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# Evaluating the Educational Impact of 3D Modelling in Construction Estimating Course: A Case Study of Washington State University

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Construction estimating courses play a vital role in preparing students for professional practice in the construction industry. However, students often face challenges when learning bridge estimating concepts due to the complexity of structural elements and limited opportunities for field exposure. This study evaluates the effectiveness of integrating a 3D bridge model as an instructional tool in a construction estimating course for undergraduate students at Washington State University (WSU). The objective is to assess how a 3D model enhances students' understanding across four key dimensions: visualization and structural comprehension, conceptual learning, efficiency and productivity, and overall satisfaction. Survey data (45 responses) collected from WSU students between 2020 and 2023 through paper-based surveys distributed in class. The results reveal overwhelmingly positive perceptions of the 3D model's usefulness; 69 percent of students were satisfied, and 31 percent were very satisfied. Students particularly valued the model's ability to support visualization of complex bridge elements. Overall, the findings suggest that 3D modeling is a valuable instructional tool for enhancing student engagement and perceived understanding in construction estimating education. Future studies should involve multiple universities, diverse project types, and more advanced analytical methods to strengthen the robustness and generalizability of the findings.

Keywords: Construction, Estimating, Teaching, Tools

## Introduction

Estimating courses play a critical role in construction-related undergraduate programs, such as Construction management, Construction Engineering, Construction Science, etc. (Kisi & Shrestha, 2025; Kisi et al., 2025), by equipping students with the ability to accurately forecast project costs, an essential competency for preparing bid documents and performing Quantity Take-Off (QTO) (Ryoo & An, 2021). As with all technical courses, effective instructional strategies are vital for fostering student comprehension and engagement. Generally, two instructional methods dominate estimating education: traditional teaching and technology-enhanced learning.

The traditional "pen-and-pencil" method (ASCEBC, 2023) uses two-dimensional (2D) drawings and manual calculations. While long established, this approach often limits students' ability to visualize construction components effectively. It typically involves lectures, printed drawings, and formula memorization (Hajirasouli & Banihashemi, 2022), which can be particularly challenging for visual learners. Previous studies have shown that students lacking construction site exposure struggle to grasp spatial relationships among structural elements in QTO exercises (Glick & Porter, 2012; Deno, 1995). Conversely, experiential and hands-on activities have been found to strengthen estimating skills (Collins & Redden, 2022; Batra et al., 2020).

Although Virtual Reality (VR) tools present some challenges (Gandhi & Patel, 2018), technology-enhanced teaching using visualization tools such as 3D models and VR environments offers dynamic, interactive learning experiences that help overcome the limitations of traditional teaching methods (Kaminska et al., 2019; Sampaio & Martins, 2017). As construction education increasingly embraces digital technologies to bridge the gap between theory and practice (Reyes et al., 2015), 3D modeling has emerged as a valuable method for improving spatial reasoning and interpretation skills, especially when site exposure is limited.

To address these instructional challenges, the Construction Engineering (ConE) 360 course at Washington State University (WSU) integrated a 3D model of the SR 508 concrete bridge into its estimating curriculum. The bridge is a real project located approximately six hours from WSU, Pullman campus. This initiative aimed to offer students an interactive, realistic visualization to supplement traditional coursework. Prior studies support the educational benefits of such approaches, highlighting the pedagogical value of 3D modeling in construction classrooms (Teply & Smejkal, 2022).

The integration of 3D visualization into bridge estimating education reflects a broader shift toward experiential, technology-supported learning within construction curricula. This study examines the classroom application of a real-world 3D bridge model in an undergraduate construction estimating course. It evaluates its perceived instructional effectiveness using multi-year student survey data. By analyzing the student survey data collected, this study contributes to construction education literature by offering empirical insights into how 3D visualization tools are perceived to support learning and engagement in a real instructional setting. Specifically, the study aims to investigate student perceptions of the 3D bridge model with the following objectives:

- To evaluate the perceived impact of the 3D model on students' visualization and structural understanding of bridge components
- To assess how the model supports conceptual learning related to bridge estimating concepts
- To examine perceived effects on efficiency and productivity during estimating tasks
- To assess overall student satisfaction with the integration of the 3D bridge model as an instructional tool

## Literature Review

A recent study explored the integration of Immersive Virtual Reality (IVR) in bridge engineering education to address the limitations of traditional teaching methods that often rely on teacher-centered, lecture-based instruction with limited interactivity or visualization (Li et al., 2023). This study highlighted that conventional "spoon-feeding" approaches and static teaching materials hinder students' ability to grasp complex bridge construction concepts. IVR, on the other hand, provides a 3D and interactive learning environment that enhances engagement, motivation, and conceptual understanding. The study demonstrated the use of IVR to automatically generate realistic 3D bridge scenes, enable immersive interaction, and evaluate teaching communication effectiveness. Using a mega suspension bridge under construction as a case study, the experimental results revealed a notable improvement in student engagement and satisfaction—approximately 94 percent of participants reported being satisfied or very satisfied with the immersive learning experience. These findings underscore the potential of IVR as an effective pedagogical tool for improving visualization, interaction, and communication in bridge construction education.

Visualization and modeling technologies have become integral components of construction education, particularly in QTO and estimating courses where students must interpret complex construction drawings and spatial relationships. Shrestha & Bakari (2025) conducted a national study to identify effective tools for teaching construction estimating and take-off courses. Their findings revealed that nearly 80 percent of QTO instructors across U.S. universities employed visualization tools to enhance students' understanding of construction plans. Among the most widely used tools were 3D SketchUp models, 3D Revit models, 3D objects, augmented reality (AR), VR, and multimedia applications such as YouTube videos. The study found that 3D objects, SketchUp, 3D, and YouTube videos were particularly effective in improving visualization and comprehension, especially for visual learners. However, instructors reported challenges related to the limited availability of project-specific models, software licensing, and the misalignment of public digital resources with course objectives. Despite these barriers, visualization tools were shown to enhance engagement and conceptual understanding, with further potential applications in safety, scheduling, and site logistics-related courses.

Complementing these findings, Hajirasouli & Banihashemi (2022) explored AR as a transformative pedagogical tool in architecture and construction education. The authors argued that traditional instruction often relies on passive learning, where students act as information recipients rather than active participants. AR, in contrast, provides interactive and immersive experiences that bridge theoretical knowledge with practical, real-world applications. Through virtual overlays, students can visualize abstract concepts and understand spatial and contextual relationships within a construction environment. The researchers emphasized AR's potential to foster engagement, enhance spatial understanding, and provide experiential learning opportunities that traditional methods often lack. They concluded that AR is a promising and accessible educational tool that equips students with skills aligned with contemporary industry demands.

Building on the momentum of digital visualization, Ryoo & An (2021) investigated the use of 3D models in online construction education during the COVID-19 pandemic. They implemented a course designed around Revit-based 3D modeling to improve students' ability to interpret plans and develop estimates. The course structure followed a cognitive progression—from understanding basic construction drawings to creating complex 3D models—adapting the flipped classroom model for virtual delivery. Post-course assessments demonstrated significant gains in students' comprehension and practical skills. Similarly, Glick & Porter (2012) investigated the influence of 3D models in construction materials and methods courses, particularly on topics such as masonry and metals. Their results indicated improved spatial reasoning and visualization abilities, addressing challenges noted by Sorby & Baartmans (1996). Importantly, the findings suggested that such improvements were consistent across diverse student backgrounds, highlighting the broad pedagogical value of 3D visualization tools in construction and engineering education.

Expanding on the use of immersive visualization, Messner et al. (2003) investigated the incorporation of VR and four-dimensional (4D) computer-aided design (CAD) modeling into construction education. Their study involved two experimental approaches: developing 4D CAD models for vertical construction projects and using immersive VR environments to simulate construction planning scenarios. The findings revealed that these advanced visualization tools substantially enhanced students' understanding of construction processes, facilitating the rapid acquisition of practical planning and coordination skills. VR-based learning environments also replicated essential elements of real-world construction sites, providing virtual alternatives to physical field visits. Such simulations allowed students to practice sequence planning, temporary facility layout, trade coordination, safety evaluation, and constructability analysis—core competencies that are often difficult to develop through conventional classroom instruction alone.

Collectively, these studies underscore the growing role of visualization and immersive technologies in enhancing construction education. Tools such as AR, VR, and 3D modeling not only promote engagement and comprehension but also bridge the gap between theoretical learning and real-world applications. Continued integration and development of these digital resources can create more interactive, inclusive, and industry-relevant learning environments for future construction professionals.

While visualization technologies such as 3D modeling, AR, and VR are increasingly used in construction education, limited research has examined their course-integrated, classroom-based use of real-project 3D bridge models in construction estimating courses. Existing studies rarely focus on bridge estimating or on evaluating learning outcomes within a real instructional setting. This study addresses this gap by assessing the educational effectiveness of integrating a 3D bridge model into an undergraduate construction estimating course at WSU.

## Research Methods

The study utilized a survey-based research approach focusing on students who have taken the construction estimating course at WSU. The survey consisted of both quantitative questions, such as effectiveness rating scales, and qualitative, open-ended questions. Data were collected through paper-based surveys administered during class sessions, and they were voluntary. Table 1 illustrates the number of responses collected each year. The research methodology consisted of defining study objectives, reviewing extant publications, developing a paper-based survey, followed by conducting data analysis and drawing conclusions. The collected quantitative and qualitative data were then analyzed using descriptive statistics and thematic analysis to evaluate the educational impact of the 3D model.

**Table 1.** Number of student survey responses by year (2020–2023)

| **Years** | **2020** | **2021** | **2022** | **2023** |
|---|---|---|---|---|
| Number of survey responses | 13 | 16 | 6 | 10 |

### *Survey Design*

The survey instrument was developed by the author specifically for this study, building on insights from a prior study on effective teaching tools for construction estimating and take-off courses (Shrestha & Bakari, 2025). The questions were designed to evaluate student perceptions of the 3D bridge model across key learning dimensions, including visualization, conceptual understanding, efficiency, and overall satisfaction.

### *Data Collection*

Data for this study were collected using a structured survey administered to all students who took the construction estimating course between 2020 and 2023. To maximize participation, students who were absent on the day of survey administration were given an opportunity to complete the survey at a later time. The primary purpose of the survey was to capture student perceptions of the effectiveness of using a 3D model of the SR 508 bridge as a learning tool in the estimating course.

### *Data Analysis*

The collected data were divided into two categories: qualitative and quantitative. Qualitative data consisted of students' written comments and open-ended feedback, while quantitative data included responses to rating-scale questions measured using a five-point Likert scale (1 = very ineffective to 5 = very effective). For example, students rated questions such as, "How effective is the 3D model for viewing the overall bridge from different angles?" A five-point Likert scale was selected for such questions because it is widely used in educational research, provides sufficient response granularity, reduces respondent fatigue, and is easy to interpret. Survey responses were available by academic year for the period 2020–2023; however, because instructional delivery methods changed in 2020 and remained consistent in subsequent years, the data were aggregated to evaluate the overall and sustained educational impact of the 3D bridge model.

Descriptive statistical analyses were performed on the quantitative data for each survey question, and the findings are presented in the results section. Qualitative responses were examined to identify recurring themes and insights, providing context to the quantitative findings.

Although formal reliability testing was not conducted due to the limited sample size, the questionnaire survey questions were carefully developed by the author based on previous studies and course objectives. The generally consistent response patterns across the questionnaire survey suggest that the instrument provided coherent and meaningful measures of student perceptions.

## Results

A survey was conducted with undergraduate students who took the construction estimating course to evaluate the educational effectiveness of the 3D bridge model. The survey consisted of ten questions grouped into four categories: (1) visualization and structural understanding, (2) learning and conceptual understanding, (3) efficiency and productivity, and (4) overall satisfaction and feedback. A total of 45 responses were collected in this four-year study from 2020 to 2023.

In the first category, *visualization and structural understanding*, three questions were included. The first asked, "How effective is the 3D model in viewing the overall bridge from different angles?" Among 45 respondents, 31 percent rated the model as "very effective," and 69 percent rated it as "effective." The other two questions examined how well the 3D model supported students' understanding of structural components—such as pier caps, wing walls, and decks—and improved their ability to interpret bridge elements. Overall, responses indicated that students consistently found the 3D visualization beneficial in enhancing their comprehension of structural relationships (see Figure 1).

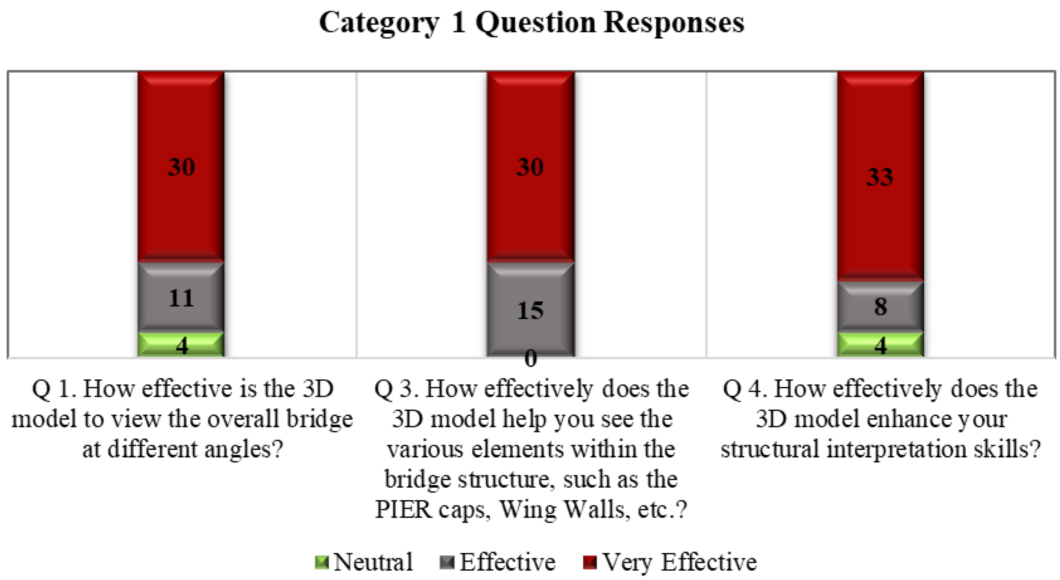


**Figure 1.** Student responses for category 1 questions

The second category, *learning and conceptual understanding*, included two questions addressing how effectively the 3D model improved conceptual learning and confidence in understanding bridge construction. All students responded to these questions, and Figure 2 presents the student responses.

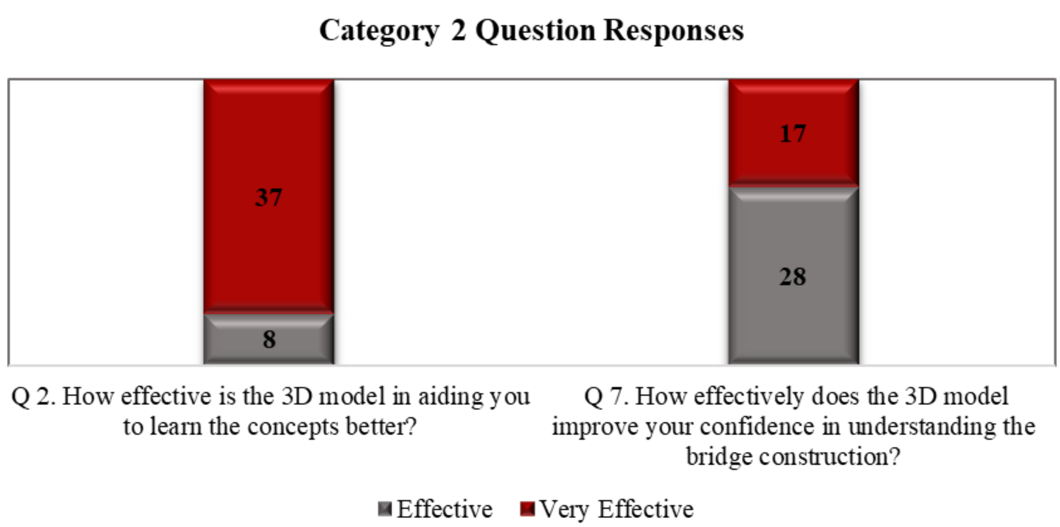


**Figure 2.** Student responses for category 2 questions

In the third category, *efficiency and productivity*, three questions examined the 3D model's impact on reducing the time required to interpret drawings and complete assignments. Students were asked to rate the model's effectiveness in enhancing efficiency, reducing drawing reading time, and supporting assignment completion. Results showed strong positive feedback, indicating that the 3D model noticeably improved students' productivity in course assignments. Figure 3 presents their responses.

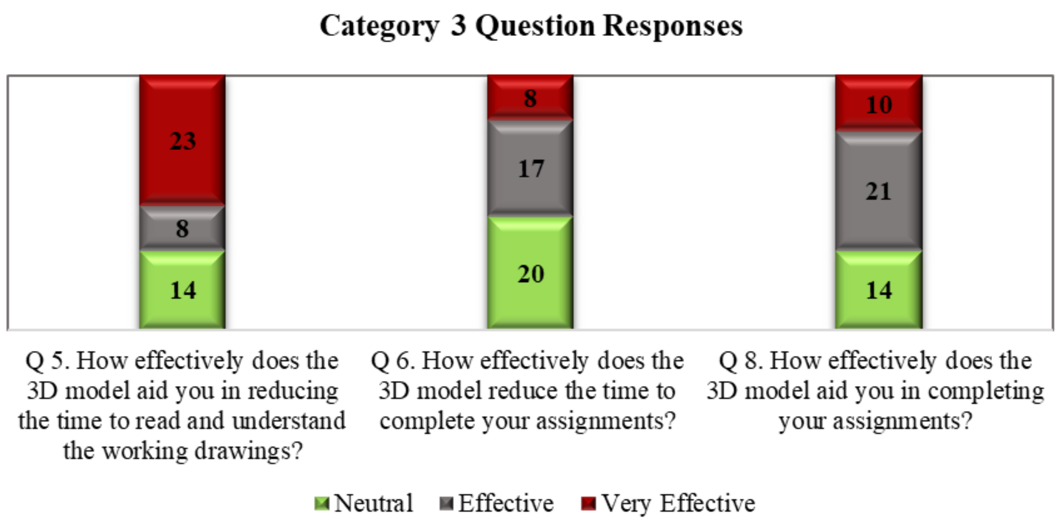


**Figure 3.** Student responses for category 3 questions

The final category, overall satisfaction and feedback, included both quantitative ratings and open-ended responses that were analyzed using a thematic approach. The results showed that 31 percent of students were "very satisfied" and 69 percent were "satisfied" with the use of the 3D bridge model. Thematic analysis of the qualitative responses revealed three primary themes: (1) enhanced visualization and understanding of bridge components, (2) increased confidence in learning complex bridge concepts, and (3) suggestions for functional enhancements. Most students emphasized that the 3D model considerably improved their ability to visualize and understand structural elements, particularly for those with limited prior exposure to bridge projects. Several respondents noted greater confidence in interpreting drawings and comprehending construction concepts, while a smaller subset suggested enhancements such as incorporating measurement tools and expanding quantity take-off capabilities. Overall, the qualitative themes align with the quantitative satisfaction results and reinforce the effectiveness of the 3D model as an instructional tool.

In this study, the author collected student response data from 2020 to 2023. Although instructional context varied across years, the descriptive results show consistently positive student responses across cohorts, suggesting that the perceived instructional value of the 3D model remained stable over time.

*Limitations*

This study primarily relies on descriptive statistical analysis and thematic interpretation to evaluate student perceptions of the 3D bridge model. While the results indicate consistently positive outcomes, the absence of inferential statistical testing limits the ability to assess statistical significance or make formal comparisons across cohorts or instructional conditions. Future studies could strengthen the analytical depth by incorporating inferential analyses, such as hypothesis testing, to further validate the observed trends. In addition, the findings are based on data collected from a single academic program and a single bridge project used as a case study, which may limit their generalizability to other institutions, instructional contexts, or project types.

## Conclusion

The primary objective of this study is to evaluate the effectiveness of using a 3D bridge model as an instructional tool in a construction estimating course for undergraduate students at WSU. Specifically, the study aims to assess how the integration of 3D modeling enhances students' visualization and structural understanding, conceptual learning, efficiency and productivity, and overall satisfaction. Conducted in the post-COVID-19 pandemic period (2020–2023), this study also reflects adaptations in instructional delivery and student engagement that occurred during and after pandemic-related disruptions. By analyzing student responses collected during this period, the study seeks to determine the educational impact of 3D visualization on improving comprehension of complex bridge estimating concepts and to provide insights for incorporating digital modeling technologies into construction engineering education.

The findings of this study demonstrate the meaningful educational value of integrating 3D modeling into construction engineering courses, particularly in bridge estimating and visualization instruction. The survey results from undergraduate students enrolled in the estimating course revealed overwhelmingly positive perceptions of the 3D bridge model's effectiveness in enhancing visualization, conceptual understanding, and learning efficiency. Across all four evaluated categories—visualization and structural understanding, learning and conceptual understanding, efficiency and productivity, and overall satisfaction—the majority of students rated the 3D model as either "effective" or "very effective." These results suggest that 3D modeling serves as a powerful instructional tool that helps students interpret complex bridge elements such as pier caps, wing walls, and decks while reinforcing their ability to understand spatial and structural relationships. Ryoo & An (2021) and Glick & Porter (2012) also found that 3D modelling improved students' ability to interpret construction plans and their visualization skills.

Beyond improving visualization, students reported that the 3D model increased their confidence in understanding bridge design concepts and reduced the time required to interpret working drawings and complete assignments. This indicates that 3D models not only enhance comprehension but also contribute to greater productivity and engagement. The overwhelmingly positive satisfaction ratings further validate the model's utility in supporting experiential and interactive learning experiences within the construction engineering curriculum.

Student responses also offered valuable insights for future improvements. While most respondents were satisfied with the existing model, several recommended improvements, such as incorporating measurement functions and expanding the model's capabilities for QTO applications. These suggestions underscore opportunities for further refinement and customization of digital tools to better align with practical learning outcomes in construction estimating and project planning.

Overall, the study reinforces the growing role of digital visualization technologies in construction education. The incorporation of 3D modeling fosters deeper understanding, promotes active engagement, and bridges the gap between theoretical instruction and real-world applications. Future research could explore the integration of advanced visualization methods such as AR and VR to create immersive, interactive environments that further enhance spatial reasoning and decision-making skills. As construction education continues to evolve, leveraging tools like 3D modeling will be essential to preparing students for the future construction industry.

This study has a few limitations that should be considered when interpreting the findings. First, the research was conducted at a single institution, which may limit the generalizability of the results to other construction programs. Second, the study relied on one case study involving a single bridge project, and student perceptions may differ when using other project types or levels of complexity. Finally, the analysis was limited to descriptive statistics and thematic interpretation, which restricts the ability to draw statistically significant comparisons. Future research should involve multiple institutions, diverse project types, and more advanced analytical methods to strengthen the robustness and generalizability of the findings.

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This manuscript was prepared entirely by the author. OpenAI's ChatGPT was used solely as a language and style tool to improve clarity and readability. All substantive content, data analysis, and conclusions were determined by the author.

## 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/

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, Vol. 3, 552-559.

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; pp. 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

Kisi, K.P. & Shrestha, K. (2025). Student Perceptions of Construction Program Naming Distinctions. Proceedings of 61st Annual Associated Schools of Construction International Conference, Calgary, Canada, April 2025.

Kisi, K.P., Shrestha, K., Tafazzoli, M., & Rokooei, S., and Shrestha, K.J. (2025). STEM Education and Academic Identity: The Influence of Program Titles on Construction Students' Perceptions. American Journal of STEM Education: Issues and Perspectives, Star Scholars Press. 2025. DOI: https://doi.org/10.32674/enm6ay26

Li, W. Zhu, J., Dang, P., Wu, J., Jhang, J., Fu, & L., Zhu, Q. (2023). Immersive virtual reality as a tool to improve bridge teaching communication. Expert Systems with Applications, Vol. 217. https://doi.org/10.1016/j.eswa.2023.119502.

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, Vol. 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 2017, New York, NY, USA, 22–24.

Shrestha, K. & Bakari, B. (2025). "Identifying Effective Teaching Tools for Construction Estimating Courses," Proceedings of 61st Annual Associated Schools of Construction International Conference, Calgary, Canada.

Sorby, S., & Baartmans. (1996). A course for the development of 3-D spatial visualization skills.

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