USE OF XR TECHNOLOGIES TO TRIGGER INTEREST IN HIGH SCHOOL STUDENTS IN A CONSTRUCTION MANAGEMENT CAREER

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USE OF XR TECHNOLOGIES TO TRIGGER INTEREST IN HIGH SCHOOL STUDENTS IN A CONSTRUCTION MANAGEMENT CAREER

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This thesis work is dedicated to my boyfriend, Mateus, who has been a constant source of support and encouragement during the challenges of graduate school and life. I am truly thankful for having you in my life. This work is also dedicated to my family, Sandra, Orlan, and Carol, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

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LIST OF SYMBOLS AND ABBREVIATIONS

3D	Three-dimensional
4D	Four-dimensional
ABC	Associated Builders and Contractors
AEC	Architecture, Civil Engineering, and Construction Management
AR	Augmented Reality
BC	Building Construction
BIM	Building Information Modeling
BSBC	Bachelor of Science in Building Construction
CM	Construction Management
CMU	Concrete Masonry Unit
GC	General Contractor
GT	Georgia Tech
HMD	Head-Mounted Display
IVR	Immersive Virtual Reality
LOD	Level of Detail
MR	Mixed Reality
MAG	Masonry Association of Georgia
MDL	Model of Domain Learning
nIVR	Non-Immersive Virtual Reality
OHMD	Optical Head-Mounted Display
QC	Quality Control

SBC	School of Building Construction
SCCT	Social Cognitive Career Theory
SCMA	Southeast Concrete Masonry Association
STEM	Science, Technology, Engineering, and Mathematics
US	United States
VDC	Virtual Design and Construction
VR	Virtual Reality
XR	Extended Reality

SUMMARY

The construction management skilled workforce in the United States is shrinking as a big number of its employees approach retirement and are not being replaced quickly enough by younger generations. According to the literature, pre-college educational programs can help address this issue by attracting a broader and more varied pool of students into Construction Management and related programs. The literature also indicates that the application of Extended Reality (XR) modalities generates student benefits such as increased engagement and self-efficacy that could be derived from bringing these modalities into educational settings. These benefits, in turn, help recruitment efforts for these domains. Georgia Tech's School of Building Construction developed a Building Construction Summer Camp in 2022 using the Model of Domain (MDL) educational framework and its theory on triggering situational interest in students, to recruit students to the Bachelor of Science in Building Construction program. To trigger interest, memorable situational activities must be incorporated. As such, all camp activities were carefully selected to be engaging and memorable and included hands-on activities such as building a masonry wall with professional masons and use of advanced technology, such as Building Information Modeling (BIM) technology such as REVIT and Masonry iQ, infrared cameras, laser scanners, and various XR modalities.

Pre- and post-surveys for the entire summer camp and shorter surveys after three specific activities using XR modalities were conducted to evaluate the effectiveness of the camp in triggering interest in the participants into pursuing a career in construction management. This thesis summarizes the evidence-based research results on the impact of

these specific activities that used XR modalities as well as the overall camp on triggering situational interest in students. The post-camp survey results show a significant increase in the participants' interest in a career in Construction Management after the camp. The findings contribute to the body of knowledge regarding the use of hands-on and XR-technology-based educational activities, specifically in the context of a summer camp for student recruitment purposes. Moreover, the findings provide an empirical foundation for developing a pre-college educational program to intrigue high school students' interests in the construction management domain. Analysis of the results also presents findings and recommendations useful to academia with respect to proper selection of XR modalities when different educational objectives and priorities are considered, such as student comfort. A limitation of the study is the small sample size, but data from future camps will be used to verify these findings.

CHAPTER 1. INTRODUCTION

1.1 Background

One of the biggest challenges that the construction management industry is facing is a shortage of skilled labor. The United States (US) Bureau of Labor Statistics (2022) reported that the projected growth percentage of employment in construction management is 8% from 2021 to 2031. This represents a higher rate than the average for all occupations (5%). This higher progression rate in the construction management field can be attributed to three main factors. First, the expansion of construction activity in general as a consequence of population and business growth. Second, the fact that construction processes are becoming more complex and demand more specialized management personnel. Finally, 9% of workers in construction management are already above the retirement age (65 years old), and 37% are expected to retire in the next 20 years (Bureau of Labor Statistics 2022, Sharma et al. 2022).

Due to this current and projected labor scarcity in the construction management field, graduates from construction-related degree programs are very high in demand. According to Bankrate's 2021 Ranking, Construction is the second most valued college major, trailing only Architectural Engineering. The ranking is based on the unemployment rates and average earnings of American workers based on their college education (Ostrowski 2021). Furthermore, a professional career in construction can be very satisfying and rewarding, financially and personally. It provides the opportunity to make a difference in the lives of thousands by building their homes, schools, hospitals, parks, and many more elements of the built environment. However, high schoolers and early college students

(first and second year) do not always understand the myriad of highly meaningful and lucrative career paths that a degree in construction management can offer (Erdogmus et al. 2021). Additionally, stigmas and realities related to inclusion of gender, race, and ethnicity surround Construction Management professions, making it difficult to recruit a broad set of college-bound youth to this sector (Washington, 2022; Spitzer et al. 2022).

Most people associate the word "construction" with physical labor; however, they do not immediately think of Construction Managers, Superintendents, Virtual Design and Construction (VDC) managers, or other professional/leadership positions that have little-to-no physical work expectations but are professional careers that predominantly require a college degree. This lack of understanding or inaccurate perception makes attracting high school students to Construction Management and related college degrees difficult. Furthermore, early-life self-identities (e.g., I am not strong at math and science; girls or Black and Hispanic people do not advance in Construction Management, etc.) or a lack of examples and role models might restrict consideration of construction-related degrees in college choices (Washington, 2022). Consequently, Construction Management is traditionally a white-male-dominated field (Zippia, 2022).

To address these issues, many higher education institutions implement pre-college outreach programs, such as explorer programs and summer camps, as a recruitment technique. Employing cutting-edge visualization/simulation technology in classrooms has been increasingly common to make construction instruction more interesting and participatory for the younger generations. Several pre-college programs recently started utilizing various XR modalities, which is in alignment with advancements in these technologies and their increasing use in related college curricula as well as in actual

construction projects. Prior research has shown that XR modalities such as virtual reality (VR), augmented reality (AR), and mixed reality (MR) may be effective tools for motivating and engaging construction students (current and prospective) in understanding these fields better and achieving specific learning objectives (Spitzer et al. 2022, Erdogmus et al. 2021, Sepagozar 2020, Patil et al. 2020, Vasilevski and Birt 2020).

The School of Building Construction (SBC) at Georgia Tech (GT) created a two-week-long summer camp for its recently revitalized Bachelor of Science in Building Construction (BSBC) degree program. The camp's educational curriculum was designed using the Model of Domain (MDL) educational framework. This model suggests that memorable and interesting activities presented in an educational context can *trigger situational interest*, which constitutes the first step toward developing deeper individual interest and enhancing learning in a domain. Therefore, the activities for the summer camp were designed with *triggering situational interest* as the main goal. As such, hands-on, interactive, and technology-enhanced activities were prioritized. The attendees were first given theory-based lectures on masonry construction and Building Information Modeling (BIM). BIM technologies such as REVIT and Masonry iQ were then used as a hands-on activity in a computer lab, where they virtually designed the walls, created material take-offs and cost estimates, and simulated the construction process in 4D using Navisworks. Then, they were paired with professional masons from the Southeast Concrete Masonry Association (SCMA) and the Masonry Association of Georgia (MAG) to build their walls. After construction, various technology applications such as AR and Infrared imaging were used as quality control tools to inspect the masonry walls. Other XR-based and traditional activities were also used, such as a unique AR application designed to help students better

understand the components of a double-wythe masonry wall, a fully virtual site visit, two actual site visits, and one construction office visit.

1.2 Research goal, research questions and hypothesis

The **goals** of this thesis are two-fold. First, to contribute to the literature regarding the use of hands-on and XR-technology-based educational activities, specifically in the context of a summer camp for student recruitment purposes. Second, to measure if the activities that implemented XR modalities during the Building Construction Summer Camp at GT can *trigger situational interest* in the participants. To achieve that, the evidence-based research methodology includes pre- and post-camp surveys intended to measure the increase in the level of interest in a construction management career, as well as shorter surveys after specific technology-based interventions to distinguish their particular impact on the generation of situational interest. The surveys were designed to answer four main **research questions**:

1) What is the impact of the summer camp in helping high-school students choose Construction Management as a career path or increase their self-efficacy toward a college major decision (i.e. shift their decision from unsure to sure)?

2) Does the impact of the camp and its activities vary among different demographics?

3) What activities included in the camp are most effective in creating a triggered situational interest toward a career in construction management?

4) How can the camp program be continuously improved for the purposes of recruitment into Construction Management and related degree programs?

Additionally, observations made by the author throughout the summer camp and comments reported in the student reflections were also analyzed. Based on the literature studied, the author **hypothesizes** that the use of XR applications in a summer camp setting can *trigger situational interest* in high school students in pursuing a career in construction management.

1.3 Thesis outline

Chapter One presented the background information regarding the thesis goal, research questions and hypothesis. The subsequent chapters of this thesis are structured as it follows: Chapter Two highlights relevant literature to identify how interest can be triggered, how XR has been used in construction education, and the outcomes of similar summer camps from other universities. Chapter Three presents the research methodology employed to achieve the objective of this thesis. In Chapter Four, the results of the surveys are summarized and discussed, followed by a conclusion in Chapter Five.

CHAPTER 2. LITERATURE REVIEW

In this section, pertinent literature is summarized. First, in section 2.1, Model of Domain Learning (MDL) and Social Cognitive Career Theory (SCCT) are briefly introduced in connection to how interest is generated. Second, in section 2.2, the applications of XR technologies in construction education are summarized. Third, in section 2.3, case studies of similar educational interventions by other institutions are reviewed.

2.1 Interest Development

This study used the MDL framework and the SCCT to explain how interest is generated and how can it be triggered. MDL is a theoretical framework for the study of students' academic development in domains, such as subject areas or fields of study (Kulikowich and Hepfer 2017). The framework is divided into three areas: knowledge, interest, and strategies/strategic processing. Knowledge and strategies are deemed as cognitive factors, whereas interest is defined as a motivational variable.

Interest, as the motivational variable, is discovered to have a major impact on what students will learn (Renninger and Hidi 2016) and can be split into two main types: situational and individual interest. Situational interest refers to the attention that is triggered by a motivating external stimuli and might not persist over time. Individual interest, on the contrary, denotes a person's long-lasting tendency to reengage in a domain over time. The development of interest has been conceived of as occurring in four phases: triggered situational interest, maintained situational interest, emerging individual interest, and well-

developed individual interest. The literature suggests that the situational interest serves as a foundation to the emergence of individual interest (Hidi and Renninger 2006, Fives and Dinsmore 2018).

The first phase of the interest development, which is the *triggered situational interest,* is the phase of interest for this study. The situational interest can be triggered by contextual or text elements such as unexpected information or character identification, and excitement. Situational interest has been observed to be triggered by instructional situations or learning contexts that include group work, puzzles, computers, and so on (Hidi and Renninger 2006).

Many complex factors play into one's individual interest development in a particular domain, as explained in the SCCT, such as predispositions, gender, race/ethnicity, disability/health status, background, learning experiences and expectations from the individual (Lent et al. 2003). SCCT employs self-efficacy beliefs, outcomes expectations and goals as basic building blocks to explain three connected elements of career development: (1) how basic academic and career interests develop, (2) how educational and job choices are determined, and (3) how academic and career success is achieved (Lent et al. 2002).

Self-efficacy denotes an individual's personal beliefs about their ability to execute specific activities or courses of action. SCCT proposes that people are more likely to develop interest in and accomplish superior performance in activities in which they have strong self-efficacy beliefs. Outcome expectations refer to beliefs about the outcomes of performing particular behaviors. For instance, people are more inclined to choose to

participate in an activity if they believe it will generate valuable, positive outcomes results. Based on the SCCT, people's participation in activities are influenced by their self-efficacy beliefs as well as their outcome expectations. Lastly, personal goals are one's aspirations to participate in a certain activity or to achieve a particular performance level. According to SCCT, goals are significantly linked to self-efficacy and outcome expectations because individuals have a tendency to set goals that are congruent with their opinions of their personal capabilities and the outcomes they hope to achieve by taking a certain course of action. In turn, success or failure in achieving personal goals becomes essential knowledge that may be used to change or reinforce self-efficacy beliefs and outcome expectations (Lent et al. 2002).

Moreover, in order for interests to develop in areas where individuals are skilled, their environments must expose them to the sorts of direct, vicarious, and persuasive experiences that can lead to solid efficacy beliefs and positive outcome expectations. SCCT suggests that educational programs that focus on broadening interests and nurturing career ambitions in children and adolescents help them create and achieve career goals (Lent et al. 2002). MDL's phases of interest fit nicely in the larger SCCT context, and it further suggests that via well-designed educational activities, a new interest can be triggered and developed despite a lack of initial and deep-seated interest from one's background. Pre-college programs fit into the first phase of interest in the MDL framework, which is the *triggered situational interest* (Spitzer et al. 2022).

2.2 XR Applications in Construction Education

Use of XR technologies present a way of making education in construction related degrees more engaging and interactive. Use of various XR modalities in classrooms are increasingly being experimented with, and positive outcomes are reported, such as improving student engagement, motivation, and satisfaction, for example (Sepagozar 2020, Alizadehsalehi et al. 2019, Patil et al. 2020, Vasilevski and Birt 2020).

The majority of the course content in postsecondary institution classes, in general, is presented by the educators to the students through lecture-based traditional teaching methods. Stains et al. (2018) performed a massive study that analyzed over 2,000 science, technology, engineering, and mathematics (STEM) classes in 25 institutions across the United States and Canada and reported that 55% of the STEM classes observed consist of a passive group of students being lectured by the instructor at least 80% of the time and 27% of the classes are lecture-based complemented by group activities. More alarmingly, only 18% of the classes are noted to be taught in a student-centered style. Considering that every student acquires knowledge, skills, and abilities in their own unique way, and people are heterogeneous in their instructional needs, the classroom outcomes are positively affected if various educational activities and methods are explored by the educators (Pashler et al. 2008).

The literature suggests that the traditional methods could be positively complemented by the XR modalities because they can help accommodate different learning styles, engage the students, and provide enjoyment (Sepagozar 2020, Alizadehsalehi et al. 2019, Bashabsheh et al. 2019). Students' feedback on various activities that applied XR

modalities reported that the students' engagement and satisfaction increased during the activities and that they not only enjoyed the experiences, but the use of XR acted as a motivator for learning (Sepagozar 2020, Alizadehsalehi et al. 2019, Patil et al. 2020, Vasilevski and Birt 2020).

Kim and Irizarry (2021) performed a study with 254 participants and investigated whether a non-immersive AR tool using iPads would improve construction management students' spatial skills learning. The participants responded to a pre-assessment in a quiz format to measure their current knowledge. Then, they were divided into control and test groups and asked to perform a group lab assignment where they were asked to solve spatial practical problems. The test group had access to an AR software to help them perform the lab assignment, control group did not have access to this three-dimensional (3D) visualization. After the lab-assignment, both groups performed a post-assessment (quiz) to measure their improvements, and also post-surveys to access the perceived effort by the students in performing the assignment and to obtain the students' perceptions regarding their experiences using AR as a learning tool. The mean score in the pre-assessment were 55.5 and 60.5 for the control and test groups, respectively, and 65.9 and 70.8 in the post-assessment, which represents similar improvements in both groups. However, the survey completed by the test group revealed that the students' perceived effort was lower and satisfaction, enjoyment, and confidence in their learning were increased due to using AR, which provided them with a better learning experience even though their assessment scores were similar to the control group.

Lucas and Gajjar (2021) experimented with a non-immersive web-based VR simulation application to test whether this would enhance the students' understanding of

the sequence of wood frame construction. The 77 participants were divided into control group, that learned about wood frame construction through traditional classroom instructions, and test group, that used non-immersive VR (nIVR) simulations along with traditional construction instructions. To measure their understanding of the content, both groups performed the same knowledge assessment with open-ended and true or false questions about the wood frame construction process and its sequencing. The test group responded to a perception survey in addition to the knowledge assessment. The results showed that there was no statistical difference in the overall assessment scores between the control and test groups. Still, the students' survey responses on the use of the nIVR simulation show that they support the use of this type of technology to complement traditional classroom learning and that they believe the application allows for an active and engaging learning environment.

These two studies highlight an important differentiation that must be considered in educational research and the educational applications of XR. While these specific case studies do not necessarily show significant improvements in learning outcomes related to spatial visualization, there seem to be evident gains in enjoyment which can be and should be leveraged for recruitment within the framework of *triggering situational interest* in a particular career.

Further, virtual site visits present another focus that is being considered in construction education as the technologies evolve and allow this type of activity. This is an extremely powerful tool for educators in construction management, given the logistical challenges of arranging an in-person site visit as well as costs and personal safety considerations (Sepagozar 2020, Wen and Gheisari 2020, Kim 2022). It also affords

students with disabilities to participate in a virtual site visit that enables them to have a very similar experience as the in-person site visit.

Behzadan and Kamat (2013) developed an interactive and immersive MR virtual site visit. On a large screen, a real-time video of a construction job site was streamed to the students. Using an AR optical head-mounted display (OHMD) and a connected device that allowed to track finger motion, the students were able to interact with the scene and retrieve information of objects of interest. Moreover, the students were also equipped with an AR book that contained markers that augmented relevant information, such as 2D and 3D models, manufacturer's data, and loading charts, on the OHMD. This prototype developed by the authors allows the students to communicate with each other during the activity to exchange information and learn about the construction site together.

In another study, intending to promote a site experience to the students, Kim (2022) created an immersive VR (IVR) experience to visualize a 360º image of a construction site using HMD and hand controllers. Participants (n=81) were divided into control and test groups to visualize a static 360º image of a music auditorium under construction. The control group had access only to the image. The test group had textual, video, and quiz annotations in addition to the same image. The students had up to ten minutes to freely observe the image and after the viewing time, they completed a post-survey to self-evaluate their understanding of what they observed on nine subscales using a 5-point Likert scale. The student's self-reported scores demonstrated a higher perceived learning performance by the test group students in eight out of nine categories. The annotated 360° photographs provided a better-perceived learning experience for the test group. Still, the data suggest that the non-annotated 360º images used for the control group were also significant as a

learning tool. According to the author, the IVR experience is a significant contributor to the learning experience.

As can be seen, the literature supports the implementation of XR virtual site visits as a potential instructional tool to complement traditional teaching methods and in-person field excursions.

2.3 Summer Camps in Construction Education

A few scholars have conducted studies similar to the one presented in this thesis to assess the efficiency of the implementation of construction management pre-college programs.

Redden and Simons (2018) reported the outcomes of the Auburn University 2017 Building Construction Summer Camp that aimed to educate high school students about the various opportunities in construction management, employ hands-on activities to facilitate the learning of the construction knowledge taught in the camp, and to attract high school students to consider a career in construction management. The one-week long camp was attended by 11 high school students (ten men and one woman) that responded to pre- and post-surveys before and after their participation in the camp. The authors reported that the camp successfully increased students' interest in a career in construction management and favorably influenced their understanding of the construction management industry as a career path.

Yilmaz et al. (2010) described the results of the Texas A&M University-Kingsville 2008 Summer Camp that was attended by 30 students (15 men and 15 women). Surveys,

daily student evaluations and student summaries of the camp learning experience were used to assess the outcomes of the one-week long camp. Based on the three aforementioned tools, the authors concluded that the activities conducted during the camp increased students' satisfaction and interest in engineering disciplines. Student survey responses revealed the program's effectiveness in attracting students to engineering professions.

Similarly, according to Gaedicke et al. (2016), the Construction Management and Engineering Summer Camp conducted by California State University helped 60 students by increasing student understanding of construction as an appealing career option. Their research also found that students are very interested in the use of technology, and they concluded that the application of advanced technologies in construction management related summer camps is one strategy to boost recruitment in this field.

Additionally, similar to GT's approach explained in this thesis, a few other schools are also investigating the applications of XR modalities in construction management pre-college programs, including Colorado State University (CSU), Auburn University, and Florida International University (High School Summer Institute 2022, CADC Communications 2021, Trimble Camp 2022). According to the CSU website, immersive virtual reality (IVR) and MR technologies were used for viewing and inspection of a construction project (Dodge 2019). However, the author could not locate research publications linked to these XR applications and the extent and educational merits of the use of such technologies in relation to their summer camp activity were not disclosed on the websites of the other initiatives.

CHAPTER 3. METHODOLOGY

Pre- and post-survey data were collected before and after the 2022 Building Construction (BC) Summer Camp at Georgia Tech. Specific surveys were also conducted after specific activities that involved XR modalities. Finally, the students' reflections about their camp experiences collected as part of their final presentations were also analyzed. In section 3.1, first the setting and participants in this study are described. In section 3.2, the complete 2-week summer camp curriculum is briefly introduced, followed by more in detail explanation of the activities particularly relevant to this thesis. In section 3.3, the methodology used to develop the surveys is summarized. Lastly, in section 3.4, a description of how the students' reflections were collected is presented.

3.1 Participants

The setting for this thesis study was the Georgia Tech Building Construction Summer camp that took place at Georgia Tech during summer 2022. The first offering of the program had 15 participants, 10 male and five female. Eight participants identified themselves as white/Caucasian, three as Asian, three as Latinx/Hispanic, and one as African American. Regarding the types of high schools that the participants attend, six students reported that they attend *public high schools*, eight students attend *private high schools,* and one male student attends a *specialty school*.

3.2 Description of the Georgia Tech Building Construction Summer Camp

This section describes the GT BC Summer Camp program offered by the School of Building Construction in summer 2022. Table 1 presents all of the activities performed by

the students during the camp. However, due to the scope of this thesis, the rest of the discussion will focus only on the activities marked with an asterisk (*) on their name.

Table 1 – List of Activities at the 2022 GT BC Summer Camp

Activity	Description	Type of Activity
Introduction to Construction	Overview of construction and career paths	Lecture
Masonry 101	Main terminology about masonry walls	Lecture
BIM and Project Delivery Methods	Overview of BIM and project delivery methods	Lecture
4D BIM on Masonry Wall	Creation of High LOD BIM model of a masonry wall followed with scheduling, estimating, and AR QC	Lecture/Hands-on
Meet with Professional Masons	GC- Subcontractor Coordination Experience- Learn the masonry trade-related subcontractor concerns	Hands-on
Masonry Wall Construction	Build the masonry wall with professional masons	Hands-on
*Masonry Wall AR Comparison	Construction QC: compare built versus modeled walls	Hands-on/XR
InfraRed Scan	InfraRed thermographic scan of the built wall	Hands-on
Presentation 1	Presentation of the activities and learnings of the week	Presentation
Site Visit	Visit to two construction sites	Hands-on
*Virtual Site Visit	Visit to another construction site in VR	Hands-on/XR
Visit to a GC Office	Exposure to the construction industry	Visit
Introduction to Drones	Overview of the use of drones in construction	Lecture
Drone Simulator Activity	Drone simulator	Hands-on/XR

Drones Activity	Drone demonstration and fly drones	Hands-on
Laser Scanning 101	Laser scanning overview and training	Lecture
Laser Scan Activity	Use a laser scan to scan Caddell Building	Hands-on
Laser Scanning Digital Prototype	Digital demonstrator to learn laser scanning	Lecture/Hands-on
Introduction to 3D Printing	Overview and introduction to 3D printed buildings	Lecture
Sketchup Activity	Create your 3D printable NASA base on Mars	Hands-on
Maker Space Tour	Visit to view additive manufacturing/3D printing lab	Visit
*Masonry Wall Toggle AR	Toggle on/off the elements of a cavity wall model using AR	Hands-on/XR
Robot	Astro: Construction robot dog demonstration	Hands-on
Final Presentations	Presentation Topic: My experience at the GT BC Camp	Presentation

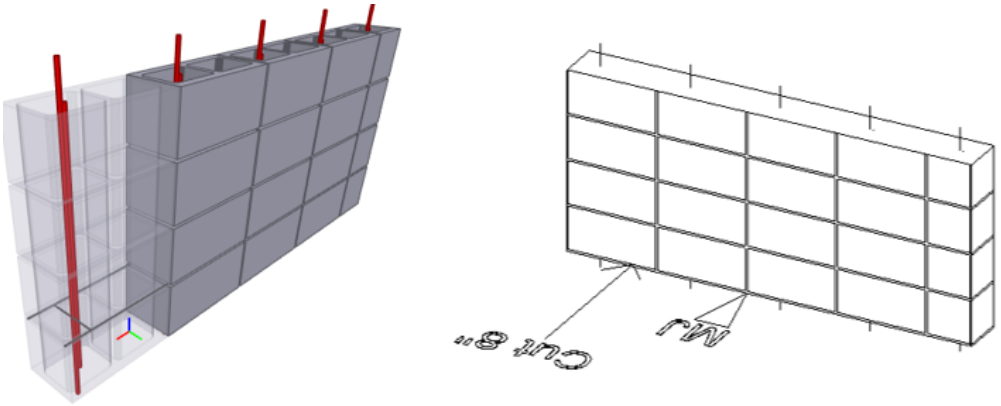
Notes: *The activities marked with an asterisk (*) are the ones that used XR technologies and are the focus of this thesis. Specific activity surveys were implemented after each one of the activities marked with an asterisk.

LOD: Level of detail, BIM: Building Information Modeling, GC: General Contractor, QC: Quality Control, 4D: 4-dimensional.

In the Masonry 101 lecture, students were provided with an overview of masonry-related terminology, a description of each of the components of masonry construction, and an explanation of the wall design-build activity they will carry out. This lecture was provided first so that they are familiar with these concepts for modeling, estimating, scheduling, and subcontractor coordination purposes.

4D BIM activity set comprised of several stages in a computer-lab setting, where the students can all practice software-based activities in real time. First, a low level of detail

(LOD) masonry wall was created in REVIT (Figure 1). Then, the LOD was increased using the proprietary REVIT plugin Masonry iQ (3DiQ, 2022).



Wall Schedule

A	B	C	D	E	F	G	H	I	J
Family and Type	Area	Cost	Total Material Cost	Labor Cost	Total Labor Cost	Total Construction	Volume	1 block volume	Block Count
Basic Wall: Generi	16 SF	2.50	40.00	12.00	192.00	232.00	10.17 CF	0.59	17.231638

Figure 1 – REVIT/Masonry iQ model of the masonry wall designed by the students

To teach the concept of BIM-based cost-estimating, REVIT was used to create material take-offs and cost estimates for the designed masonry walls. The REVIT models were then transferred into Navisworks to simulate the scheduling of the construction of the walls. Finally, the high LOD models were transferred into BIM Vision software.

The following day, students worked in one of three teams to build the masonry wall that they had previously modeled (Figure 2). The construction of the walls was assisted by professional masons provided with the support of SCMA and MAG.

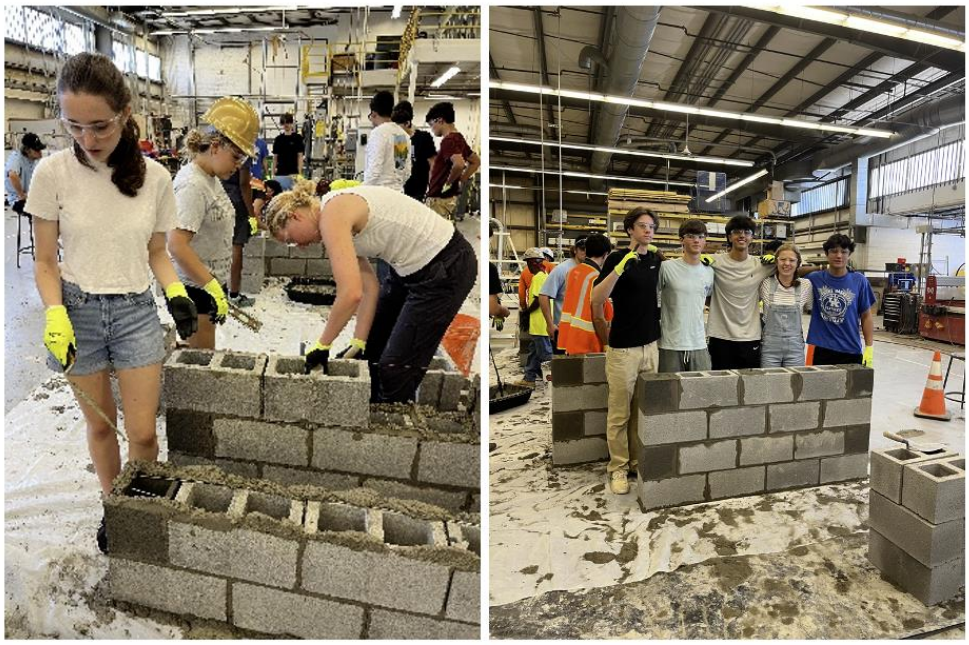


Figure 2 – Wall under construction and finished wall by one team

After the walls were built, the students used the previously prepared REVIT models transferred to optical head-mounted displays (Hololens and Trimble XR10) via BIM vision to compare their designs with the constructed walls (Figure 3). Optical head-mounted display (OHMD) is a type of head-mounted display (HMD) that has a see-through display built-in that allows the user to overlay the virtual element, in this case, the REVIT model of the wall, to what they see in the real environment, the physical wall they built (Spitzer et al. 2022). This was an immersive experience called *Masonry Wall AR Comparison* activity, which was the first activity using XR technology the students experienced during the camp.

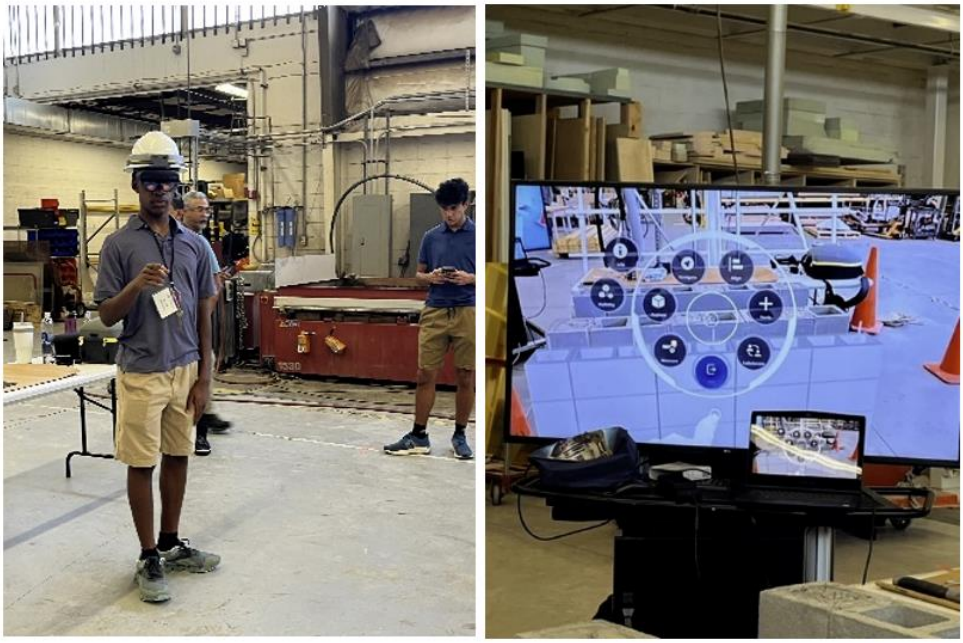


Figure 3 – Student using OHMD to compare as-built wall to REVIT model on the left and view from the OHMD on the right

The second activity that used XR technology during the 2022 GT BC Summer Camp was the *Masonry Wall Toggle AR* activity (Figure 4). In this activity, the students were able to study the components of a concrete masonry unit (CMU) backup- brick veneer masonry cavity wall by turning the components and layers on and off and observing the impact of these components on cost and heat transfer resistance (i.e. R-value). This activity was presented to the students in two different XR modalities: 1) a non-immersive VR (nIVR) modality using a web-based version (WebGL) interface, and 2) a non-immersive AR modality using an iPad (Figure 4).

Figure 4 – Wall toggle activity on AR (iPad) version

The third and last activity that used XR technology was a v*irtual site visit*. This immersive virtual reality (IVR) experience was created by pre-recording 360 videos of a site visit in advance and presenting this site visit to the students using HMD (Oculus Quest 2). HMDs are generally goggles that include a stereoscopic display that encloses the user's vision to enable immersive and realistic experiences and controllers that allow the user to explore a VR environment (Spitzer et al. 2022). In this experience, the students were able to walk through the pre-recorded construction site visit in the form of six visit stops (i.e., six separate videos), where the project manager of a construction project explained different components and processes of the project to the students the entire time, as if they were attending the site visit in-person. The hand-held Oculus Quest devices (controllers) were used to set up the activity and to pass from one video to the next one.

Figure 5 – Students using HMD goggles during the Virtual Site Visit

3.3 Description of the Surveys

The surveys were designed to answer four main research questions:

1) What is the impact of the summer camp in helping high-school students choose Construction Management as a career path or increase their self-efficacy toward a college major decision (i.e. shift their decision from unsure to sure)?

2) Does the impact of the camp and its activities vary among different demographics?

3) What activities included in the camp are most effective in creating a triggered situational interest toward a career in construction management?

4) How can the camp program be continuously improved for the purposes of recruitment into Construction Management and related degree programs?

Based on these research questions, the pre-survey (Appendix A) was organized into three sections based on the SCCT basic building blocks: self-efficacy, outcome expectations and goals. First, the background section asked questions about the factors that influenced their perceptions of construction as an industry or career choice (i.e., family members or friends that work in construction, previous internships experiences, and the type of school they attend) and how much they already knew about the construction management field in general, and how technologies such AR and VR are used in construction, in particular, which are determinant to their opinions on self-efficacy. Second section of the surveys dealt with their educational and career goals and asked the participants about their future plans and interests, such as major and college preferences, and if they considered construction management as a possible career path, in connection to the goals basic building block from SCCT. Third and the last section was a demographic section that asked about the participants gender and ethnicity/race identities which are also major determinants on the individual's perceptions of self-efficacy and expected outcomes given the stigmas in the construction management field. This information was intentionally inquired last, so as not to bias their thoughts about the previous sections being dependent on their identity.

The post-survey (Appendix B) that was answered at the end of the summer camp was also divided into three sections. First, the same educational and career goals section from the pre-survey was repeated to be able to measure change in the responses to these questions. Second, the technology applications section asked how the advanced technologies they explored during the summer camp impacted their knowledge and interest in a career and a degree in construction management. The third section asked how they

believed their participation at the GT BC Summer Camp impacted their future academic life. One difference between the pre- and post-surveys is that after the camp, their *background* now also included the camp experience. Therefore, it is expected to see a major change in knowledge, which consequently affects the perceptions of self-efficacy and outcome expectations, and ideally, also interest. It is possible however that a better comprehension of a career path can also decrease interest and serves as a way to rule-out a major selection, and thus still increases self-efficacy.

The specific activity surveys implemented in the Masonry Wall AR Comparison (Appendix C), Masonry Wall Toggle AR (Appendix D), and Virtual Site Visit (Appendix E) activities that used advanced technology inquired the students about the enjoyment of the activity (i.e., trigger situational interest), if the activity made them more interested in pursuing a career in construction, and their level of comfort with the technologies. The specific activity surveys also implemented the System Usability Scale (SUS). The SUS was utilized to measure the ease that the students perceived in using different systems. The SUS scores are divided into worst imaginable, poor, ok, good, excellent, and best imaginable, as presented in Figure 6 (Smyk 2020).

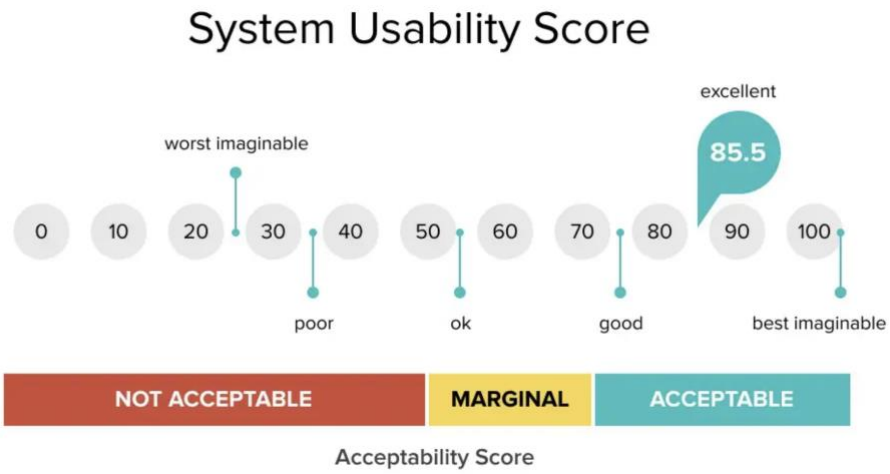


Figure 6 – SUS score guide

In addition to the frameworks used in SCCT and MDL, survey questions were also benchmarked and, at times, inspired by similar previously published, and therefore tested, measures, where possible. Washington (2022) used surveys to identify the perceptions held by middle and high-school-age female students that inspired the background section of the pre-survey and some of the educational and career goals section for both the pre- and post-surveys. Mehany et al. (2019) used pre- and post-survey to evaluate the students' learning experience and the change perception of construction management after a summer camp experience. Therefore, some of the questions in the educational and career goals section about were inspired by their work. Yilmaz et al. (2010) used pre- and post-surveys to assess the impact of an engineering summer camp on high school students. Some of their questions were also utilized for the academic impact section of the post-survey. Finally, Lucas (2018) used surveys to evaluate the students' understanding and enjoyment after an immersive VR experience (IVR). The questions related to the level of comfort and usability in the Masonry Wall AR Comparison were based on the surveys created by Lucas (2018).

3.4 Student Reflections

During the two-week camp, the students were asked to prepare two presentations, one at the end of the first week and one on the last day of camp. Even though students presented in teams in general, for both presentations, the students were asked to present individual reflections at the end with one slide per team-mate, which helped interpret some of the survey results with these qualitative student reflections as well as get some insight that was not directly questioned via surveys.

CHAPTER 4. RESULTS

The results from the pre- and post-camp surveys completed by the camp participants are summarized in Section 4.1, specific survey results for the XR activities are provided in Section 4.2, and the student reflections are discussed in section 4.3.

4.1 Pre- and Post-Surveys Results

To facilitate the understanding of the results of the pre- and post-surveys, this section is divided into four subsections. Subsection 4.1.1 presents the results of the demographics section of the pre-survey. Subsection 4.1.2 summarizes the results of the background section of the pre-survey. Subsection 4.1.3 presents the comparison of the results between the pre-and post-surveys. Finally, subsection 4.1.4 summarizes the results of the technologies application section of the post-survey.

4.1.1 Demographics Section of Pre-Survey

The demographics of the participants in the GT BC Summer Camp show that the participants were more diverse in both gender and race/ethnicity compared to the construction management industry. Construction management is a predominantly white-male-dominated industry. Zippia (2022) estimated the demographics of construction management workers in the United States using a database of 30 million profiles. According to their estimates, the construction industry is composed of 92 % men and 8% women in gender. As for the camp participants, out of 15 participants, five (33.3%) identified as women and ten (66.7%) as men. Figure 7 presents the comparison between the industry and the camp demographics regarding gender.

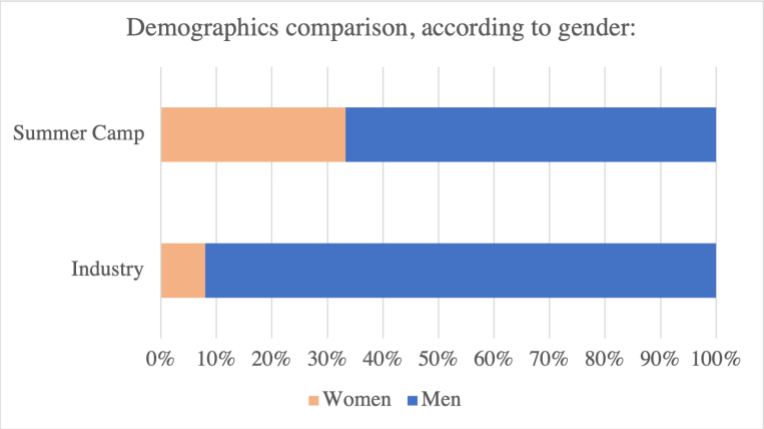


Figure 7 – Gender comparison between camp participants and industry

Regarding race/ethnicity, the construction industry is estimated to be comprised of 78% white, 13.9% Hispanic/Latinx, 3.4% African American/Black, 2.7% Asian, and 2% other in race/ethnicity (Zippia, 2022). In the 2022 GT BC Summer Camp, eight participants (53.3%) identified themselves as white/Caucasian, three (20%) as Asian, three (20%) as Latinx, and one (6.7%) as African American. The comparison for race/ethnicity between the industry and the camp are presented below (Figure 8).

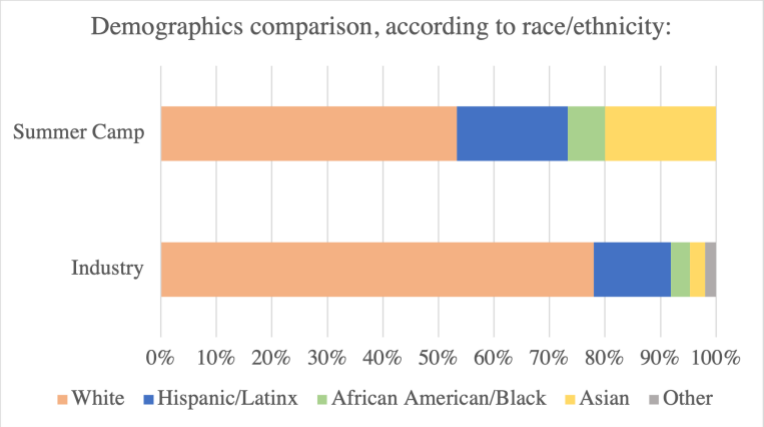


Figure 8 – Race/ethnicity comparison between camp participants and industry

One student, a woman, did not complete the camp for personal reasons; thus, the post-survey had 14 responses instead of 15. Further, one student had health issues and was not able to complete the Masonry Wall AR Comparison and the Masonry Wall Toggle AR activities, and the specific activity surveys that followed them. These issues are reflected in the reported number of responses in the results.

4.1.2 Background of Participants

In the background section of the pre-survey, the students were asked if they knew someone in construction management. Four students (26.7%) responded *yes*, and 11 students (73.3%) responded *no*. Of the four students that said *yes*, three described the acquaintance as family/friend and one as other. To the question 'Have you done any internships related to construction management?', 12 students (80%) answered *no*, and three students (20%) answered *no, but I have been invited*. Two out of the three that reported they were invited to an internship related to construction management did not know anyone in the field, and all three were men.

To the question ‘How much have social media influenced your perceptions of work in the construction management industry?’, three students (20%) said *very much*, 10 students (66.7%) said *somewhat*, and two students (13.3%) said *not at all*. No students answered *not sure*. It is clear that the majority of the students (86.7%) had some level of influence from social media about the construction management industry.

When asked ‘How much have Media or TV news influenced your perceptions of work in the construction management industry?’, four students (26.7%) answered *very much*, eight students (53.3%) said *somewhat*, one student (6.7%) answered *not sure*, and two students (13.4%) said *not at all.* Again, it appears Media and TV has influenced 80% of the participants to some degree about construction management industry. The comparison of the responses about the influence of social media and media or TV news is presented in Figure 9.

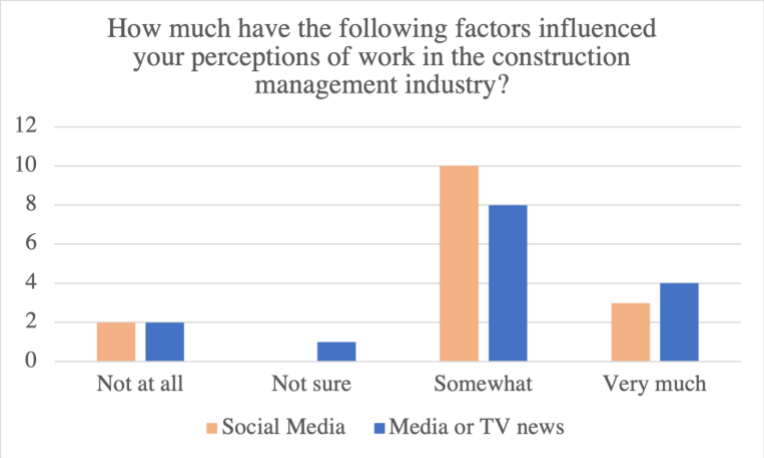


Figure 9 – Influence of social media and media or TV news

To measure the familiarity of the students with using XR technologies, the students were asked if they had previous experiences with AR/VR (Figure 10). Only one student (6.7%), which was a man, answered *no*.

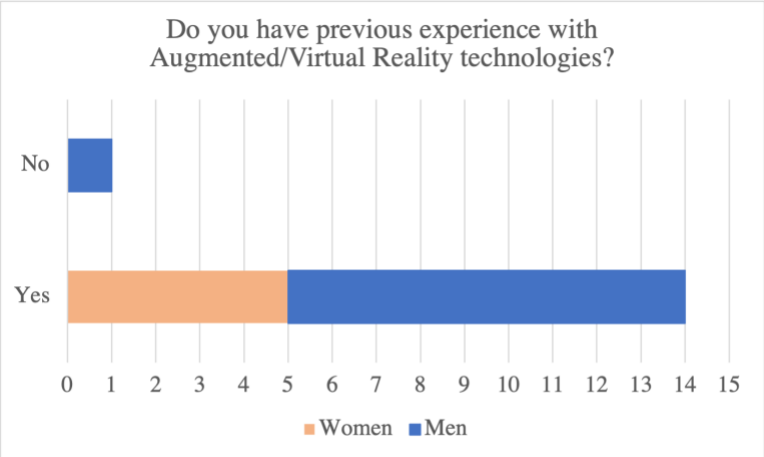


Figure 10 – Previous experience with AR/VR technologies by gender

Of the 14 students (93.3%) that said *yes*, seven students reported they had previous experience with AR/VR technologies through videogames (all seven are men), six reported

that they used AR/VR in a school activity (three from private high schools and three from public high schools), and four reported they used AR/VR in theme parks, arcades and/or museums (two males and two females). Zero participants reported previous experiences with AR/VR related to construction. Figure 11 presents the types of previous experiences with AR and VR by gender.

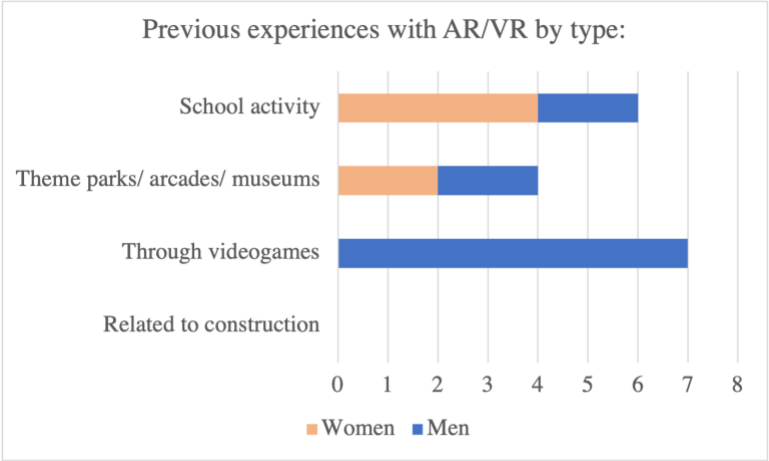


Figure 11 – Types of previous experiences with AR/VR by gender

4.1.3 Comparison of Pre- and Post-Surveys Results

In this subsection, the pre- and post-surveys are compared to identify changes in students' interest, knowledge, and self-efficacy. The pre-survey results will be consistently represented by the color orange in the charts, and the post-survey results will be represented by the color green.

To measure the perceived knowledge of the students about construction management as a career path, the students were asked to answer the following questions: 'I know a great deal of what construction managers do:' and 'I know a great deal about

various career opportunities in construction management:'. The results for these questions are presented in Figure 12.

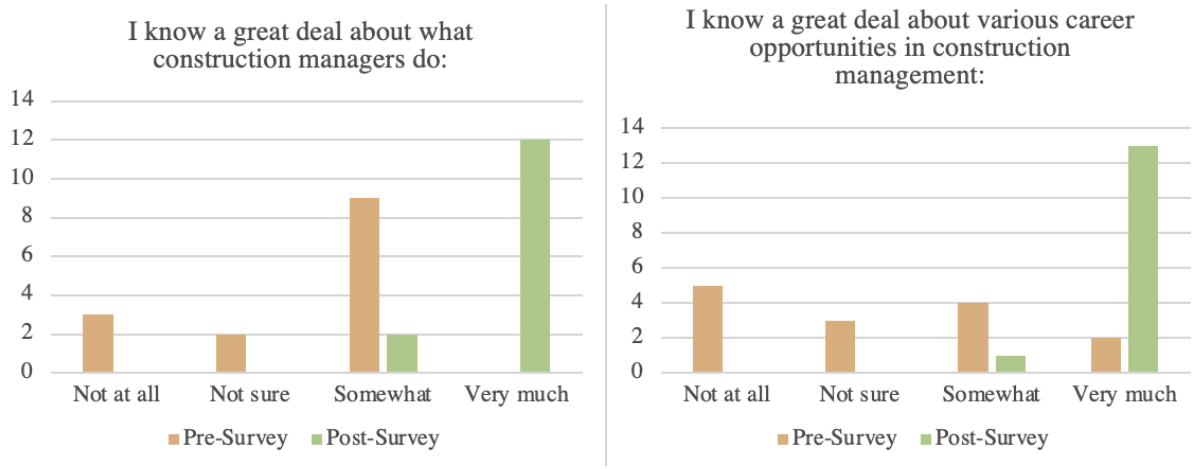


Figure 12 – Perceived knowledge about construction management

For the former question (Figure 12, left), the average response was 2.43 in the pre-survey and 3.86 in the post-survey. More importantly, while none of the students claimed to know a great deal about this career path before the camp, an impressive 85.7% (12 out of 14 students) reported that they now know *very much* about what construction managers do.

In the follow up question (Figure 12, right), the comparison between pre- and post-survey responses also demonstrated a significant increase (77.8%) from an average response of 2.21 in the pre-survey to 3.93 in the post-survey, where 13 students (92.9%) reported that they now know *very much* about various career opportunities in construction management. Based on these findings, it appears that the summer camp was very effective in explaining the career path and opportunities in construction management.

In terms of advancing their knowledge about this career path, the surveys asked the students to rate their current level of knowledge about construction management on a Likert scale of 10. A score of zero represented *no knowledg*e and ten denoted *I know a lot about construction*, both before and after the camp. The mean score for the pre-survey was 4.07, while for the post-survey it was 8.21. As this represents an increase of 102% in the average response to this question, the camp is also deemed successful in helping them understand and visualize a career in Construction Management.

Figure 13 presents the answers to the following questions from the educational and career goals section of the pre- and post-surveys 'I know a great deal about how additional education can help me achieve my career goals:' and 'I know a great deal about my educational opportunities after high school:'.

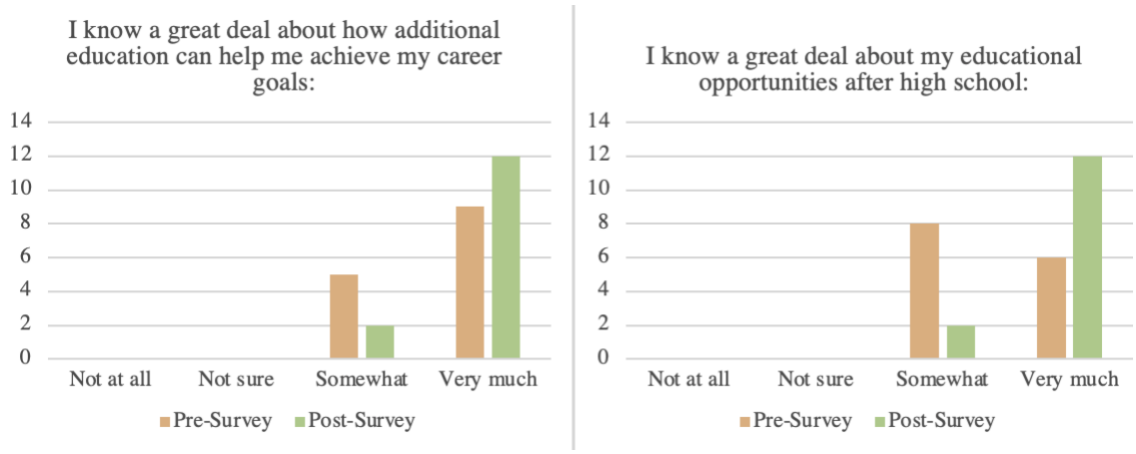


Figure 13 – Comparison of perceived knowledge about educational opportunities in the pre- and post-surveys

The responses to both questions show that all of the students were at least somewhat confident about their knowledge of how additional education can help them to achieve their

career goals and about their educational opportunities after high school. However, there is still an increase of 100% in the number of students that changed from *somewhat* to *very much* confident about their 'knowledge on educational opportunities after high school'; and a 33.3% increase in the number of students that changed from *somewhat* to *very much* confident about their knowledge on 'how additional education can help them achieve their career goals'. These increases are aligned with the goals of this study and indicate that the summer camp was also successful in presenting to the students the educational opportunities available, such as the recently renovated BC undergraduate degree at GT, and how they can assist them in achieving their career goals.

The students were also asked about their educational plans after high school and their college preferences. Figure 14 presents the pre- and post-survey results for the question 'Which statements best describe your educational plans?' which asked the students about their college preferences for after high school and their. In the pre-survey, six students (five men and one woman) reported that they had plans to go to Georgia Tech, and after the program, this number rose to nine (seven men and two women). The results indicate that the camp was effective particularly in moving two students from unsure to making a decision, and completely changed the mind of one female student that was sure that she wanted to go to another university and now is sure that wants to go to Georgia Tech.

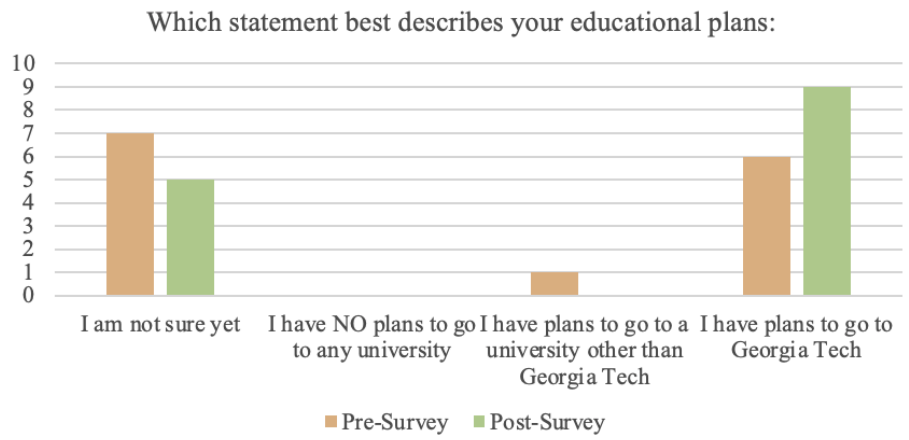


Figure 14 – Comparison of educational plans in the pre- and post-surveys

The students were also asked about their preferences of major by providing the choices of Architectural Engineering, Architecture, Civil Engineering, Construction Management, undecided, and other. The results are presented in Figure 15.

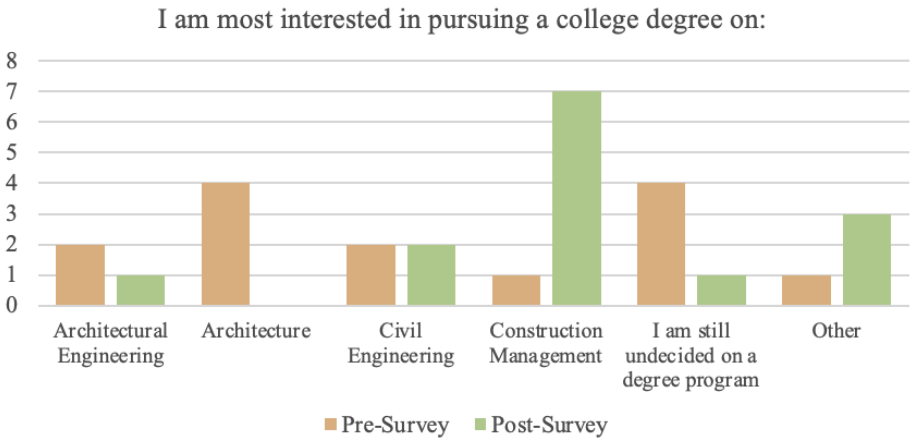


Figure 15 – Comparison of choice of major in the pre- and post-surveys

The results of this question really quantify the impact of this summer camp. Before the program, only one student responded that construction management was their primary

choice of major. In the post-survey, on the other hand, seven students (one woman and six men) stated that they were most interested in pursuing a college degree in construction management, which represents a significant increase (600%). The camp was also successful in reducing indecision (*i.e.,* improving self-efficacy) among students. Some students identified that they really are *not* interested in a career path in the AEC industry (Architecture, Civil Engineering, and Construction Management), as the selected choice of *other career* has increased from one student to three. Most notably, all students considering architecture before the program seem to have decided that this career path is not for them, and for most of these students, construction management is their new choice of career. The author rationally assumes this result is impacted by the fact that the School of Architecture camp took place simultaneously, and all of the students stayed in the same dorms and performed the same extracurricular activities. During the camp, the students informed the author and other camp instructors that they found Construction Management camp activities much more interesting in comparison to what they heard from the Architecture camp participants. This anecdotal observation is aligned with the theory of stages of interest in MDL in that the situational interest triggered through a variety of exciting activities embedded in an educational setting can transform into deeper levels of interest.

Similarly, the results for the question 'Which statement best describes your career goals:' aims to measure the level of interest in pursuing a career in construction management. Results presented in Figure 16 demonstrate a significant increase (200%) in the number of students that are *excited to pursue a career in construction*. During the pre-survey only one student (7.1%) showed this level of excitement/interest, while after, three students (21.4%) were very interested/excited. Seven students (50%) in both the pre- and

post-surveys are *considering a career in construction*. The number of students that were *undecided about a career in construction* decreased from six students (42.9%) in the pre-survey to four students (28.6%) in the post-survey. Moreover, zero students picked the option *I have NO plans to pursue a career in construction management*. The fact that the results for this question show a smaller impact from the camp when comparing to the results to the question about their primary choice of major be due to the young age of the students. Since they are still juniors and seniors in high school, they might find it difficult to have set plans for their careers. Analyzing the answers to this question, one can assume that the camp helped the students to move from undecided to considering/excitrd to pursue a career in construction management. Moreover, considering that zero students rejected a career in construction management, there is a chance that all participants might consider pursuing a career in construction management in the future.

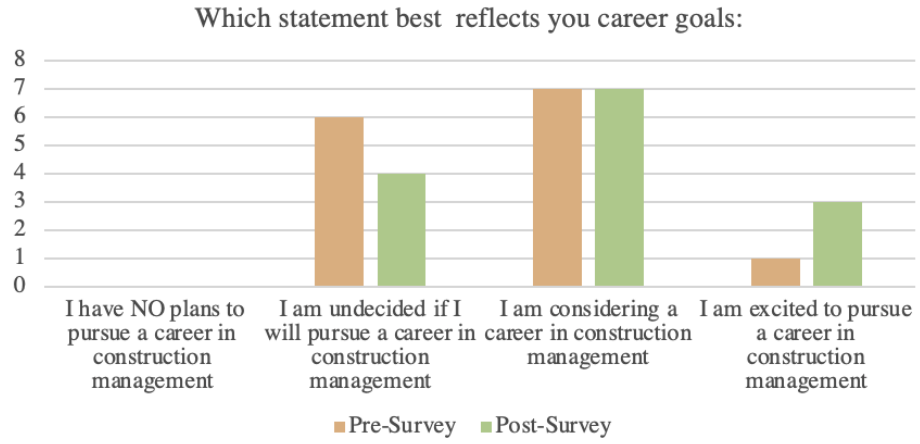


Figure 16 – Comparison of career goals in the pre- and post-surveys

One of the students (male) that was *undecided* about a career in construction in the pre-survey and changed to *I am excited to pursue a career in construction management*,

shared in the pre-survey that his first choice of major was architecture, and now he is sure that he will pursue a degree in construction management at Georgia Tech. Another student (male) that was *considering a career in construction management* before the camp, and changed to *I am excited to pursue a career in construction management*. Further, the same student responded to the open-ended question 'What are your perceptions of the construction management industry as a career choice?' as follows: "*It's growing at an extremely fast rate, and there are lots of new innovations and job opportunities. I would really like to be part of the industry".* This student was undecided on a major before the camp, and in the post-survey, he stated that he will pursue a degree in construction management at GT.

The following two questions were asked in both pre- and post-surveys to measure the perceived knowledge about the applications of technologies in construction management: 'I know a great deal about the importance of technology in construction management:' and 'I know a great deal about how AR and VR applications can improve construction management:'. The responses to these questions are presented in Figure 17 below.

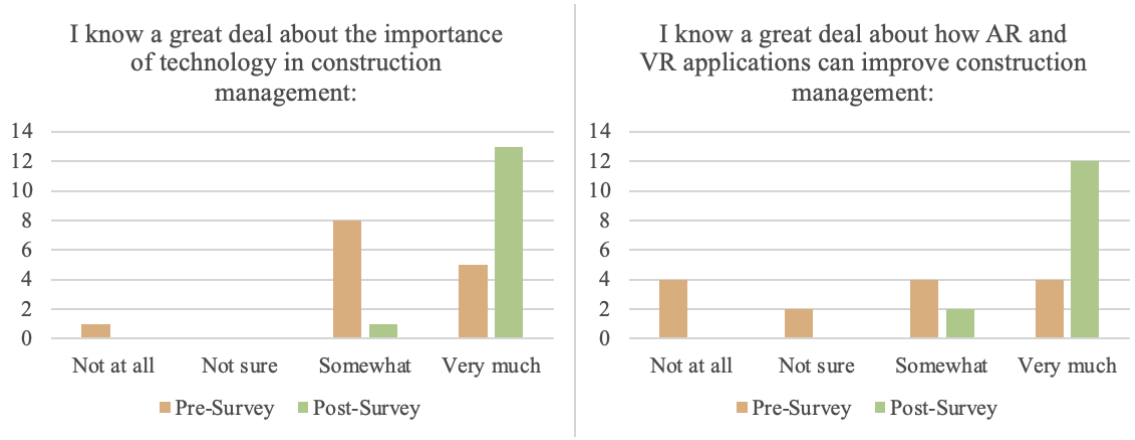


Figure 17 – Comparison of perceived knowledge about technology applications in construction management between pre- and post-surveys

The average score for the former question was 3.21 before the program and 3.93 after the program, showing an increase in awareness of the importance of technology in this career path. The average result for the latter question was 2.57, while the average score in response to the same question in the post-survey was 3.86, which also demonstrates a significant increase in the students' awareness regarding the use of technology in today's construction industry. Significantly, six out of the 14 students responded that they knew *nothing at all* or were *not sure* of how AR and VR could improve the construction management industry before they participated in the summer camp. In contrast, all students were *somewhat* or *very much* confident in their knowledge after the camp. In fact, 12 students out of the 14 (86%) reported that they knew *very much* about how AR and VR can improve the field of construction management after the camp.

Similarly, when asked, 'Do you know how Augmented Reality and Virtual Reality are being used in construction?', only five students (35.7%) responded *yes*, and nine students (64.3%) said *no* in the pre-survey. After their participation in the summer camp,

all (100%) students reported that they *know* how AR and VR are being used in construction. This represents a great effect of the camp in helping the students understand how these technologies are used in the construction management field, especially given the fact that any of the students had previous experience with AR/VR related to construction before their participation in the camp.

4.1.4 Technology Application Section of Post-Survey

In the post-survey, one question inquired how each of the technology applications they experienced affected their level of interest in pursuing a career in construction management (Figure 18). The technology application that most increased their level of interest was drones, with 100% of the participants reporting that this technology made them more interested in construction management as a career choice, followed by robots and laser-scanning. XR applications were also impactful in terms of their decision to pursue a career in construction management, with nine participants (64.3%) stating that these applications increased their interest, and three participants (21.4%) said that it did not affect their interest. Interestingly, two participants (14.3%), both women, reported that AR and VR applications *decreased* their interest in construction management as a career choice. The author interprets these results as being related to two issues: 1) there were technical issues faced during the AR/VR activities that caused the students to wait around for periods of time, and 2) some students experienced physical discomfort when using HMD, such as nausea and dizziness. The activity-specific surveys, which are reported in further detail in the next section, correlate with these interpretations as one of the same participants reported that they felt nausea, eye strain, and vertigo during both the activity on AR OHMD and the

virtual site visit on VR HMD. The other participant was comfortable with AR OHMD but reported nausea when using VR HMD.

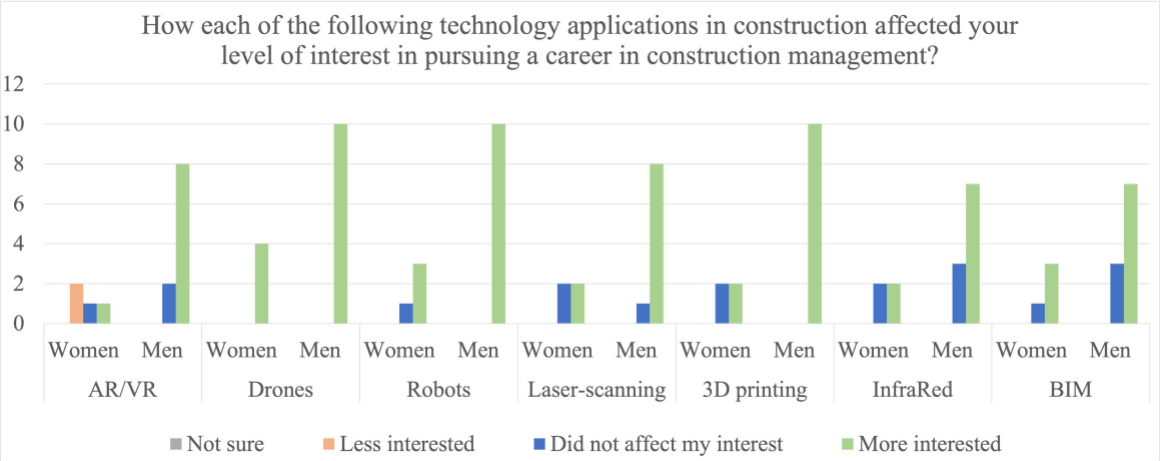


Figure 18 – Comparison of the impact on interest of various technology applications

Nonetheless, it is notorious that all technology applications implemented during the camp increased the interest of most of the students, being InfraRed and AR/VR applications the least two with nine (64%) of 14 participants reporting they made them *more interested* in pursuing a career in construction management.

The author suggests making improvements upon these activities for future camps by providing options for other activities as goggles are reset and by offering a choice of use of HMD versus browser-based extended reality experiences for students who experience physical discomfort. It is common for VR users to be most physically uncomfortable, as this is the modality where the user's real-life view is completely obstructed. Another idea is to introduce VR in 1-minute installments instead of a longer experience until the user gets used to the activity.

4.2 Results from Activity-Specific Surveys

The activity-specific surveys were conducted after three activities that used an XR modality: Masonry Wall AR Comparison, Masonry Wall Toggle AR, and Virtual Site Visit activities. As stated earlier, one student did not complete the Masonry Wall AR Comparison activity nor the Masonry Wall Toggle AR activity. The number of responses in the surveys reflect this with 13 responses for these two activities and 14 for the Virtual Site Visit activity. The results about the enjoyment of the activity (i.e., trigger situational interest) and if that activity changed their level of interest in pursuing a career in construction are described in subsection 4.2.1. Subsection 4.2.2 presents the results for discomfort perceived during the immersive activities. Lastly, subsection 4.2.3 summarizes the SUS scores for each activity.

4.2.1 Perceived Enjoyment and Change on Interest Level

When answering the question 'How did you like this activity?', the results were similar for all three activities (Figure 19). For the Masonry Wall AR Comparison activity, eight students (61.5%) reported they liked it *very much*, and five students (38.5%) stated they *somewhat liked it*. No students reported that they *did not like it* or were *not sure*. For the Masonry Wall Toggle AR activity using an iPad, seven students (53.8%) reported they liked it *very much*, and six participants (46.2%) informed that they *somewhat liked it*. Zero participants picked the options *not sure,* or *I did not like it*. For the Virtual Site Visit, seven students (50%) reported they liked it *very much*, and six participants (42.9%) informed that they *somewhat liked it,* and one student (7.1%) answered *did not like it*. Zero participants picked the option *not sure.*

The results presented in Figure 19 show that the almost all students at least somewhat liked the activities that used XR modalities – 100% for the Masonry Wall AR Comparison and Masonry Wall Toggle AR, and 92.9% for the Virtual Site Visit.

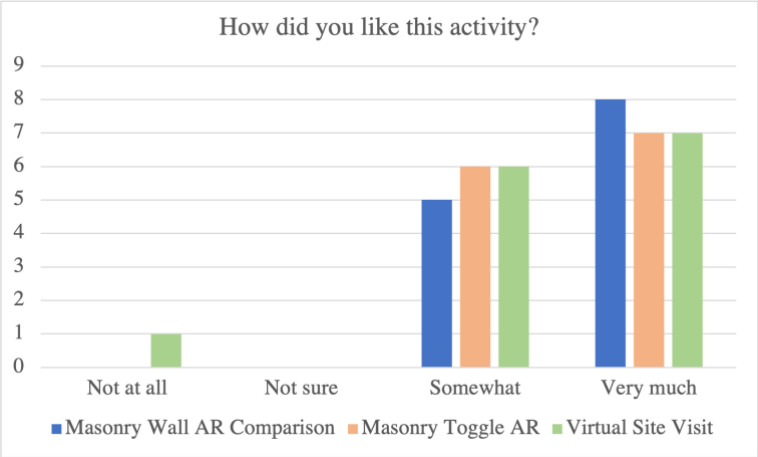


Figure 19 – Comparison to the results regarding enjoyment

When answering the question, 'Did this activity make you more interested in pursuing a career in construction management?'(Figure 20), for the Masonry Wall AR Comparison activity, four students (30.8%) reported the activity made them *more interested* in pursuing a career in construction management, eight students (61.5%) stated it *did not affect their interest*, and one student (7.7%) was *not sure*. No students reported that it made them *less interested*. For the Masonry Wall Toggle AR activity using an iPad, three students (23.1%) reported it made them *more interested*, nine participants (69.2%) informed that it *did not affect their interest*, and one student (7.7%) reported it made them *less interested*. Zero participants picked the option *not sure*. For the Virtual Site Visit, six students (42.9%) reported the activity made them *more interested* in pursuing a career in construction management, and six participants (42.9%) informed that it *did not affect their*

interest. One student (7.1%) was *not sure*, and one student (7.1%) stated this activity made them *less interested*.

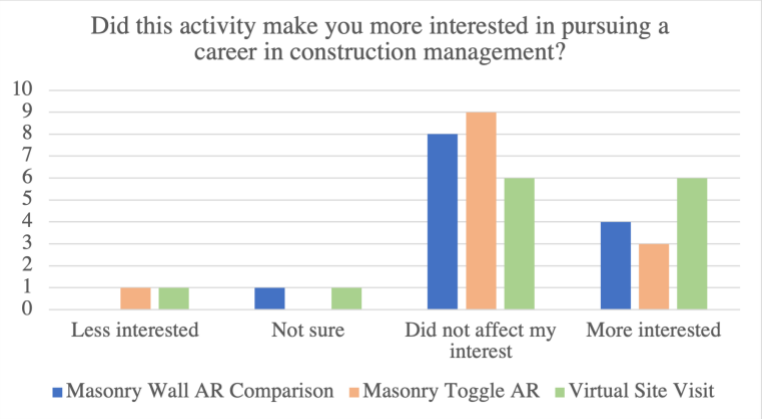


Figure 20 – Comparison of the results about the impact on interest

The survey responses presented on Figure 20 indicate that the enjoyment perceived by the majority of students during the activities reported on Figure 19 did not necessarily represented a perceived change in interest about a career in construction management, given that many students reported the activities did not affect their interest. However, it is important to consider that 64.3% of the students stated that the activities using AR/VR modalities increased their interest in construction management as career (Figure 18).

Moreover, for both the Masonry Wall Toggle AR and the Virtual Site Visit activities, the same student, which is a female, reported that the activities made her less interested in pursuing a career in construction management. This one student also reported that the application of AR/VR during the summer camp, made her less interested in pursuing a career in construction management, as presented in Figure 18. This student did

not complete the Virtual Site Visit activity as it caused her to feel nauseous and vertigo. The results regarding discomfort are presented in the following subsection.

4.2.2 Perceived Discomfort

The activity-specific surveys for the Masonry Wall AR Comparison and the Virtual Site Visit activities, that were both immersive, asked the camp participants questions about the discomfort perceived during the activities.

Figure 21 presents the answers for 'Did you feel nausea or queasiness during the activity?' for both activities. For the Masonry Wall AR Comparison, eight participants (66.7%) stated *not at* all, two participants (16.7%) reported *minimal discomfort,* and two participants (16.7%) were *somewhat uncomfortable.* One student left this question blank for the Masonry Wall AR Comparison Activity, which is reflected in the number of responses. For the Virtual Site Visit, eight participants (57.1%) stated *not at* all, three participants (21.4%) reported *minimal discomfort*, two participants (14.3%) were *somewhat uncomfortable,* and one participant (7.14%) was *very much uncomfortable, enough to stop the activity.*

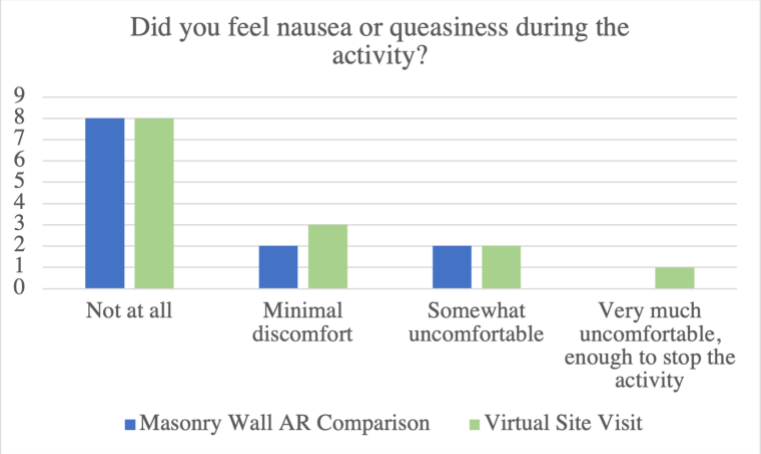


Figure 21 – Discomfort perceived regarding nausea/queasiness

For the perceived discomfort regarding eye strain (Figure 22), the results were slightly better than the previous question. For the Masonry Wall AR Comparison, eight participants (61.5%) stated *not at* all, four participants (30.8%) reported *minimal discomfort,* and one participant (7.7%) were *somewhat uncomfortable.* For the Virtual Site Visit, eight participants (57.1%) stated *not at* all, three participants (21.4%) reported *minimal discomfort,* and three participants (21.4%) were *somewhat uncomfortable.* Zero participants reported they were *very much uncomfortable, enough to stop the activity,* for any of the two activities.

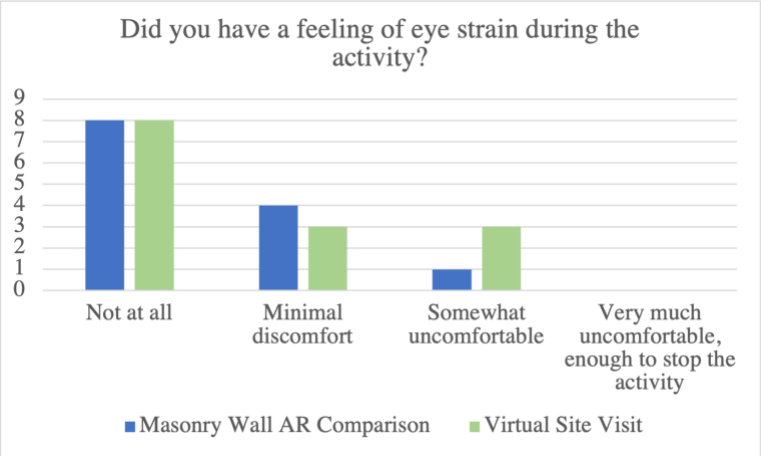


Figure 22 – Discomfort perceived regarding eye strain

Finally, the results for the question 'Did you feel vertigo or difficulty maintaining balance during the activity' show that these symptoms were the noticed to the lowest degree by the students (Figure 23). For the Masonry Wall AR Comparison, 11 participants (84.6%) stated *not at* all, one participant (7.7%) reported *minimal discomfort,* and one participant (7.7%) were *somewhat uncomfortable.* For the Virtual Site Visit, 11 participants (78.6%) stated *not at* all, two participants (14.3%) reported *minimal discomfort,* and one participant (7.14%) was *very much uncomfortable, enough to stop the activity.* Zero participants picked the option *somewhat uncomfortable* for the Virtual Site Visit activity.

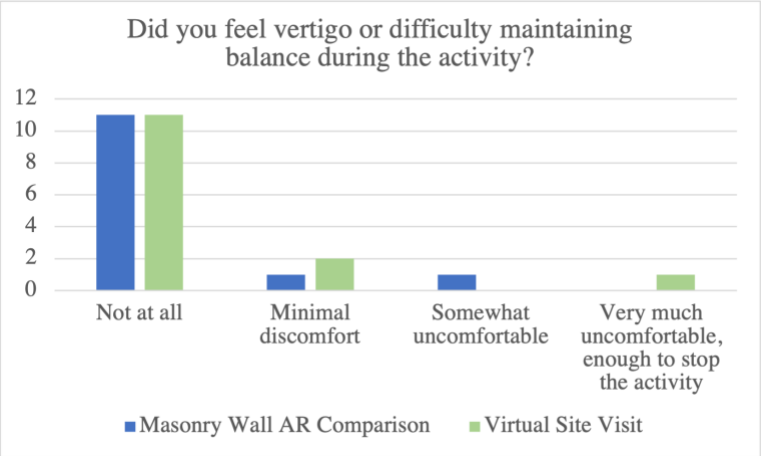


Figure 23 – Discomfort perceived regarding vertigo/difficulty maintaining balance

Although the results show that the majority of the students did not feel any discomfort during the immersive activities, some students reported some level of discomfort regarding nausea, queasiness, eye strain, vertigo, and difficulty to maintain balance in both activities, with a higher number in the Virtual Site Visit activity. Moreover, one female student reported that she felt very much uncomfortable during the Virtual Site Visit, to the point she could not complete the activity, and possibly made her less interested in a career in construction management. A possible cause for this is the fact that the HMD used during the Virtual Site Visit, a VR experience, occludes completely the user's vision, that cannot see the real environment with the HMD on. On the contrary, the OHMD used in the Masonry Wall AR activity, an AR experience, allowed the user to overlay the virtual object to the real environment.

To avoid the negative impact on the students' interest due to the perceived discomfort during immersive activities, the author suggests that these activities could be

offered in non-immersive versions for the students that prefer so or make the activity non-mandatory.

4.2.3 System Usability Scale Scores

The SUS score results were very different for each activity. For the Masonry Wall AR Comparison activity, where the students used AR goggles to compare their wall REVIT model to the as-built masonry wall, the SUS score was 61.73, which according to the SUS score guide (Figure 6) is considered 'ok'. The SUS score for the Masonry Wall Toggle AR activity using an iPad was 86.73, which is 'excellent', according to the score scale. For the Virtual Site Visit activity, the SUS score was 76.61, which is considered 'good' per the score guide. The lower SUS scores for the Masonry Wall AR Comparison and Virtual Site Visit activities can be explained by the fact that these two activities incorporated more complex equipment compared to a computer browser or an iPad. Further there were technical difficulties in both HMD and OHMD- based activities with connecting to the Wi-Fi and streaming the planned activities. The students had to be patiently waiting while the issues were being resolved.

The higher results for the Masonry Wall Toggle AR can also be attributed to the fact that this activity was non-immersive and was presented in an interface more familiar to the students (iPad and computer, versus HMD or OHMD), which does not present any physical discomfort to the users as immersive modalities can cause in certain people. In this activity, all participants said that the AR version was more fun/enjoyable than the WebGL version. Eight students (61.5%) considered that the AR version was more

informative, and five (38.5%) considered the WebGL version more informative than the AR version.

4.3 Student Reflections

Finally, the first-week and final presentations included individual student reflections that were very informative. After the first week, all students commented that their favorite activity was building a masonry wall. This activity, which only took about 3 hours of the entire 2-week-camp, is identified as an important one that *triggered situational interest* and one that simulates the pride many in the construction field experience over contributing to the built environment.

Although the final presentations were in groups, the students were asked to provide their individual opinions about the summer camp when presenting. The individual students' reflections on what were their favorite parts of the summer camp were extracted from their presentations and analyzed by the author. The analysis was made by separating the most cited topics and counting the number of appearances of each topic in each one of the responses from the 14 participants. The most cited topics were Advanced Technologies, XR, Hands-on, Self-efficacy (i.e., "I can see myself in this field"), Knowledge (i.e., "I learned"), Interest (i.e., "I found interesting", "it made me interested"), and Enjoyment (i.e., "fun", "loved it", "enjoyed"). A summary of the responses can be found in Figure 24.

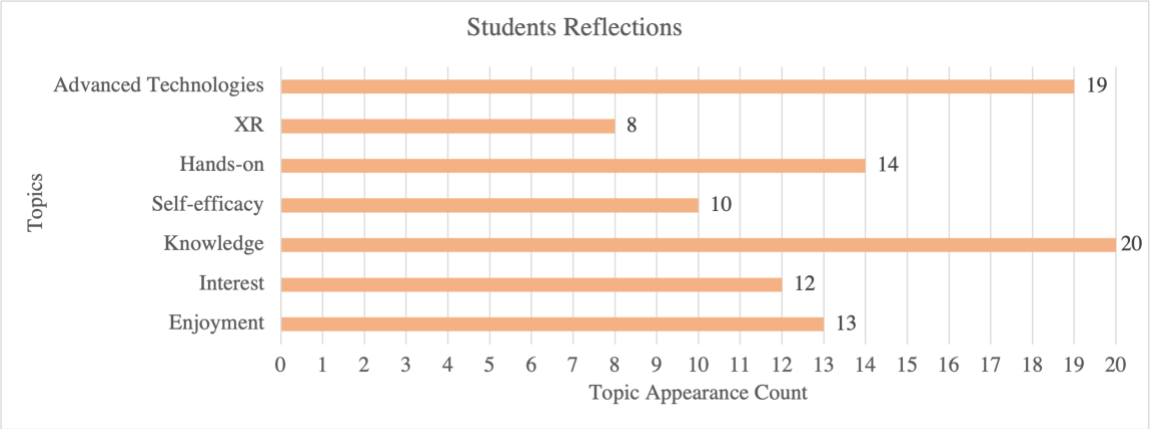


Figure 24 – Student reflections by topic appearance

Some examples of responses that mentioned 'advanced technologies' are:

*"One of my favorite parts of the camp was seeing the Boston Dynamics Astro (the **robot dog**)."*

*"We utilized multiple **cutting-edge technologies** to gain a further understanding of the challenges during construction."*

*"Highlight of the week – **drones**! Flying them around the Caddell building and learning how they are used."*

Some of the comments that mentioned 'XR technologies' are:

*"Seeing our project through **augmented reality** overlayed with our real-life project."*

*"The capability and ease that **XR technology** can bring to the construction industry will allow the owners to visual what will be created and truly bring their vision to life."*

"*The constant advancement of technology echoes throughout the construction and building industries which leads to the use of cool tools such as* ***augmented reality****."*

Some examples of responses that mentioned 'hands-on' are:

"I would love more ***hands-on*** *activities"*

"Please, incorporate more ***interactive*** *activities"*

"I enjoyed the ***hands-on*** *work that we did."*

Some examples of responses that mentioned 'self-efficacy' are:

"Finishing this program, I am more ***confident*** *in my choice"*

"*This program helped me* ***gain confidence*** *in pursuing a profession in this field."*

"*I met a lot of interesting people in the industry that* ***showed me that I could chose building construction****"*

Some examples of responses that mentioned 'knowledge' are:

*"****Learn*** *about building construction as an industry and a major."*

"This camp really helped become more ***knowledgeable*** *in the studies of building construction."*

"This camp helped me ***learn*** *more about college and I* ***learned*** *about how the construction industry works."*

Some examples of responses that mentioned 'interest' are:

*"After these two weeks here, I really have more knowledge and **interest** in BC."*

"*Great experience. I have been **inspired** to seriously consider a degree in construction management"*

*"All the hands-on activities really gave me a newfound **interest** for the Building Construction Program at Georgia Tech."*

Some examples of responses that mentioned 'enjoyment' are:

*"A lot of **fun** and really fulfilling."*

*"I had a **great time**."*

*"I really **enjoyed** the camp."*

Still in the final presentations, a noteworthy reflection was made by a female participant, who commented that before the camp, she did not feel she belonged in this career path. However, after meeting several successful female faculty and industry members throughout the camp, she now believes she can succeed in this career path. This fact is supported by SCCT that imposes that interest in career-related activities is viewed as a result of self-efficacy and outcome expectations. So, after this participant was exposed to the field, she could develop a sense of self-efficacy in specific activities and create certain expectations regarding the outcomes of her participation. This gained sense of self-efficacy and positive outcome expectations could hopefully help her develop interest that particular career (Lent et al. 2002).

Moreover, many students expressed their desire in being a part of the construction management industry after their participation in the camp: *"I would really like to be part of the industry", "CM is a growing, modern industry that I would like to be a part of",* and *"Construction Management is what I want to pursue"*. The responses also show that the camp helped them make their choice: *"At the beginning of this camp I wasn't too sure about going into building and construction but now it's my top choice by far"* and *"Going into this program, I was on the fence between architecture and building & construction I met a lot of interesting people in the industry that showed me that I could chose BC"*.

CHAPTER 5. CONCLUSION

This thesis presents pilot research results from a technology-intense two-week-long summer camp offered at Georgia Tech's School of Building Construction. The summer camp had 15 participants in demographics that were more diverse than the industry in both gender and race/Ethnicity. However due to the small sample size, these results should not be used for generalizations. The main goal of this thesis was to measure whether or not the application of activities using XR technologies during the summer camp would *trigger situational interest* in the participants to pursue a career in construction management. The methodology utilized to measure the outcomes of the work included pre- and post-surveys before and after the summer camp and activity-specific surveys after interventions that utilized various XR modalities. The surveys were formulated aiming to answer four main research questions, which are:

1) What is the impact of the summer camp in helping high-school students choose Construction Management as a career path or increase their self-efficacy toward a college major decision (i.e. shift their decision from unsure to sure)?

The results of the surveys showed that after the summer camp there was an significant increase of 600% of participants that have construction management as their primary choice of major, and a 200% increase of participants that are excited to pursue a career in construction management. The students' reflections support the results from the surveys with many students stating they were unsure about a career in construction management and the camp helped them decide.

2) Does the impact of the camp and its activities vary among different demographics?

The survey results regarding the students' educational plans show that the program was effective in both men and woman. Among the men there was a 40% increase in the number of students that want to go to Georgia Tech after high school and a 500% increase in the number of participants that have construction management as their primary choice of major. For women, there was a 100% increase in both number of students that want to go to Georgia Tech after high school and number of participants that have construction management as their primary choice of major.

The impact of the activities that used XR modalities were significant among men and women but were greater among men with 80% of the men reporting that AR/VR made them more interest in a career in construction management against 25% of the women. Nonetheless, the sample size is too small to generalize, especially given there was way less women than men (4 women and 10 men).

3) What activities included in the camp are most effective in creating a triggered situational interest toward a career in construction management?

All activities that implemented advanced technologies were effective in triggering situational interest in the majority of the participants of the summer camp. Drones was the favorite one with 100% of the participants stating that it made them more interested in career in construction management. In regards of the activities that employed XR modalities, the results for enjoyment were very similar for the three activities with the Masonry Wall AR Comparison activity having more students that reported the activity very

much (61.5%). The results for impact on interest show that the activity with more participants reporting that it made them more interest in a career in construction management was the Virtual Site Visit (42.9%).

It is noteworthy to mention that while the great majority of the students somewhat or very much enjoyed all of the technology applications in the program, two female students reported that AR/VR made them less interested in pursuing a career in construction management. As explained earlier this could be attributed to the idle wait times that the students were subjected during these activities and the levels of discomfort reported by these two students when experiencing immersive XR modalities. Another factor is that maybe they are just not interested in this type of technology.

4) How can the camp program be continuously improved for the purposes of recruitment into Construction Management and related degree programs?

Based on the findings, some improvements are recommended to improve the efficacy of the camp activities. For instance, alternative activity stations can be offered to minimize idle wait time when AR/VR goggles are cleaned and reset, or in case any of the activities present a technical difficulty, so that the students do not develop negative associations with this technology. Moreover, the author suggests making improvements upon the immersive XR activities for future camps by offering a choice of use of HMD versus browser-based (non-immersive) extended reality experiences for students who experience physical discomfort. It is common for VR users to be most physically uncomfortable, as this is the modality where the user's real-life view is completely

obstructed. Another idea is to introduce VR in 1-minute installments instead of a longer experience until the user gets used to the activity.

It is noted that non-immersive extended reality technologies are more open to use on larger scales in educational settings, as it does not create physical discomfort. These findings contribute to the body of knowledge in construction management pedagogy by proposing a systematic approach to leveraging emerging technologies with theory-based lectures around a well-defined scope involving virtual design, planning, simulation, construction, and quality control activities. Moreover, the findings provide an empirical foundation for developing a pre-college educational program to trigger career interest in high school students in the Construction Management domain.

A limitation of the study is the small sample size. This was linked to the limited time and approach for the marketing of the program, given that it was the first time it was offered. The program will continue to be offered in the future years with improved marketing strategies, along with the improvements made to the program's curriculum based on the findings of the pilot research study. Cumulative data will be presented in a future publication.

A statistical data analysis should be employed in a future publication to ensure the validity of the results. For this thesis work, the lack of a statistical analysis is due to the fact that to ensure validation on the effectiveness of the surveys, they were created based on the literature and the final format of the surveys (various different multiple choice questions and open-ended questions) did not allow the author to analyze them statistically.

Further, future research should rely on quantitative data over self-reported survey results and long-term real-life results such as number of participants that enrolled in the program after the participation on the summer camp. Lastly, the author recommends a more structured collection of the students' reflections, to separate each type of XR modality in the survey questions to get specific and more accurate data for each modality, to emphasize the importance and how the surveys will be used to the camp participants to ensure they will take it as seriously as possible and to shorten the surveys to avoid survey fatigue on the participants.

In sum, the results presented in this thesis show that an immersive summer camp that implements various hands-on activities and advanced technologies is a powerful way to trigger an interest in a career in Construction Management in high-school students, help them better understand their career options in this field, improve their self-efficacy, and understand the trending technologies that have been transforming the industry. Finally, the results support the hypothesis that the use of XR technologies in a summer camp setting can *trigger situational interest* in high school students in pursuing a career in construction management.

APPENDIX A. PRE-SURVEY

BACKGROUND SECTION

1) **Name: (Open ended)**

2) **Last Name: (Open ended)**

3) **Do you know anyone in construction management?**

   a) Yes

      If yes, what is this person's relationship to you?

      1- parent 2 - sibling 3 - family/friend 4 – other _____

   b) No

4) **Have you done any internships related to construction management?**

   a) Yes, 6 months or longer

   b) Yes, shorter period than 6 months

   c) No, but I have been invited

   d) No

5) **How much have the following factors influenced your perceptions of work in the construction management industry?**

a) Social Media:

1 - not sure 2 - not at all 3 - somewhat 4 - very much

b) Media or Television news:

1 - not sure 2 - not at all 3 - somewhat 4 - very much

6) Which of the following options best describe the high school you attend?

- o Trade school
- o Specialty school
- o Public High school
- o Private High school

7) I know a great deal about:

a) What construction managers do

1 - not sure 2 - not at all 3 - somewhat 4 - very much

b) Various career opportunities in construction management

1 - not sure 2 - not at all 3 - somewhat 4 - very much

c) The importance of technology in construction management

1 - not sure 2 - not at all 3 - somewhat 4 - very much

d) How AR and VR activities can improve construction management

1 - not sure 2 - not at all 3 - somewhat 4 - very much

e) My educational opportunities after high school

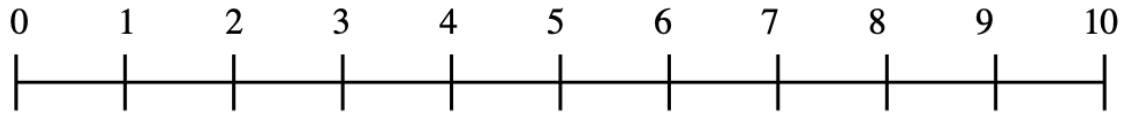
1 - not sure 2 - not at all 3 - somewhat 4 - very much

f) How additional education can help me achieve my career goals

1 - not sure 2 - not at all 3 - somewhat 4 - very much

8) Place an "X" at the position along the line that best reflects your current level of knowledge about construction management:

(0 = no knowledge, 10 = know a lot about construction)



9) Do you have previous experience with Augmented/Virtual Reality technologies? (Check all that apply)

o Yes, related to construction

o Yes, through videogames

o Yes, theme parks/ arcades/ museums

o Yes, school activity

o Yes, other

o No, I have never experienced activities using AR/VR

10) Do you know how Augmented Reality and Virtual Reality are being used in construction? If yes, please provide some examples: (Open ended)

CAREER/EDUCATIONAL GOALS SECTION

11) Are you planning to apply to/go to college?

a) Yes, 4-year institution

b) Yes, 2-year institution

c) Yes, I am considering both 2- and 4-years college options

d) Yes, I want to start at a 2-year college and transfer to a 4-year college

e) No, I would like to start my career right after graduation from high school

12) Which statement best describes your educational plans:

a) I have plans to go to Georgia Tech

b) I have plans to go to a university other than Georgia Tech

c) I have NO plans to go to any university

d) I am not sure yet

13) I am most interested to pursue a college degree on:

a) Construction Management

b) Civil Engineering

c) Architectural Engineering

d) Architecture

e) Other _____

f) I am still undecided on a degree program

14) Which statement best describes your career goals:

a) I have NO plans to pursue a career in construction management

b) I am undecided if I will pursue a career in construction management

c) I am considering a career in construction management

d) I am excited to pursue a career in construction management

15) What are your general perceptions of the construction management industry as a career choice? (Open ended)

16) Which aspect of the construction management industry are you most interested in? (Check all that apply)

a) Superintendent – responsible for coordinating all the work carried out by laborers and tradespeople. They work closely with architects and engineers, and the project team.

b) Project manager – plans and oversees the building process of the construction project from start to finish.

c) BIM manager – BIM (Building Information Modelling) managers act as collaborators between the client's team, design team, contractor team and supply chain and oversees the production of project information models using 3D visualizations.

d) VDC Manager – VDC (Virtual Design & Construction) Manager is responsible for leading preconstruction, engineering, and field installation of all BIM related project deliverables for the project.

e) Building Trades – Trade work completed during building construction: plumbing, welding, equipment operator, mason, electrician…

f) Other: _____

17) What aspects of working in construction management make it seem a less attractive career for you? (Check all that apply)

o I think it is physically challenging

o I do not like being outdoors exposed to the elements

o I don't think it is a career suited for people like me

o I have never seen someone like me succeed in construction management

o I do not know what people really do in construction management

o I do not know what a career in construction management entails

o I like to dress nicely and be in an office at all times

18) In thinking about your career, what factors are important to you?

o The amount of money I can earn

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o Benefits (health insurance, retirement, company stocks)

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o Flexibility of work hours/remote

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o Must be all office work

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o Must be all outside work

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o Prefer 50-50 outside and office work

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o Travel opportunities

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o I do not ever want to relocate for my job

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o Family friendliness (e.g. maternity/paternity leave)

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o Leadership opportunities

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o My gender and ethnicity are well represented in that industry

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o Diversity of personnel in the workplace

1 - not sure 2 - not important 3 - somewhat important 4 - very important

o Diversity in leadership

1 - not sure 2 - not important 3 - somewhat important 4 - very important

19) Would your career choice in construction management be influenced if people who are like you (same gender, race, etc.…) were more represented in leadership roles?

1 - not sure 2 - not important 3 - somewhat important 4 - very important

20) How important is it to you to have a mentor if you selected construction management as a profession?

1 - not sure 2 - not important 3 - somewhat important 4 - very important

DEMOGRAPHICS SECTION

21) What gender do you identify as?

- Male
- Female
- _____ (Short Answer Space)
- Prefer not to answer

22) Please specify your ethnicity:

- Caucasian
- African American
- Latino or Hispanic
- Asian
- Native American
- White

- Native Hawaiian or Pacific Islander
- Two or More
- Other/Unknown
- Prefer not to say

APPENDIX B. POST-SURVEY

CAREER/EDUCATIONAL GOALS SECTION

1) **Name: (Open ended)**

2) **Last Name: (Open ended)**

3) **After participating in the Building Construction Pre-College Program at Georgia Tech, I know a great deal about:**

a) What construction managers do

1 - not sure 2 - not at all 3 - somewhat 4 - very much

b) Various career opportunities in construction management

1 - not sure 2 - not at all 3 - somewhat 4 - very much

c) The importance of technology in construction management

1 - not sure 2 - not at all 3 - somewhat 4 - very much

d) How AR and VR activities can improve construction management applications

1 - not sure 2 - not at all 3 - somewhat 4 - very much

e) My educational opportunities after high school

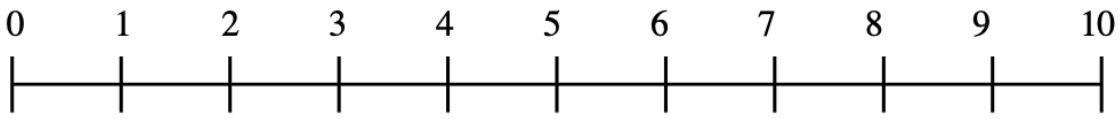
1 - not sure 2 - not at all 3 - somewhat 4 - very much

f) How additional education can help me achieve my career goals

1 - not sure 2 - not at all 3 - somewhat 4 - very much

4) **Place an "X" at the position along the line that best reflects your current level of knowledge about construction management after your participation in the Building Construction Pre-College Program at Georgia Tech:**

(0 = no knowledge, 10 = know a lot about construction)



5) **After your participation in the Building Construction Pre-College Program at Georgia Tech, are you planning to apply to/go to college?**

a) Yes, 4-year institution

b) Yes, 2-year institution

c) Yes, I am considering both 2- and 4-years college options

d) Yes, I want to start at a 2-year college and transfer to a 4-year college

e) No, I would like to start my career right after graduation from high school

6) **After your participation in the Building Construction Pre-College Program at Georgia Tech, which statement best describes your educational plans:**

a) I have plans to go to Georgia Tech

b) I have plans to go to a university other than Georgia Tech

c) I have NO plans to go to any university

d) I am not sure yet

7) **After participating in the Building Construction Pre-College Program at Georgia Tech, I would like to pursue a degree in:**

a) Construction Management

b) Civil Engineering

c) Architectural Engineering

d) Architecture

e) Other _____

f) I am still undecided on a degree program

8) **After your participation in the Building Construction Pre-College Program at Georgia Tech, which statement best describes your career goals:**

a) I have NO plans to pursue a career in construction management

b) I am undecided if I will pursue a career in construction management

c) I am considering a career in construction management

d) I am excited to pursue a career in construction management

9) **After your participation in the Building Construction Pre-College Program at Georgia Tech, what are your general perceptions of the construction management industry as a career choice? (Open ended)**

10) **After your participation in the Building Construction Pre-College Program at Georgia Tech, which aspect of the construction management industry are you most interested in? (Check all that apply)**

a) Superintendent – responsible for coordinating all the work carried out by laborers and tradespeople. They work closely with architects and engineers, and the project team.

b) Project manager – plans and oversees the building process of the construction project from start to finish.

c) BIM manager – BIM (Building Information Modelling) managers act as collaborators between the client's team, design team, contractor team and supply chain and oversees the production of project information models using 3D visualizations.

d) VDC Manager – VDC (Virtual Design & Construction) Manager is responsible for leading preconstruction, engineering, and field installation of all BIM related project deliverables for the project.

e) Building Trades – Trade work completed during building construction: plumbing, welding, equipment operator, mason, electrician…

f) Other: _____

11) After your participation in the Building Construction Pre-College Program at Georgia Tech, what aspects of working in construction management make it seem a less attractive career for you? (Check all that apply)

- o I think it is physically challenging
- o I do not like being outdoors exposed to the elements
- o I don't think it is a career suited for people like me
- o I have never seen someone like me succeed in construction
- o I do not know what people really do in construction
- o I do not know what a career in construction entails
- o I like to dress nicely and be in an office at all times

TECHNOLOGIES APPLICATION SECTION

12) After participating in the Building Construction Pre-College Program at Georgia Tech, I know how Augmented Reality and Virtual Reality are being used in construction:

a) Yes

If yes, give some examples _____

b) No

13) **How did you like the AR/VR activities during the Building Construction Pre-College Program?**

1 - not sure 2 - not at all 3 - somewhat 4 - very much

14) **How helpful was to your understanding of construction to have AR/VR activities during the Building Construction Pre-College Program?**

1 - not sure 2 - not at all 3 - somewhat 4 - very much

15) **How each of the following technology applications in construction affected your level of interest in pursuing a career in construction management?**

a) AR/VR

1 - not sure 2 - less interested 3 - did not affect my interest 4 - more interested

b) Drones

1 - not sure 2 - less interested 3 - did not affect my interest 4 - more interested

c) Robots

1 - not sure 2 - less interested 3 - did not affect my interest 4 - more interested

d) Laser-scanning

1 - not sure 2 - less interested 3 - did not affect my interest 4 - more interested

e) 3D printing

1 - not sure 2 - less interested 3 - did not affect my interest 4 - more interested

f) InfraRed camera use

1 - not sure 2 - less interested 3 - did not affect my interest 4 - more interested

g) BIM

1 - not sure 2 - less interested 3 - did not affect my interest 4 - more interested

ACADEMIC IMPACT SECTION

16) **For each of the following, indicate how your participation in the Building Construction Pre-College Program at Georgia Tech has impacted your academic life:**

a) I plan to expand my experience by telling my high school friends about my camp experience.

1 - strongly agree 2 - agree 3 - disagree 4 - strongly disagree

b) My participation in the Pre-College Program at Georgia Tech has changed my opinion towards construction management.

1 - strongly agree 2 - agree 3 - disagree 4 - strongly disagree

c) My participation in the Pre-College Program at Georgia Tech increased my confidence in my choice of major.

1 - strongly agree 2 - agree 3 - disagree 4 - strongly disagree

d) Because of my participation in the Pre-College Program at Georgia Tech, my skills in writing, documentation, and oral presentations have improved.

1 - strongly agree 2 - agree 3 - disagree 4 - strongly disagree

e) I will take the skills I have learned from the Pre-College Program at Georgia Tech and apply them to my academic practices in high school.

1 - strongly agree 2 - agree 3 - disagree 4 - strongly disagree

f) Interactions between my teammates and myself have been a positive experience.

1 - strongly agree 2 - agree 3 - disagree 4 - strongly disagree

g) The activities' expectations were explained to me in a clear manner.

1 - strongly agree 2 - agree 3 - disagree 4 - strongly disagree

h) Although the activities were challenging, the instructors provided clear instructions so that I was able to understand what was expected of me and my teammates.

1 - strongly agree 2 - agree 3 - disagree 4 - strongly disagree

APPENDIX C. MASONRY WALL COMPARISON AR ACTIVITY SURVEY

1) **Name: (Open ended)**

2) **Last Name: (Open ended)**

3) Rank the quality of the rendered images of the **Masonry Wall Comparison AR Activity.** Was it difficult to understand the intent of the model?

1 - not sure 2 - not clear at all 3 - somewhat clear 4 - very much clear

4) Rank how easy it was to navigate the model.

1 - very easy 2 - easy 3 - hard 4 - very hard

5) Did the movement lag during the **Masonry Wall Comparison AR Activity** made you distracted? Was it an issue?

1 - not sure 2 - not at all 3 - somewhat 4 - very much

6) Rank your ability to identify the different components that were used in the Masonry Wall structure (e.g. brick, mortar, weep holes…).

1 - not sure 2 - not able at all 3 - somewhat able 4 - very much able

7) Rank the ability of the **Masonry Wall Comparison AR Activity** to provide you with an understanding of spatial qualities and components of the Masonry Wall in comparison to the actual Masonry Wall.

1 - not sure 2 - not able at all 3 - somewhat able 4 - very much able

8) How did you like the **Masonry Wall Comparison AR Activity**?

1 - not sure 2 - not at all 3 - somewhat 4 - very much

9) Did the **Masonry Wall Comparison AR Activity** make you more interested in pursuing a career in construction management?

1 - not sure 2 - less interested 3 - did not affect my interest 4 - more interested

10) System Usability Scale (SUS): 1 - strongly disagree/ 2 - somewhat disagree/ 3 - neither agree nor disagree/ 4 - somewhat agree/ 5 - strongly agree

- I think that I would like to use this system frequently.
- I found the system unnecessarily complex.
- I thought the system was easy to use.
- I think that I would need the support of a technical person to be able to use this system.
- I found the various functions in this system were well integrated.
- I thought there was too much inconsistency in this system.
- I would imagine that most people would learn to use this system very quickly.
- I found the system very cumbersome to use.

- I felt very confident using the system.

- I needed to learn a lot of things before I could get going with this system.

APPENDIX D. MASONRY WALL TOGGLE ACTIVITY SURVEY

1) **Name: (Open ended)**

2) **Last Name: (Open ended)**

3) Rank how easy it was to navigate the **WebGL version** of the model:

1 - not sure 2 - not clear at all 3 - somewhat clear 4 - very much clear

4) Rank how easy it was to navigate the **AR (iPad) version** of the model.

1 - very easy 2 - easy 3 - hard 4 - very hard

5) Rank your ability to identify the different components that were used in the Masonry Wall structure (e.g. brick, mortar, weep holes…) using the **AR (iPad) version**:

1 - not sure 2 - not able at all 3 - somewhat able 4 - very much able

6) Rank the ability of the **AR (iPad) version** to provide you with an understanding of spatial qualities and components of the Masonry Wall in comparison to the actual Masonry Wall.

1 - not sure 2 - not able at all 3 - somewhat able 4 - very much able

7) Considering the two versions of the activity, **WebGL and AR (iPad)**, which one was more informative (enhanced your learning)?

- o WebGL version
- o AR (iPad) version

8) Considering the two versions of the activity, **WebGL and AR (iPad)**, which one was more enjoyable/fun?

o WebGL version

o AR (iPad) version

9) How did you like the **AR (iPad) version** of the **Masonry Wall Toggle Activity**?

1 - not sure 2 - not at all 3 - somewhat 4 - very much

10) Did the **WebGL version** of the **Masonry Wall Toggle Activity** make you more interested in pursuing a career in construction management?

1 - not sure 2 - less interested 3 - did not affect my interest 4 - more interested

11) Did the **AR (iPad) version** of the **Masonry Wall Toggle Activity** make you more interested in pursuing a career in construction management?

1 - not sure 2 - less interested 3 - did not affect my interest 4 - more interested

12) **System Usability Scale (SUS):** 1 - strongly disagree/ 2 - somewhat disagree/ 3 - neither agree nor disagree/ 4 - somewhat agree/ 5 - strongly agree

o I think that I would like to use this system frequently.

o I found the system unnecessarily complex.

o I thought the system was easy to use.

- I think that I would need the support of a technical person to be able to use this system.
- I found the various functions in this system were well integrated.
- I thought there was too much inconsistency in this system.
- I would imagine that most people would learn to use this system very quickly.
- I found the system very cumbersome to use.
- I felt very confident using the system.
- I needed to learn a lot of things before I could get going with this system.

APPENDIX E. VIRTUAL SITE VISIT ACTIVITY SURVEY

1) **Name: (Open ended)**

2) **Last Name: (Open ended)**

3) Rank the quality of the rendered images of the **Virtual Site Visit**:

1 - not sure 2 - not clear at all 3 - somewhat clear 4 - very much clear

4) Did the movement lag during the **Virtual Site Visit** made you distracted? Was it an issue?

1 - not sure 2 - not at all 3 - somewhat 4 - very much

5) Rank the ability of the **Virtual Site Visit** to provide you an understanding of the spatial qualities of the construction site in comparison to the "standard" in-person site visit.

1 - not sure 2 - not able at all 3 - somewhat able 4 - very much able

6) Rank your ability to identify the different components/systems of the construction site presented during the **Virtual Site Visit.**

1 - not sure 2 - not able at all 3 - somewhat able 4 - very much able

7) During the **Virtual Site Visit**, did you feel like you were on site (developed a sense of presence within the space)?

1 - not sure 2 - not at all 3 - somewhat 4 - very much

8) How did you like the **Virtual Site Visit** activity?

1 - not sure 2 - not at all 3 - somewhat 4 - very much

9) Did the **Virtual Site Visit** activity make you more interested in pursuing a career in construction management?

1 - not sure 2 - less interested 3 - did not affect my interest 4 - more interested

10) Did you feel nausea or queasiness during the activity?

1 - not at all 2 - minimal discomfort 3 - somewhat uncomfortable
4 - very much uncomfortable, enough to stop the activity

11) Did you have a feeling of eye strain during the activity?

1 - not at all 2 - minimal discomfort 3 - somewhat uncomfortable
4 - very much uncomfortable, enough to stop the activity

12) Did you feel vertigo or difficulty maintaining balance during the activity?

1 - not at all 2 - minimal discomfort 3 - somewhat uncomfortable
4 - very much uncomfortable, enough to stop the activity

13) Did you feel comfortable having your vision occluded in front of others when using goggles?

1 - very comfortable 2 - indifferent 3 - somewhat uncomfortable
4 - very much uncomfortable, enough to stop the activity

14) Did you feel safe while using the device in front of others?

1 - very comfortable 2 - indifferent 3 - somewhat uncomfortable

4 - very much uncomfortable, enough to stop the activity

15) Did the use of VR technology cause you any anxiety?

1 - not sure 2 - not at all 3 - somewhat 4 - very much

16) System Usability Scale (SUS): 1 - strongly disagree/ 2 - somewhat disagree/ 3 - neither agree nor disagree/ 4 - somewhat agree/ 5 - strongly agree

- I think that I would like to use this system frequently.
- I found the system unnecessarily complex.
- I thought the system was easy to use.
- I think that I would need the support of a technical person to be able to use this system.
- I found the various functions in this system were well integrated.
- I thought there was too much inconsistency in this system.
- I would imagine that most people would learn to use this system very quickly.
- I found the system very cumbersome to use.
- I felt very confident using the system.

- I needed to learn a lot of things before I could get going with this system.

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