



Increasing Diversity in Construction Management using Hands-On Activities and VR Technology at the Middle School Level

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Increasing diversity in construction management (CM) benefits the profession by bringing multiple perspectives and skill sets, improving project outcomes, and helping alleviate the problem of current and projected vacancies in CM while simultaneously providing opportunities for future construction managers such as fulfilling careers and higher pay. This study advances understanding of whether an intervention at the middle school level, in this case a hands-on workshop, results in an increased interest in pursuing CM as a career. The workshop included site logistics planning, target value delivery, and a quantification exercise using Meta Quest 2 VR headsets. Participant understanding of, and interest in, CM before and after the workshop were determined through deployment of surveys with a combination of multiple choice and open-ended questions. Surveys also included participant demographic questions. 41 students aged 10-15 years old participated in our study. Our analysis found that interest in CM increased significantly post-workshop. Increased interest was not impacted by the students' gender or having family members in construction.

Keywords: Construction Management Education, Diversity and Inclusion, Virtual Environment

Introduction

According to recent statistics, construction management (CM) only comprises 10.6% women, 4.8% Black or African American, 2% Asian, and 16.1% Hispanic or Latino (U.S. Bureau of Labor Statistics, 2023). Enrollment for many universities is projected to drop significantly between 2025 and 2029 (Farrow, 2020; Grawe, 2018) while the demand for construction managers continues to rise, with the job outlook for Construction Managers expected to grow by 9% between 2023 and 2033 (U.S. Bureau of Labor Statistics, 2024). Increasing diversity in CM would benefit the profession by helping fill current and projected vacancies in our field, bringing multiple perspectives and skill sets (Moore & Gloeckner, 2007) and improving project outcomes (Wu et al., 2019), while simultaneously providing opportunities for future construction managers such as fulfilling careers and higher pay.

CM has many paths to a fulfilling career. With such varied positions available such as a superintendent working on the jobsite, an estimator working in the office, or a technology-oriented position such as a BIM manager (Jackson, 2020), CM is one of the most diverse fields available. It is also one of the highest paid positions in the AEC industry, with a median annual wage of \$104,900 per year (U.S. Bureau of Labor Statistics, 2024). While increasing diversity in CM is the primary

goal, the approach in this study was to “cast a wide net” – i.e. include all groups – in an effort to raise the profile of CM to all groups and not single out individuals from targeted groups.

Background

Teachers, parents, and counselors have little knowledge of the construction industry and misconceptions persist that construction requires brute strength and tolerance for inclement weather and bad language (Agapiou, 2002, Amaratunga et al., 2006; Bilbo et al., 2009; Mathew, 2014) which may be why some young students are not steered toward a career in CM. A study in which 24 women who graduated from a CM program over a ten-year period found that only 1 in 24 had entered the degree program as a freshman with the remaining 23 being transfers from other programs after finding their original major would lead to a career with lower pay, that it did not hold their interest, or they felt alienated them from their peers (Moore & Gloeckner, 2007). Women in this study reported that they changed their major “with very little information about the construction industry or the role of a constructor” (Moore & Gloeckner, 2007, p. 128). Conclusions can be drawn from the literature that middle and high school students are largely unaware of CM as a potential career path unless they have a family member in the industry.

Several factors impact career choice. In one study, family and peer factors were found to be less significant than future job opportunities and working conditions in students’ career choices in commerce and management (Panakaje et al., 2024). Other research points to parental influence being the most significant factor in career choice with financial factors being less significant and gender having no impact (Kazi & Akhlaq, 2017). Family background played a significant role in choices that lead to careers in education, law, business and engineering (Amani, 2016). Studies examining CM, specifically, indicate that female and male students are attracted to CM for similar reasons such as career opportunities and better pay, and that newly hired women in construction report that their career expectations were generally met or exceeded and experienced overall job satisfaction (Bigelow et al., 2017; Oo et al., 2020).

According to the U.S. Bureau of Labor Statistics, construction managers “plan, coordinate, budget, and supervise construction projects from start to finish” (U.S. Bureau of Labor Statistics, 2024). Several additional sources reiterate this definition, e.g. CMs schedule, coordinate, and supervise construction processes including the selection, hiring, and oversight of trade contractors (McKeon, 2012) and CMs manage projects, quality, information, risk, safety, value, contracts, and schedule (Arditi et al., 2019). Activities developed as part of this study were derived from these various descriptions of CM responsibilities and simplified such that middle or high school students could grasp the concepts.

As part of this study, participants used a virtual reality headset to explore a building and quantify building elements such as windows and doors. Virtual reality is a tool becoming more prevalent in education (Boyles, 2017; Lee & Wong, 2008; Pantelidis, 2010) and, more specifically, construction education (Alizadehsalehi et al., 2019) as well as in the construction industry (Noghabaei et al., 2020). Virtual reality is able to present a simulated environment resembling the real world and create a sense of copresence with other participants in the space (Anderson et al., 2017). Simulated environments allow students to explore structures and facilitate access to the multiple and varied layers that comprise a structure (Fernandez, 2017). The ability to visualize and interact with these environments benefits students by allowing them to be immersed in a programmed environment that simulates sight, touch, and hearing to better comprehend building concepts. Prospective AEC students can explore and manipulate three dimensional interactive environments and apply skill sets such as the electrical, plumbing and HVAC trades which allows students to gain hands-on learning experience in the

classroom prior to their entry into the industry. Our goal was to use virtual reality as a tool to attract students who enjoy hands-on learning, and to enhance their learning experience and capabilities using these technologies.

In this study, we sought answers to two primary questions: (1) after learning about what CMs do in a workshop deployed by undergraduate researchers, are students more interested in pursuing construction management as a career, and (2) how do demographic factors, such as gender, family background in construction, and initial interest in technology, influence changes in students' interest in construction management following the workshop?

Methodology

The study described in this paper was deployed in Spring 2024 at a middle school located in New England. A total of 41 middle school students participated in the study, with an age range of 10 to 15 years old. Figure 1 presents the demographic information of participants, showing that 66% are male and 34% are female. Caucasian/White participants represent the largest proportion, while some participants selected the option "Prefer Not to Say" for race/ethnicity. The study was conducted in two sessions, the first being 7th and 8th graders (N=26) and the second being 5th and 6th graders (N=15). Both quantitative and qualitative survey data were collected in the form of multiple-choice and open-ended questions (Creswell, 2013) to determine participant understanding of and interest in CM before and after a workshop based on typical CM activities. The survey included demographic questions such as gender, age, race/ethnicity, and family experience in the construction industry. Prior to the commencement of the research activities, we sought and received approval from the University's Human Subjects Research Board. As part of the protocol, we developed an informed consent sheet for participants' parents to review and obtained written permission from the school superintendent to collect data from students.

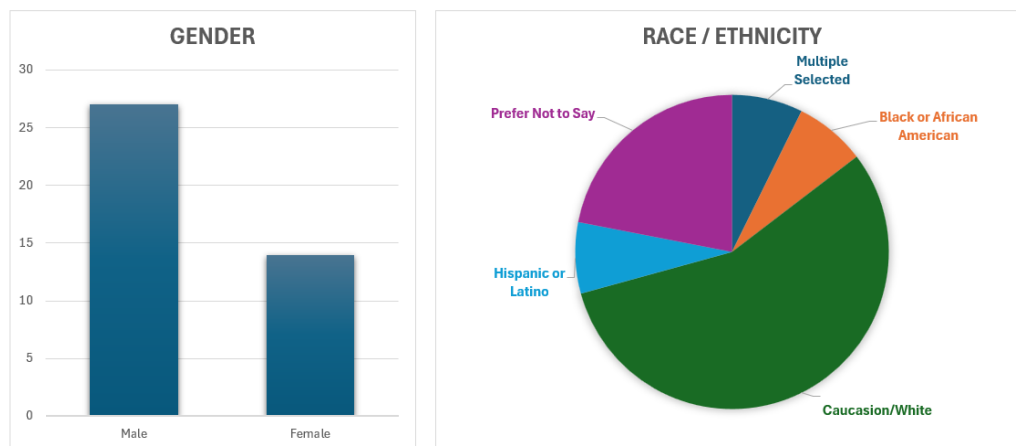


Figure 1. Participant Demographics

In each session, the undergraduate researchers spent 10-15 minutes introducing themselves, talking about their background and experience, then providing a general overview of the workshop activities. Prior to beginning the workshop activities, a pre-workshop survey was distributed to the participants. The surveys were deployed on paper. Each participant was given a unique 4-number code so data could be collected anonymously and allowed researchers to directly compare responses to pre- and post-workshop questions.

In addition to providing demographic and background information, students were asked the following in the pre-workshop questionnaire:

- What do you know about the job of being a construction manager? [Open-ended question]
- Do you have any interest in becoming a construction manager? [1-100 scale with 0=No, 100=Yes]
- Does anyone in your family work in the construction industry? [Yes; No; I'm not sure]
- Are you familiar with technology like virtual reality, mixed reality, or augmented reality? [Yes, I've used it; No, I don't know what that is; I've heard of it but am not familiar with it; Other _____]
- Do you think technology like virtual reality, mixed reality, or augmented reality is used in construction? [Yes, used often; Yes, used sometimes; No, not used; Don't know, haven't thought about it; Other _____]

After the pre-workshop survey was completed, the students completed three workshop activities comprising site logistics planning, target value delivery, and a quantification exercise using Meta Quest 2 VR headsets. These topics were chosen to highlight some of the key responsibilities that construction managers have on a day-to-day basis per the literature review and to illustrate that construction is complex, diverse, and requires careful planning and execution. Participants were divided among three stations, with one workshop activity at each station. Each activity was designed to be completed in approximately 15 minutes. After completing the activity, the group at each station would rotate to a new station so all participants had the opportunity to work through all three activities (see Figure 2).

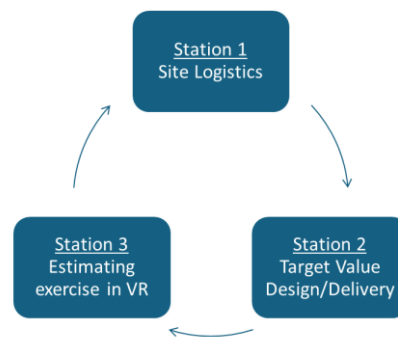


Figure 2. Workshop Activity Stations

For the workshop site logistics activity, students were given two aerial views of their school on paper. On one they were asked to find a truck route to enter, exit, and navigate the site. On the other were asked to place equipment, such as job trailers, dumpsters, and site fences, for the project, mirroring how construction managers optimize limited space on a real job site. The goal was to explore the role of a construction manager in organizing and coordinating essential site logistics to ensure a smooth operation. In the target value delivery activity, students were provided with a variety of LEGO® blocks with an attached price tag and asked to build a structure, such as a small building or bridge. After completing their construction, students were tasked with estimating the total project cost by summing the prices of each LEGO® block they used. The goal was to demonstrate the importance of planning and budgeting in construction, showing how even simple design choices can affect project costs. In the estimating exercise in VR, students explored a pre-developed 3D model of a construction project. The model was developed using Autodesk Revit and exported to SentionVR allowing the

students to view the model in the Meta Quest 2 headsets. Using Sentio's multi-user meetings feature, several students were able to explore the model together. Working in pairs, one student in each pair wore the VR headset to navigate and examine the virtual construction model. The partner without the VR headset used a worksheet listing specific construction elements and asked their partner to locate and measure these items in the virtual model. This activity aimed to experience the immersive environment of a construction site, while practicing key skills in quantity take-offs and communication.

After the workshop activities were completed, the post-workshop survey was distributed. The post-workshop questionnaire included the following questions:

- After this presentation/activity, do you have any interest in becoming a construction manager? [1-100 scale with 0=No, 100=Yes]
- After this presentation/activity, do you have an increased understanding of what a construction manager does? [Yes, I have a good idea of what they do; Maybe, I'm still unsure of some things; No, I don't know what they do; Other _____]
- What about Construction Management sounds appealing to you? [Open-ended question]
- What about Construction Management sounds unappealing to you? [Open-ended question]
- Do you think technology like virtual reality, mixed reality, or augmented reality is used in construction? [Yes, used often; Yes, used sometimes; No, not used; Don't know; Other _____]
- What did you like about this presentation/activity? [Open-ended question]
- How could this presentation/activity be improved? [Open-ended question]

Upon completion, the paper surveys were collected, scanned, and digitalized to facilitate accurate data entry and ensure the integrity of the responses for further analysis. After digitalizing the survey responses, data were prepared for statistical analysis. The primary measure of interest was the change in students' interest levels in CM from pre- to post-workshop, as recorded on the survey. To evaluate the significance of changes in interest levels, pre- and post-tests were administered. The normality of the pre-test and post-test interest scores was assessed using the Shapiro-Wilk test. The results indicated that both pre-test scores ($W=0.903$, $p=0.002$) and post-test scores ($W=0.940$, $p=0.032$) deviated significantly from a normal distribution, as both p-values were below the 0.05 threshold. Due to this lack of normality, the Wilcoxon Signed-Rank test was selected as a non-parametric alternative to the paired t-test to analyze changes in interest scores. The statistical analysis was conducted in Python to perform both the Shapiro-Wilk and Wilcoxon Signed-Rank tests, with a significance level set at 0.05.

Additionally, the study examined whether changes in interest levels varied according to participants' demographic backgrounds. To investigate the potential impact of factors, such as gender, family background in construction, and interest in technology on interest change, non-parametric tests were used due to the data's non-normal distribution and small subgroup sizes. Specifically, the Mann-Whitney U test, a non-parametric test that compares two independent groups, was used to evaluate gender differences in interest change. This test was chosen because gender consisted of two categories (male and female), making it appropriate for pairwise group comparisons. For categorical factors with more than two levels, such as family background ("Yes," "No," or "I'm not sure") and interest in technology ("No, I don't know what that is," "I've heard of it but am not familiar with it," and "Yes, I've used it"), the Kruskal-Wallis test, also known as one-way analysis of variance (ANOVA) on ranks, was applied to compare three or more independent groups to determine if there is a statistically significant difference in interest change across these categories.

Results

To evaluate the impact of the construction workshop activities on middle school students, a series of statistical analyses were conducted to examine changes in their interest in CM as a potential career. The study included a total of 41 participants, which was sufficient for overall analysis. However, breaking the data into smaller groups based on demographic factors such as gender, family background, and technology use resulted in smaller sample sizes within each subgroup. Combined with deviations from normality in the distribution of interest scores, non-parametric statistical tests were chosen as a more appropriate method to analyze the findings and ensure reliable results.

Workshop Effect on Students' Interest in Construction Management

The Wilcoxon Signed-Rank test was conducted to assess whether students' interest in CM increased after participating in a workshop that introduced middle school students to provide with a hands-on understanding of what construction managers do. In order to address the research question "after learning about what they do in a workshop deployed by undergraduate researchers, are students more interested in pursuing construction management as a career?", the test results provided a W-statistic of 0.0 and a p-value of 0.000004, indicating a statistically significant increase in students' interest in CM after the workshop. The W-statistic of 0.0 reflects the consistent direction of change in the data, with all participants reporting an increase in interest following the workshop. The extremely low p-value suggests that this observed increase is highly unlikely to have occurred by chance, underscoring the effectiveness of the workshop in enhancing students' interest in CM. This uniform positive response indicates that the workshop was effective in engaging students across diverse backgrounds, potentially enhancing their perception of CM as an exciting and viable career path.

Demographic Impact on Interest Changes in Construction Management

To address research question (2) how do demographic factors, such as gender, family background in construction, and initial interest in technology, influence changes in students' interest in construction management following the workshop? statistical tests were conducted for each demographic variable to explore potential differences in interest change.

Impact of Gender on Interest Change

To evaluate the influence of gender, a Mann-Whitney U test was performed, comparing changes in interest between male and female participants. The test yielded a U-statistic of 200.0 and a p-value of 0.764, indicating no statistically significant difference in interest change based on gender. The U-statistic represents the relative ranking of the scores between the two groups, and the high p-value suggests that any observed differences are likely due to random variation rather than a systematic effect of gender. This result suggests that the workshop was equally impactful for male and female students, demonstrating its broad effectiveness across genders.

Impact of Family Background on Interest Change

The influence of family background in construction was assessed using a Kruskal-Wallis test, which examined differences in interest change among students with varying family connections to the construction industry. The results showed an H-statistic of 5.795 and a p-value of 0.055, falling slightly above the conventional significance threshold of 0.05. While the result is not statistically significant, it points to a potential trend where students with family ties to the construction industry may experience different levels of interest change compared to those without such ties. This marginal

result warrants further exploration in future studies with a larger sample size to better understand the role of family background.

Impact of Technology Familiarity on Interest Change

Finally, the impact of initial familiarity with technology was analyzed using a Kruskal-Wallis test, comparing interest change among students who reported different levels of familiarity with tools like virtual reality, mixed reality, or augmented reality. The test resulted in an H-statistic of 1.091 and a p-value of 0.580, indicating no statistically significant differences in interest change based on technological familiarity, suggesting that the workshop's effect on students' interest in CM was consistent across participants, regardless of their initial comfort with or exposure to technology.

Open-Ended Questions

In the post-workshop survey, we sought to contextualize the quantitative results by asking participants open-ended questions such as what sounded appealing and unappealing to them about CM. Participants were also asked what they liked about the workshop and what could be improved.

When expressing what sounded appealing about CM, 28 of the 41 respondents (68%) either directly or indirectly referenced the workshop activities, e.g. "Helping with where things go on a job site" (site logistics activity), "Making and building things" (LEGO® activity), and "Technology" (VR quantification activity). 9 responses were more general, e.g. "The finished result of my hard work." These results reflect the importance of carefully curating workshop activities to represent construction management activities as accurately as possible while simultaneously making them engaging for a young audience. When asked what sounded unappealing, 33 out of 41 (80%) had varied responses, with the most common being *hard work* and/or *long hours* (7 out of 41), followed by *math* (6 out of 41) and *injury/health* (4 out of 41), e.g. "risk of stepping on nails or getting hurt" or "working in the heat." Other responses were more general, such as "building" and "a few things." Activities could be added that emphasize the focus of health and safety in construction.

Nearly all participants reported something they liked about the workshop, e.g. "Makes construction look more interesting than I thought it was," "I thought it was really educating and pulls my interest to a construction major," and "It was fun and a good learning experience." These results help support the quantitative results indicating their increased interest in construction management as a career. Of the 41 participants, 16 stated no improvement was needed, while 9 would have liked longer activities (students were allotted 15-minutes at each station), and 5 would have liked more than just three activities. These results will inform planning of future workshops.

Discussion

This study explored two questions: (1) after learning about what CMs do in a workshop deployed by undergraduate researchers, are students more interested in pursuing construction management as a career, and (2) how do demographic factors, such as gender, family background in construction, and initial interest in technology, influence changes in students' interest in construction management following the workshop?

The findings support the conclusion that after learning about the role of construction managers through a structured, interactive workshop, students were indeed more interested in pursuing CM as a career. This outcome underscores the value of experiential learning in early career exploration, especially for professions that may be unfamiliar to younger students, supporting conclusions drawn

from the literature that students may be largely unaware of CM as a potential career path and the need for more outreach. The findings suggest that similar outreach programs could play a valuable role in shaping career interests and addressing workforce needs in the CM field.

Additionally, the findings from this study indicate that demographic factors, such as gender, family background, and technology use, did not significantly impact interest in CM. Coupled with the findings from the pre-and post-analysis, indicating the increasing interest change after the workshop, the findings suggest that regardless of prior exposure to construction-related environments or technological tools, the workshop was effective in engaging students from diverse backgrounds. The findings highlight the potential for early exposure to career-focused workshops to level the playing field, providing all students with an opportunity to explore and consider future career options. Such workshops can be particularly impactful for students who may not otherwise encounter these career options through their family, education, or community networks. The findings suggest that this early exposure has the potential to broaden students' perspectives and inspire them to consider careers they may not have previously envisioned.

While the overall sample size was adequate for the study, breaking the data into smaller subgroups based on demographic factors (e.g., gender, family background, and technology use) led to reduced sample sizes within each category, potentially limiting the generalizability of the findings. Nevertheless, non-parametric tests were selected due to their suitability for small sample sizes and non-normal distributions, making them appropriate for this exploratory analysis. Future research could address these limitations by increasing the sample size to enable more robust subgroup analysis and achieve greater representation across demographic categories.

Additionally, some limitations of this study include the quantity and length of workshop activities. We limited the workshop to a total of three activities that represent what construction managers do. Because the responsibilities of CMs are so varied, more activities could be introduced in future workshops to better represent the field and address concerns expressed by participants, such as health and safety. The intent of the shorter workshop times (15 minutes at each station) was to prevent students from becoming bored, but feedback from the post-workshop survey indicated that students enjoyed the activities and would have liked them to be longer in duration or have additional activities. Additionally, data were collected from one middle school in New England, therefore results wouldn't be generalized to other groups of students.

Conclusion

The study described in this paper shows promising results. By raising the profile of CM at the middle and high school levels, students will be able to make more informed choices about their career path and CM programs may attract interest from students who would not have otherwise considered it. Students who had little knowledge of what a construction manager does prior to this workshop gained a better understanding of the profession. Post-workshop interest in the profession increased significantly. With the literature indicating underrepresented students in CM tend to transfer from other majors rather than choosing CM at the outset, our results indicate that knowledge of CM at an earlier stage may help increase enrollment in CM programs. Increasing enrollment in CM programs will help alleviate current and projected vacancies in the field and can provide fulfilling and high-paying careers for those who choose CM. By "casting a wider net," the goal is that new enrollees in CM programs will have more diverse backgrounds which will increase the skill set of the workforce and introduce new perspectives to the industry.

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