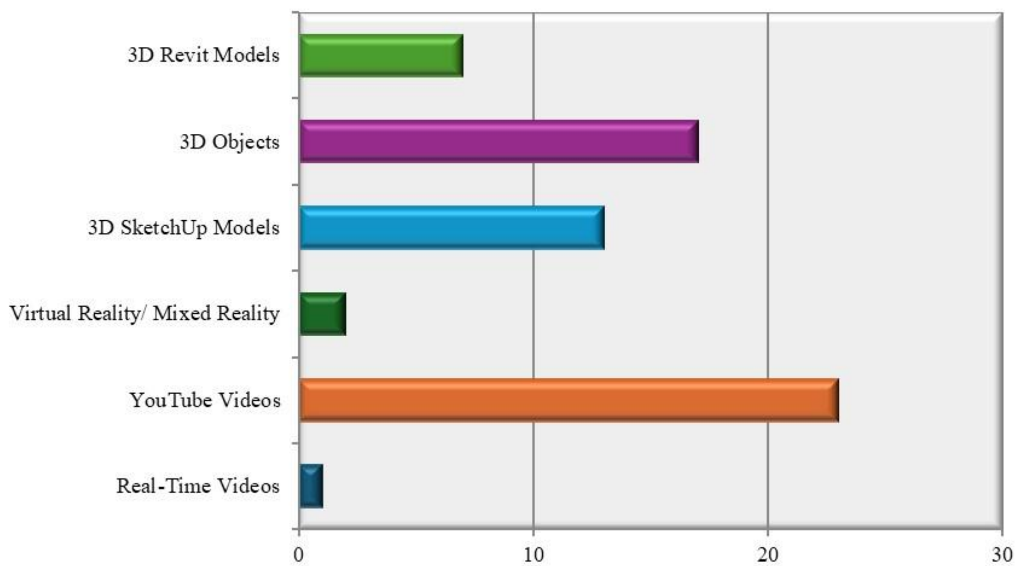

Figure 3. Tools/ applications used in construction estimating QTO courses

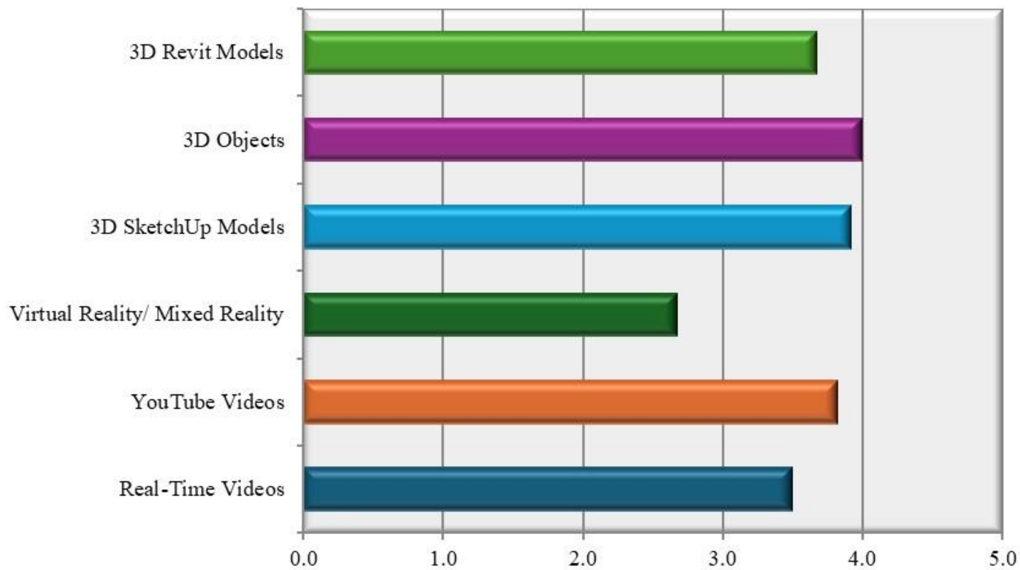

Figure 4. Rating on the common tools used in construction estimating QTO courses

In another question, the respondents were asked "In a few words, please share your experience of how the visualization tools/applications have helped your students." Twenty-six responses were collected in the text format as visualization tools and applications have greatly enhanced students' learning experience by enabling them to visualize and understand unfamiliar or uncommon elements, such as underground complex components, in a multi-dimensional way. These tools have simplified the QTO process, improved students' confidence, and supported them in planning for their assignments more effectively. They have also helped students understand complex construction elements and dimensions, which is especially beneficial for visual learners who comprise a significant portion of the class. By correlating 3D models with real construction scenarios, students gain a clearer, more practical understanding of the construction elements, leading to more accurate and efficient quantity take-offs and better overall performance.

The eighth question was "What limitations/ challenges have you encountered with visualization tools/applications?" Twenty-five responses were gathered in the text format. Some limitations and challenges encountered include the availability of course project-specific models. Although YouTube videos provide basic understanding, they often lack advanced content specific to course lectures. Creating 3D objects for each lesson is challenging, and existing virtual tools may oversimplify physical structures and interactions. There is also inconsistency in technology, software licenses, and equipment availability for students, and some students may overly rely on these tools for interpreting drawings. Tailored educational videos and resources are also needed to enhance learning but are currently limited.

In the ninth question, the respondents were asked "In your experience, can the tools/ applications you use also be applied in other courses, such as safety? Please explain in a few words." A total of 24 responses were collected for this question. Their responses indicated that the tools and applications used in the construction QTO course have versatile applications across other construction-related courses. They are especially useful in courses like construction safety, scheduling, site logistics, and project management, where visual aids can enhance understanding. Tools such as AR/VR are valuable for simulating scenarios and safety planning. Video content and 3D models can effectively support training, visualizing safety controls, and planning measures.

The last question asked was "If you have not used any tools/applications, please briefly share what you use instead and explain why you do not use these tools/ applications." Eighteen respondents who have not used any tools/ applications responded to this question. Several respondents indicated that they often do not use specialized visualization tools or applications because they are in administrative positions. Instead, they rely on traditional methods like paper drawings, colored pencils, and markerboard sketches to help students visualize projects. Additionally, some respondents believe the traditional method is working and enough for their needs. Some respondents shared that they lack the resources to introduce advanced tools in their classrooms.

Conclusion

The main objective of this study was to identify and evaluate the effectiveness of the current tools and applications used in teaching construction QTO courses across various engineering and construction management departments in US universities. An online survey was conducted with construction QTO instructors in the United States to achieve the study objective. Out of fifty-five responses received, thirty-nine completed the survey, with an average teaching experience of 6.7 years. Their responses indicated that almost all of them were teaching either horizontal or vertical construction projects in their QTO courses. The results revealed that a majority of respondents (80 percent of respondents) used visualization tools to help students understand complex plans. This study identified eight tools that were used in teaching QTO courses in various institutions. They were 3D SketchUp models, 3D Revit models, 3D objects, AR, VR, YouTube videos/ images, and real-time videos. These tools were rated on a Likert scale of 1-to-5 to identify the highly rated or effective tools. The results showed that the most highly rated (effective) four tools were 3D Objects, 3D SketchUp Models, 3D Revit models, and YouTube Videos for their ability to help students visualize complex elements on construction drawings. The respondents stated that these tools were particularly effective for visual learners in their classrooms. The respondents indicated that these tools not only help students understand construction drawings but also boost their confidence and improve their skills in planning.

The authors also asked the respondents to share any challenges faced by instructors in utilizing tools in their QTO course. Common challenges include lacking specific 3D models for courses and/or project-specific construction elements, publicly available online resources not fitting the specific course and/or chapter, and technological and licensing issues. Additionally, the oversimplification of physical interactions in some virtual models and students' dependency on visual aids were identified as areas needing attention. In courses where advanced visualization tools are not accessible, instructors often revert to traditional method, which, lack the interactive benefits of using tools.
The study identified that visualization tools are useful for more than only construction QTO courses. They are also applicable to construction safety, planning and scheduling, and site logistics courses. Tools like AR/VR are particularly promising for creating immersive, scenario-based learning experiences. Overall, while visualization tools enhance educational outcomes in construction QTO, further development of tailored educational resources and broader access to technology would support a more comprehensive and interactive learning environment across construction education.

Acknowledgement

The authors would like to acknowledge the Associated Schools of Construction (ASC) for providing funds to conduct this study (ORSO # 143989-001). The authors would also extend gratitude to the ASPE staff for their assistance in preparing the survey and sincerely thank all the respondents for their participation. Additionally, the authors acknowledge the use of ChatGPT and Grammarly in restructuring a few contents and checking the grammar of this paper.

References

ASC Estimating Boot Camp (ASCEBC). (2023). The ASC Estimating Boot Camp. Milwaukee, Wisconsin, June 20th – 22nd, 2023. https://www.hcss.com/blog/asc-boot-camp/
Autodesk, 2007.

Batra, J. S., Richardson, R., & Webb, R. (2020). How can instructors strengthen students' motivation to learn complex 3D concepts in an engineering classroom? Paper presented at the 2020 IEEE Frontiers in Education Conference (FIE).

Collins, W. & Redden, L. (2022). Assessing Industry Estimating Software Utilization Practices to Improve Construction Education. 58th Annual Associated Schools of Construction International Conference, 3, 552-559.

Collins, W. & Redden, L. (2020). Improving Student's Estimating Abilities through Experiential Learning. *International Journal of Construction Education and Research*, 17(2), 117–132. https://doi.org/10.1080/15578771.2020.1739178

Deno, J. (1995). The relationship of previous spatial visualization ability. *Engineering Design Graphics Journal*, 59(3), 5-17.

Gandhi, R.D. & Patel, D.S. (2018). Virtual Reality–Opportunities and Challenges. Virtual Real. 5, 482–490.

Glick, S. & Porter, D. (2012). Student Visualization: Using 3-D Models in Undergraduate Construction Management Education. *International Journal of Construction Education and Research*. DOI: 10.1080/15578771.2011.619247

Hajirasouli, A. & Banihashemi, S. (2022). Augmented reality in architecture and construction education: state of the field and opportunities. *International Journal of Educational Technology in Higher Education*, 19(39). https://doi.org/10.1186/s41239-022-00343-9

Kaminska, D., Sapinski, T., Wiak, S., Tikk, T., Haamer, R.E., Avots, E., Helmi, A., Ozcinar, C., & Anbarjafari, G. (2019). Virtual Reality and Its Applications in Education: Survey. *Information, MDPI*, 10(318). doi:10.3390/info10100318

McGee, M. G. (1979). Human Spatial Abilities. New York: Praeger Publishers Inc.

Messner, J.I., Yerrapathruni, S.C.M., Baratta, A.J., & Whisker, V.E. (2003). Using Virtual Reality to Improve Construction Engineering Education. 2003 American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education. Session 1121.

Reyes, M., Ghosh, S., Perrenoud, P. A., & Goldman, J. (2015). Teaching Plan Reading to Construction Students: The Effect of Using Tablet Computers.

Ryoo, B. & An, M. S. (2021). Improving Visualization Capability in Construction Education (Plan Reading). 57th Annual Associated Schools of Construction International Conference, 2, 478-486.

Sampaio, A.Z. & Martins, O. (2017). VR model of bridge construction: a didactic application. In Proceedings of the Virtual Reality International Conference-Laval Virtual, New York, NY, USA, 22–24 March 2017, 21.

Shrestha, K. & Shrestha, P.P. (2022). Framework to Implement Performance-Based Contracting for Chip-Seal Road Maintenance. *Journal of Construction Engineering and Management, ASCE*. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002207

Shrestha, K. & Shrestha, P.P. (2020). Framework Development of Performance-Based Striping Maintenance Contracts. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, ASCE*. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000385

Shrestha, K., Shrestha, P.P., & Lohoud, M. (2023). Critical Factors Affecting the Bid Cost of Building Projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, ASCE*. https://doi.org/10.1061/JLADAH.LADR-960

Sorby, S. & Baartmans. (1996). A course for the development of 3-D spatial visualization skills. *The Engineering Design Graphics Journal*, 60(1), 13-20.

Teply, M.T. P. & Smejkal, P. (2022). Influence of 3D models and animations on students in natural subjects. *International Journal of STEM Education*, 9(65). https://doi.org/10.1186/s40594-022-00382-8

Valdez, M.T., Ferreira, C.M., Martins, M.J.M., & Barbosa, F.M. (2015). 3D virtual reality experiments to promote electrical engineering education. In Proceedings of the 2015 International Conference on Information Technology Based Higher Education and Training (ITHET), Lisbon, Portugal, 11–13 June 2015, 1–4.

Zolfagharian, S., Gheisari, M., Irizarry, J., & Meadati, P. (2013). Exploring the Impact of Various Interactive Displays on Student Learning in Construction Courses. 120th ASEE Annual Conference & Exposition, American Society for Engineering Education, Paper ID # 6243.