INCREASING THE EFFECTIVENESS OF K-12 STEM WORKSHOPS
THROUGH TARGETED CONTEXT AND
CREATIVE TECHNOLOGIES

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ABSTRACT

Increasing the Effectiveness of K-12 STEM Workshops through Targeted Context and Creative Technologies

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Economic projections reveal a need for one million more Science, Technology, Engineering, and Math (STEM) professionals over the next decade than the United States is producing at the current rate. As a result, STEM education is a major focus of recent legislation and funding in Congress as the number of STEM professionals is inadequate to support innovation and the ever-changing economy. In response to the urgent need for more competitive STEM professionals, there has been a widespread implementation of workshops, organizations, and school programs aimed at amplifying K-12 student STEM literacy and interest. Some programs are even created to specifically reach and attract women and unrepresented minorities to STEM. Despite the increase in outreach programs, they remain limited to a straightforward discussion of a narrow scope of STEM topics. Many workshops and programs continue to validate the positive impacts of utilizing hands-on projects but cease to inform about broader STEM applications through the exploration and integration of storytelling, culture, and community.

Professors and students from the Liberal Art and Engineering Studies program at California Polytechnic State University, San Luis Obispo founded the Seeds in STEM organization to develop K-12 STEM workshops that incorporate a participants’ culture and community in the learning process per a storyline that guides the participants through several STEM activities. This paper discusses the impact of adding a workshop activity that introduces motion capture technologies and their application to
the Seeds in STEM workshop held on April 30th, 2022. The results collected from
the activity via three forms of assessment demonstrate generally positive trends in
the attitudes of the participants regarding STEM topics and the careers encompassed
by STEM.
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Chapter 1

INTRODUCTION

Economic projections reveal a need for one million more Science, Technology, Engineering, and Math (STEM) professionals over the next decade than the United States is producing at the current rate [42]. As a result, STEM education is a major focus of recent legislation and funding in Congress as the number of STEM professionals is inadequate to support innovation and the ever-changing economy [23].

To spark an interest that leads to the pursuit of STEM careers, STEM topics need to be introduced to future generations while they are in the early stages of their educational career [17, 26]. In other words, we need to allow students to familiarize themselves with STEM concepts before they reach college-level courses. It has been found that 38% of students who start college as a STEM major do not graduate as one, this is conceivable as 69% of high school graduates are not prepared for college-level math and science courses according to the National Math and Science Initiative [42]. Numerous reasons contribute to a student’s decision to drop out of college or change their major, but a long-standing and impactful reason remains that the education they received before college left them poorly prepared, leading them to feel intellectually inferior or disadvantaged. This is further supported by a National Assessment of Educational Progress study that found that roughly 75% of U.S. 8th graders are not proficient in mathematics by the time they end the academic year [19].

The prevailing shortage of representation in STEM industries is another contributor to the lack of its diversification, along with minimal early exposure to STEM and poor
preparation for college-level STEM courses as previously mentioned. For reference, Hispanic workers comprise 17% of total employment across all occupations but only make up a trifling 8% of STEM workers. Similarly, black workers comprise 11% of total employment across all occupations, but a mere 9% in STEM occupations [24]. These concerning statistics regarding the presence of underrepresented communities in STEM careers are further reflected in those that are earning college degrees in STEM. Black students earned 10% of all bachelor’s degrees, but only 7% of STEM bachelor’s degrees in 2018, and in that same year 15% of Hispanic students earned a bachelor’s degree, but only 12% earn a STEM bachelor’s degree. Moreover, women earned 85% of bachelor’s degrees in health-related fields, but just 22% in engineering and 18% in computer science [24].

A diverse STEM workforce is also favorable because it can lead to monetary benefits. Diversifying a company’s workforce can increase profits as has been observed by the $570 billion increase in profit in the technology industry from technology companies’ response to adopting diversity and inclusivity initiatives [41].

In response to the urgent need for more competitive STEM professionals, there has been a widespread implementation of workshops, organizations, and school programs aimed at amplifying K-12 student STEM literacy and interest. Some programs are even created to reach and attract women and underrepresented minorities to STEM [10, 43]. Despite the increase in outreach programs, they remain limited to a straightforward discussion of a narrow scope of STEM topics. Many workshops and programs continue to validate the positive impacts of utilizing hands-on projects, but cease to inform about broader STEM applications through the exploration and integration of storytelling, culture, and community [34]. Similarly, programs centered around informing students on various STEM careers also omit an exploration of broader applications and industries. Most adhere to exploring the various careers directly re-
lated to the four pillars of STEM such as scientist and engineer. For instance, in 2019 the Raggio Research Center hosted a STEM Career Pathways Conference, a series of seminars aimed at introducing high school students to career paths in STEM. However, they solely focused on careers in biotechnology and engineering [52]. Notably, 90% of the seminar participants stated that the most useful takeaway was gaining knowledge about careers they didn’t know existed or were achievable through STEM. Participants also recognized that they were not aware of how impactful the fields were to their everyday lives.

Schools, workshops, organizations, and professionals that aim to introduce and teach STEM subjects in an exciting, enticing, and inclusive way should consider presenting the subject matter in a relatable manner by adopting a storyline to guide the learning process and by highlighting that it can be applied to broader, interdisciplinary fields. Doing so nurtures the use of unique perspectives in STEM activities which in turn can induce new and innovative approaches and solutions [48, 47]. Aggregating a storyline can have numerous valuable effects on students. It can promote material retention, stimulate students’ integration of personal perspectives, and create a trusting relationship with teachers, moreover, it is a medium for organizing and conveying information and it can make lessons personally meaningful [29, 12, 3]. Furthermore, featuring culture and community in the storyline can bridge a connection between students and the STEM facets that they are being introduced to because they can easily relate to the characters and better visualize how the facets play a role in their community [29]. This is especially the case if the characters are from a similar culture or community as the students because they can serve as a proxy for the students to start perceiving themselves in STEM roles.

Professors and students from the Liberal Art and Engineering Studies program at California Polytechnic State University, San Luis Obispo founded the Seeds in STEM
organization to provide K-12 STEM workshops that integrate story, culture, and community. Seeds in STEM differentiates itself from other STEM-based workshops because it incorporates participants' culture and community in the learning process per a storyline that guides the participants through several STEM activities. This approach to learning was chosen to maximize the impression the activities and STEM have on its participants.

This paper discusses the impact on the interest of 9-12th graders considering a career in STEM by presenting motion capture technologies and their applications as an activity in the Spring 2022 Seeds in STEM workshop. Motion capture technologies encourage the integration of storytelling and culture as they enable interaction with imaginary digital worlds. These digital worlds provide a creative means of teaching STEM topics, inherently adding an arts aspect to STEM education in turn creating STEAM education. A discussion on the benefits of STEAM education can be found in Chapter 3. Previous case studies introducing other emerging technologies, such as augmented reality (AR), to students have found that students' desire to learn more about STEM increases [27, 31]. The results collected from the activity via three forms of assessment demonstrate generally positive trends in the attitudes of the participants regarding STEM topics and the careers encompassed in STEM.
Chapter 2

MAIN CONTRIBUTIONS

My motivation for carrying out the motion capture activity in the Seeds in STEM workshop and addressing the research question put forth in the introduction of this paper emanates from two aspects of my personal life. The first is I comprehend the struggles that one must overcome as a STEM major due to the lack of exposure to STEM topics at a young age and the lack of representation or role models in STEM industries, specifically in computer science and electrical engineering. Secondly, throughout my undergraduate and postgraduate studies, I actively explored technological solutions for creative applications in the entertainment industry.

This paper may be of interest to individuals who work in academia or in STEM industries because they most likely have witnessed the lack of representation and its impacts directly.

This paper aims to analyze the impacts of introducing motion capture technologies and their application to K-12 students from a low socioeconomic community that lacks representation in STEM careers. Motion capture technologies provide a creative means of teaching STEM topics, inherently adding an arts aspect to STEM education in turn creating STEAM education. It was crucial for me to cultivate a workshop activity that encapsulated a STEAM philosophy as Hossain and Robinson state, “The solution to the STEM education problem should be handled in an interdisciplinary manner, which must be grounded in the STEM discipline departments as well as the Colleges of Education and Human Development [30].” This paper acknowledges other STEM-based workshops with the same goal of increasing diversity in STEM careers.
and identifies where they could improve. It also describes the Seeds in STEM motion
capture activity and the generally positive trends in the attitudes of the participants
determined through questionnaires and observation.
To understand how emerging immersive technologies, such as motion capture, can play a significant role in STEM workshops, a discussion of the current education system and why it is unsuccessful in positively impacting students’ perceptions of STEM fields is needed. This section will begin by introducing Science, Technology, Engineering, and Mathematics (STEM) education and various reasons why it is currently being advocated for in classrooms, and where it lacks in successfully encouraging all students to pursue STEM careers. Then, it will discuss how adding an Arts component to STEM, creating STEAM, can help fill in the gaps STEM education has when it comes to providing students with a complete skill set in order to be successful in STEM roles. As well as, how STEAM is a means of encouraging all types of students to develop an interest in the growing careers of the 21st-century. Additionally, this section will discuss how the workforce is changing and why a STEAM education can properly prepare students for it. Lastly, an introduction to motion capture, its types, applications, and advantages are featured in this section.

3.1 What is a STEM Education

STEM is a cross-disciplinary teaching philosophy that promotes learning through critical thinking and hands-on experiments to solve real-world problems. According to the Pew Research Center, employment in STEM occupations has grown 79% since 1990 and according to the US Bureau of Labor Statistics, the number of STEM jobs is projected to grow 8% between 2017 and 2029, a much higher rate than non-
STEM jobs. Therefore, it is estimated that 3.5 million STEM-related jobs will need to be filled by 2025 [13]. Due to the increase of STEM jobs, it is important to start introducing and preparing future generations for a STEM career. However, studies have found that employers are having difficulties filling STEM jobs because STEM education is not readily available for many, especially women and people of color. Furthermore, only 20% of US high school graduates are prepared for college-level coursework in STEM majors and 2 out of 3 US women state they were not encouraged to pursue a career in STEM [13]. For students to be successful in STEM, their first introduction to STEM topics should come before college because STEM students require a style of education that allows them to steadily build the skills and mindsets that employers find valuable.

Since a STEM education requires students to have ample knowledge and understanding of a broad range of topics in mathematics, science, engineering, and technology, many students on a STEM route have fewer options over what courses they take throughout their educational career. As a result, many STEM majors lack the opportunity to explore topics outside of their set curriculum. Thus it is unlikely that many students will be able to explore their hobbies via extracurricular courses that stray from the four disciplines STEM encompasses [20].

Moreover, STEM has an infamous reputation for being difficult and solely for a particular type of student; a student that identities as white, male, or nerdy [51]. This reputation causes anxiety and low self-esteem in students if they don’t fit the mold of the stereotype, and they begin to develop reservations and doubts about pursuing careers in STEM [38, 39]. To combat this reputation, there has been a rise in the development of programs aimed to encourage women and other underrepresented groups to pursue careers in STEM. “Individuals need to perceive themselves as capable of coping with unknown situations and problems instead of becoming stressed and
experiencing anxiety [18].” This is where STEAM (Science, Technology, Engineering, Arts, and Mathematics) can help. STEAM encourages learning by problem-solving through creative and unique means to find equal, if not better, solutions.

3.2 Why STEAM Education

In 2007, members of the U.S. Senate called on the National Academies to address the impact of globalization on US economic competitiveness – particularly in the fields of science and technology, as a result, emphasis was placed on filling STEM jobs [20]. As we enter the Fourth Industrial Revolution the knowledge and skills needed to occupy those jobs are transforming rapidly to reflect the growing technological world that we are living in. So much so, that even the US government recognizes the need for emphasis on STEM career exposure and teaching in classrooms. However, we are beginning to see that the lack of skilled employees goes beyond the lack of interest and knowledge of STEM careers. Even those who do pursue a STEM career are not fully prepared to enter the workforce because they still lack the collaborative, communication, and exploration skills that can be found in the Arts [30, 15].

3.2.1 The 21st-Century Workforce

STEAM education is an approach to learning that utilizes Science, Technology, Engineering, the Arts, and Mathematics as access points for guiding student exploration, communication, and critical thinking [22]. A STEAM education empowers students to approach STEM subjects with art practices and design principles, thereby, opening the door for students to begin solving problems in a creative and personalized manner.
In 2009, The Conference Board and Americans for the Arts surveyed educators and executives to gauge their thoughts on the needs of the 21st-century workforce. They found that 97% of employers agree that creativity is of increasing importance in the workplace, but they also found that 85% of employers can’t seem to find applicants that possess the creative skills they seek [11].

The 21st-century workforce is evolving and in need of workers that can communicate with teammates and customers to create productive relationships that work to design and build products created with the best and most diverse minds. STEM lacks the art component of STEAM so, as a result, it cannot encourage creativity and innovation to the extent that STEAM does. Thus, STEM alone is no longer sufficiently preparing younger generations for the 21st-century workforce.

Studies have found that students with a STEAM education take thoughtful risks, engage in experiential learning, persist in problem-solving, embrace collaboration, and work through the creative process. These are the kinds of skills that employers of the 21st century are seeking in candidates because these skills are most valuable to companies as they aim to create products for a transforming world that requires a focus on diversification.

Therefore, to increase U.S. competitiveness and economic prosperity, we should be looking to STEAM rather than STEM alone.

3.2.2 Diversifying the 21st-Century Workforce

At its core STEAM promotes diverse thinking. It encourages students to use their personal experiences to cultivate unique solutions to new problems that face the world today. Therefore, an inherent side effect of promoting this kind of thinking, creativity, and problem solving is a diverse and inclusive workforce. STEAM eliminates the need
for students to put on a specific hat to be successful in STEM careers. It does not require students to think or behave a certain way in the classroom, but instead to use their unique and personal ideas to solve problems and make an impact [1, 18].

A 2016 study by Brouillette, L., and Graham, N. J. investigated the impact of STEAM lessons on physical science learning in third to fifth graders. The students came from ten high-poverty schools located in a large urban district in California. The study found that students exposed to the STEAM lessons demonstrated greater improvement on physical science benchmark assessments than students exposed to a STEM-only physical science curriculum [28].

Moreover, studies published by the National Endowment of the Arts and the President’s Committee on the Arts and Humanities found that low-income students that engaged in learning via the arts were more likely to attend and do well in college, build careers, volunteer within their community, and even vote [11].

3.3 Motion Capture Introduction

Motion capture, or mocap as it is commonly referred to in a professional setting, is the process of tracking human movement and expression in real-time utilizing specialized motion capture equipment and suits to collect motion data and stream it onto a digital model. In other words, it facilitates the mapping of real-world movement on computer-generated 3D models resulting in photorealistic dynamics in a virtual environment [9]. It is an immersive, cutting-edge technology that is beginning to make a presence in various industries to facilitate processes and increase productivity. Although relatively new, there are several types of motion capture technologies that are being explored and tested.
3.3.1 Where is Motion Capture Used

Motion capture is utilized in a multitude of industries including sports science, animation, film, and game production. In sports science, motion capture is used for analyzing body and muscle movement and for diagnoses, better known as gait analysis. In the film, animation, and video game industries, motion capture is employed to record the movement of actors for enabling more realistic movements in digital characters. One of the first films to utilize motion capture technologies was The Lord of the Rings (2002). The character Gollum, played by Andy Serkis and created by Weta Digital’s Bay Raitt, is recognized as one of the most impressive computer-generated characters Hollywood has ever produced. Likewise, game development companies such as Electronic Arts (EA) have made use of motion capture technologies in their games to bring characters to life resulting in visually compelling and believable characters [15]. FIFA 22 (2021) is a soccer simulation video game published by EA and it is an excellent example of how motion capture can bring photorealistic characters to life. The Xsens motion capture suits allowed EA to track the movements of twenty-two professional soccer players during high-intensity activities [54].

3.3.2 Types of Motion Capture

Motion capture can be carried out via three main techniques: optical (passive and active), mechanical, and inertial.

Optical (active and passive) is the technique that comes to mind for most when mocap is mentioned, this technique involves tracking the reflection of spherical markers attached to the actor. The data tracked is then used to map the 3D position of a subject. Active optical motion capture differs from passive optical motion capture because light is emitted from the markers instead of reflected. The pros of an optical
mocap include a lightweight suit, can work in large areas, and more data captured in great detail. On the other hand, optical mocap is expensive and is prone to light interference, therefore, one must be attentive to their surroundings.

Mechanical mocap utilizes metal strips that are attached to the actor in such a way that each joint has sensors that give accurate positions and angles [37]. Some pros with this method are there is no range limit nor the possibility of interference from light or magnetic fields. However, some cons of utilizing mechanical mocap technologies are the motions captured with this method are not as realistic as the other methods, the technology has no ground awareness, and the equipment must be calibrated often.

Lastly, inertial mocap records movement data using motion sensors known as inertial measurement units (IMU), that transmit gyroscope, magnetometer, and accelerometer data wirelessly to a computer. IMUs are attached tightly and securely to body limbs and joints in which capturing data is crucial, and data recording should occur in an area free of magnetic interference. The advantages of inertial include it’s portable, can be used in tight and large open spaces including outdoors, and it is relatively cheap. On the contrary, it is not known for the accuracy of the data or the speed at which it is captured and processed. The Liberal Arts and Engineering Studies (LAES) program at Cal Poly utilizes an inertial motion capture suit from Rokoko Electronics for student research, including the Seeds in STEM workshops. The Rokoko suit has nineteen sensors that send data wirelessly to a computer connected to the same WiFi network.

Motion capture technologies come in various forms. Most commonly it is in a motion capture suit, though as this technology becomes more known it is becoming more widely available. Thus, motion capture can also be seen in the form of facial motion capture gear, hand motion capture gear, phone applications [45], and other computer software [14].
3.3.3 Advantages of Motion Capture

The benefits of motion capture include its thorough interpretation of human movement and realistic motion data due to the volume of data generated in motion capture and the accuracy of that data [40]. Furthermore, mocap allows actors to perform and record movements that can be instantaneously placed in scenes for testing or planning, in turn, establishing it as a cheaper method of remaking scenes than animation. Similarly, the quick response time, because mocap works in real-time, results in reduced costs.
Chapter 4

RELATED WORKS

Adding an arts aspect to STEM to create STEAM in K-12 classrooms is not a new idea, nor is the idea of utilizing cutting edge and immersive technologies such as augmented reality (AR) and virtual reality (VR) in classrooms to push forth a creative way of approaching STEM topics. Nonetheless, no one has carried out a study that analyzed the impact of a STEM workshop that utilizes motion capture technologies, story, and culture on high school students that belong to an underrepresented community such as Santa Maria, California. With findings from similar studies that utilize different immersive technologies or performed studies on different age groups, I can address questions they posed in their future works section and add to their findings and concluding thoughts.

A study conducted at Oxford Brookes University in which students ages 14-17 years participated in a workshop, aimed to analyze the impacts of active learning in STEAM education through augmented reality [31]. Their reasoning for conducting the case study was they believed that the opportunity to experiment and engage in a cross-discipline education is currently missing from classrooms, and as a result, students are disinterested in pursuing careers in STEM. They further identify that this lack of participation is having a negative impact economically as “the supply in engineering occupations is not keeping pace with demand. Many companies are struggling to upgrade the skills of their employees [...] losing ground to their competition [31].” They found that students that participated in the workshop felt empowered by their new skills and were excited about the prospect of utilizing AR in classrooms. Moreover, they were able to conclude that the main advantages of AR are its potential learning
gain, increased motivation in students, responsive interaction, the potential for collaboration, development of spatial abilities, and improving performance in physical tasks. In their concluding thoughts, they acknowledged that their participants were a self-selected sample that did not represent the population as a whole and that an area of future work could focus on students who belong to disadvantaged groups such as students from families with low socioeconomic status. Workshops such as the Seeds in STEM workshop aim to address the same questions and concerns as this study, but with a focus on students that come from areas known to have a socioeconomic disadvantage making it a good continuation of their study.

Researchers in the Department of Educational Studies at Purdue University conducted a study to determine if student interest in science differs based on gender [44]. The study observed interest and liking in science amongst 162 ethnically and linguistically diverse kindergarten students that came primarily from low-income families. Three schools participated in the study, one that offered a traditional kindergarten science experience, and two that participated in the Scientific Literacy Project (SLP), a program that consists of a sequence of integrated science exploration and literacy activities. The study found that among the students that experienced traditional science lessons, boys were more likely to prefer and explore science topics than girls. However, among the students that attended the schools that participated in the SLP, regardless of gender, the children had greater motivation for learning science and displayed higher science competency than the children who experienced the traditional science experience. The study concluded by stating that these findings support the argument that meaningful and early participation in science and subjects alike is more likely to promote greater motivation for science regardless of gender. Seeds in STEM hopes to provide this meaningful and early exposure to STEM subjects to students from underrepresented communities through the spring Seeds in STEM workshop in
hopes of not only increasing the liking of these subjects but the students’ motivation to pursue a career in these fields.

A paper by Pallis and McNitt-Gray [43] discusses the implementation and impacts of the innovative week-long summer residential sports engineering academy known as Get SSET (Sports Science, Engineering and Technology). Get SSET aims to empower female students with technical skills and success strategies through engaging sports STEM lectures and hands-on activities. The academy recognizes that many young female students associate sports and recreation with the word “fun”, while science, math, and engineering are often described as “difficult.” Therefore, by introducing STEM subjects through sports-related lectures taught by female instructors who are university faculty and/or professionals in sports science, engineering, or math the academy aims to shift the female students’ idea of STEM in a more positive light. Through written student evaluations, organizers found the student experienced higher self-confidence and active learning as a result of their participation in the academy. The paper further outlines that some students hesitate to define STEM as “fun” as a result of how its taught in everyday classrooms, and that to increase interest in young women they need to be introduced to STEM topics from a relatable and fun point of view, in this case, it’s sports. The Seeds in STEM workshop’s motion capture activity shares a similar goal as Get SSET, to motivate and increase interest in underrepresented groups in STEM careers through the introduction of creative careers in which STEM topics are applied.

The recent COVID-19 pandemic has accelerated the turn to VR and other emerging technologies as a means to address educational problems and/or advancements. A study [10] incorporated fifteen VR-based lessons for varying STEM topics in undergraduate education in which all the participants identified as African American. The study aimed to observe whether visualizing complex concepts in three dimensions
helps improve understanding. Student attitudes and learning outcomes were measured via the use of pre- and post-surveys. From the surveys, the researchers were able to conclude that not only were the students more engaged in the VR lessons, but they also found that student interest in STEM-related careers and a desire to complete a STEM-related degree had a mean value of 4.16 on a 5-point scale. These results demonstrate the feasibility of incorporating VR lessons in undergraduate education and the impacts they leave on students that identify as being part of a minority community. This paper aims at observing the impact motion capture technologies have when incorporated in a similar matter as VR was in the study, but at a K-12 level.

Researcher, Iveta Pavola, composed an article [45] that aims to evaluate the impact of incorporating motion capture technologies in STEM classroom activities on student perceptions of STEM careers and their motivation to pursue a career in STEM. This article makes a case for the use of motion capture in K-12 education stating that it is likely to improve student success rates due to the introduction to multi-sensory learning. Pavola further states that it can help engage students more and improve their teamwork skills while simultaneously providing knowledge about animation and computer science. The motion capture activity in the spring Seeds in STEM workshop introduces motion capture technologies and their use in creative industries such as animation and film, in turn, making that connection between STEM topics and creative roles.
As a member of the leadership team of the Seeds in STEM organization, I was granted the opportunity to oversee and make paramount workshop decisions at all stages of its planning, as well as, suggest additions and adjustments I felt would lead to the success of the workshop and effective execution of the motion capture activity.

5.1 Workshop Overview

The Seeds in STEM workshop took place on Saturday, April 30th, 2022 on Cal Poly’s campus and had a duration of six hours. Two groups of eight students rotated to four different workshop activities starting from 10:00 am and ending at 4:00 pm with time allotted for lunch and an additional culture/community activity. The activities featured in the workshop were a computer science scratch activity, a structural engineering bridge building activity, a mobile audio experience activity, and the motion capture activity. The motion capture activity was conducted in the KTGY Gallery in the Engineering West building (21-105A). This room was chosen for the motion capture activity because it was the largest room booked for the workshop and a decent amount of space is needed to perform a live motion capture demonstration. The duration of the activity was forty-five minutes for each rotation. Figure 5.1 illustrates the layout for the front half of the KTGY Gallery on the day of the activity, on the right side of the image the projector is displaying the presentation, and in the center of the image are tables and chairs arranged for the participants. The entirety of the back half of the gallery was left vacant for the live demonstration, except for a router.
and a room divider for the volunteer to hide behind, but it too was moved to the side once the demonstration began.

Figure 5.1: KTGY Gallery motion capture activity setup.

Since the activity collected data from human participants it falls under Cal Poly’s Policy for the Use of Human Subjects in Research. Meaning that the activity along with the overall workshop received approval from the University’s Institutional Review Board (IRB) which evaluated the project and deemed it compliant with ethical standards regarding the treatment of human subjects. With this approval, we were authorized to requested permission from the participants and their guardians to use the participants’ likeness, image, appearance, and performance present in videos, slides, and photographs taken during the workshop.
5.2 Motion Capture Activity Logistics

The presentation tool, Google Slides, was utilized for the interactive presentation portion of the activity that discussed what motion capture is, the different kinds of motion capture suits and tools, the technologies and STEM facets they employ, their applications in a vast amount of industries, and various examples of its use in real-life applications. The presentation was made as interactive as possible by engaging the students with prompting questions regarding the presentation content. Such questions include, “What kinds of things would you do if you had access to a motion capture suit?” and “What movies or video games that you have seen or played do you think use motion capture?” The questions were meticulously picked to be open-ended, engaging, and encouraging of all sorts of ideas.

The scene used for the live demonstration was created using the Unity game engine and was designed with the workshop theme in mind to convey a continuous storyline. To control the character model, motion data was captured and streamed into Unity with the help of a Rokoko SmartSuit Pro II worn by a volunteer Cal Poly student, the Unity Live plugin in Rokoko Studio, and the Rokoko Live Unity asset. More information on how these tools and technologies are set up and interact with one another for use in the live demonstration can be found in Chapter 7.

In addition to Google Slides, Unity, and Rokoko, other resources used to carry out the activity include free online assets for the live demonstration scene, a slides template from Slidesgo, storyline graphics provided by Jehlia Arriola, and Santa Maria research gathered by the winter quarter 2022 LAES 411 class that assisted in bringing the workshop to fruition. The Santa Maria research was a critical component of the workshop and this activity as it was used to introduce STEM facets in a culturally aware and inviting manner.
5.3 Development of Activity Proposals

The motion capture activity planning started with the development of three activity proposals. All three proposals described a different facet of STEM that the activity would highlight, the flow of the activity, the storyline, the educational standards for our target audience, identified risks and complications, and a materials budget. The activity proposals can be found in Appendix A. The proposals were then passed along to Dr. Michael Haungs and the Seeds in STEM leadership team which consisted of myself, Jehlia Arriola, and Nishanth Narayan for review and feedback. After collecting feedback a final activity proposal was developed, which can also be found in Appendix A. Some of the alterations and additions made to the proposal include the usage of multiple STEM facets rather than just one, adjusting the story as the story changed for the overall workshop, making the activity more interactive, and mitigating ethical issues.

Instead of discussing the use of motion capture in a singular STEM industry, it was decided that it would be more beneficial to discuss various applications of motion capture in different kinds of STEM industries.

The storyline for the winter 2021 Seeds in STEM workshop had the participants explore a planet on which they had crash-landed, however, the leadership team found that the participants would have an easier time relating to the storyline if it took place somewhere that resembled their hometown. This would open the door to including more aspects of their community and culture in the storyline. So, the storyline of the motion capture activity was altered to have the live demonstration take place in Santa Airam (Maria backward) instead of outer space.
The initial goal for the live demonstration was to allow the participants to put on the motion capture suit and experience seeing their motion on the character model, but after some consideration, it was concluded that due to only having access to one suit there would not be sufficient time allotted to the activity to allow every student the first-hand experience of using the motion capture suit. Moreover, picking one person to be in the suit raises some ethical concerns. Therefore, we reached a solution in which a Cal Poly student would use the suit. By going with this option, we not only circumvent raising ethical issues in this study, but we also provide a role model for the students.

5.4 Activity Storyline

In the motion capture activity students find themselves needing to explore and navigate the Waller Park forest, a real park in Santa Maria, to accomplish the goal of the live demonstration. Moreover, the participants need to navigate the forest with caution as the park in the story is infested with large mutated strawberries, sticky goo, and sprawling vines. Strawberries were chosen to be the fruit that farmers were experimenting with at the beginning of the storyline because our research revealed that the Santa Maria Valley was the leading producer of strawberries\(^1\) and they are distributed both nationally and internationally.\(^2\) Due to this, Santa Marians are very proud of their strawberries and showcase them at the annual Santa Maria Valley Strawberry Festival.

Given that the participants of the workshop were from a particular local community, I expected them to identify with their community along with their own identities

\(^1\)https://santamaria.com/community-profile
\(^2\)https://santamariavalley.com/blog/the-source-of-sweet-strawberries/
such as race, ethnicity, and gender. Therefore, the character that the participants meet and help in the activity storyline is a nonbinary person named Jamie. Jamie is introduced as Santa Airam’s lead chemist who has been trying to find a cure to stop the mutated strawberries from growing. Throughout the workshop the students meet other characters that identify as female or male, so we found it essential to also include a nonbinary character to whom we assigned a unisex name common in the Latinx community. The decision to choose a name that is commonly used in the Latinx community came about due to research demonstrating that more than 65.7% of residents living in Santa Maria identify as being a part of the Hispanic or Latinx community.\(^3\) Due to this, it also felt appropriate and necessary to translate all subtitles accompanying the storyline visuals into Spanish as it is the most commonly spoken language in the Latinx community.\(^4\)

The synopsis of the workshop storyline is the following:

The students find themselves in Santa Airam, an alternate dimension to Santa Maria, but something feels different about this dimension. After asking the Santa Airam community members what happened, they find that the Santa Airam farmers were trying to genetically modify the strawberries so that they would grow year-round, but something went wrong! The strawberries mutated rapidly and spread overnight, next thing the Santa Airam residents knew, the prom venue and all the prom materials were covered in vines and bright sticky strawberry goo registering the prom materials virtually useless! Seeing how upset this made the Santa Airam students, the participants can’t just let the prom be canceled, so

\(^3\)https://datausa.io/profile/geo/santa-maria-ca

\(^4\)https://traveltips.usatoday.com/languages-latin-americans-speak-22661.html
they volunteer to help rebuild the prom venue and material to save the prom!

The workshop participants were acquainted with the workshop storyline and their overall goal after being briefed on workshop logistics and before they were sent to their first activity of the day. The visuals and subtitles used to convey the storyline can be found in Appendix B.

The motion capture storyline is the following:

To stop the spreading of mutated strawberries, so that the community can focus on cleaning and rebuilding efforts, Santa Airam’s lead chemist Jamie is in the process of creating a cure, but they are missing a key ingredient of Chamomile to make the cure work. To make matters worse, it is much too dangerous to leave the beaker with the rest of the ingredients unattended in the lab, therefore, Jamie needs help gathering the last ingredient. This is where the students come in, they agree to help Jamie by retrieving the Chamomile flower for them. Jamie provides the participants with a hazmat suit and reveals to them that a brave volunteer has already offered to wear the suit and go into the Waller Park forest, but that the volunteer still needs the participants’ help to navigate the forest safely.

The motion capture storyline was introduced to the participants through a series of visuals and subtitles displayed on a projector following the pre-activity questionnaire, the visuals can be found in Appendix C.
5.5 Live Demonstration

In addition to the visuals in the presentation, the activity storyline was conveyed through the live demonstration.

The live demonstration started on a “Start Game” screen that instructed the participants on how to navigate the live demonstration scene successfully as can be seen in Figure 5.2.

To complement the storyline introduced by the visuals in the presentation, the live demonstration scene was created using environmental and park assets emulating the Waller Park forest and a 3D character model wearing a hazmat-like suit. The goal put forth for the participants was to navigate the park avoiding obstacles such as strawberries, vines, and goo to reach a chamomile flower, therefore, the scene was adorned with strawberry, goo, and vine assets that obstructed the path to a chamomile flower placed at the end of the scene. If the character does not evade the obstacles, then it will collide and cause the character’s texture material to take on a red hue indicating an incorrect maneuver.

The chamomile asset displays a hover motion and a particle system to draw attention to it, similarly, a water bottle asset found halfway through the scene displays the same hover movement and particle system. The water bottle asset was added to provide an additional object for participants to interact with and to allow them to take a break in their adventure and observe the scene.

A timer was added in the top left corner of the scene to create a sense of urgency and to add a game mechanic. Five minutes were given to retrieve the chamomile flower which testing revealed was plenty of time to reach the end of the scene, this was done
purposefully because the scene was designed to not allow the students to fail as their efforts were to be celebrated despite the outcome.

Figure 5.3 illustrates the assortment of obstacles and park assets, the timer in the top left corner, the character model in the forefront of the scene, the water bottle asset to the right of the character, and the chamomile flower in the background of the scene directly in line with the character.

Once the participants reach and collect the chamomile, an “End Game” screen is displayed to indicate success and to bridge the live demonstration to the interactive presentation, see Figure 5.4.

![Unity scene start screen.](image)

Figure 5.2: Unity scene start screen.
Figure 5.3: Live demonstration gameplay.

Figure 5.4: Unity scene end screen.
The decision to collect data from an activity conducted in the Seeds in STEM spring workshop was logical because the workshop employs the same goals and methods as the motion capture activity; both enable learning through creativity and fun while telling a meaningful story that reflects the importance of culture and community in STEM careers. In other words, teaching and encouraging learning through a STEAM approach.

6.1 STEAM in the Motion Capture Activity

This activity stands as an example of how participants can learn about STEM topics using creative techniques because motion capture relies on the comprehension of computer science and engineering fundamentals. Additionally, because motion capture relies on computer science and engineering knowledge, it also stands as an example of how participants can utilize their current or future STEM knowledge gained at school to positively impact the development of emerging technologies.

Through the use of a STEAM learning approach, participants are acquainted with the fact that applying one’s STEM knowledge is not limited to the conventional science, math, and engineering applications but rather that there are interactive and immersive ways to apply the STEM concepts to creative out-of-the-box products and solutions. For example, via the motion capture technologies presentation, participants learn that an inertial motion capture suit, like the one utilized in the live demonstra-
tion, functions due to the integration of digital components, such as a magnetometer, that operates on physics principles taught in high school and college courses.

6.2 Culture and Community Integration

As previously mentioned, the Seeds in STEM workshop stands out because STEM facets are taught using a STEAM approach to learning. This is done by placing a storyline about culture and community at the center of the workshop and having the STEM activities be the vessels through which the story is told. As a result, the workshop encapsulates STEM learning objectives while emphasizing that STEM is more than just being smart, but that it’s an engaging and fulfilling method by which one can help and positively impact their communities.

The goal of incorporating culture in the storyline is to facilitate student engagement in the activities and visualization of themselves succeeding in the STEM roles the workshop discusses. The diverse set of characters present in the storyline are engineers, scientists, and political figures from Santa Maria. Another way the motion capture activity promote diversity in the storyline is by giving the characters different ethnic backgrounds and unisex names.

6.3 Constraints

Because many variables with the ability to impact the motion capture activity were at play throughout the planning and development stages of the activity, the constraints that were encountered are divided into sections to allow for a dedicated discussion of each. Time constraints are those dictated by limitations to the time dedicated to the workshop and activity. Activity constraints encapsulate those that impose restrictions
on the flow or content of the motion capture activity. Workshop constraints are constraints that affect the workshop as a whole such as room bookings and participant turnout.

6.3.1 Time Constraints

The workshop featured four different activities and was allotted six hours from 10 am - 4 pm to be conducted, therefore, the leadership team needed to tactically allocate time to all four activities, lunch, and a culture/community activity such that every student was able to participate in all the activities. This resulted in each workshop activity being allocated 45 minutes for each rotation. Knowing this time constraint, planning for the motion capture activity began winter quarter in such a way that it would utilize and take advantage of the time allotted to it, without the need to rush or skip over planned features.

6.3.2 Activity Constraints

The first constraint encountered while developing and organizing the motion capture activity was establishing how to operate with only one motion capture suit. This was an issue at the beginning of the planning stage because, as mentioned earlier, initial plans of the activity desired to allow participants to put on the suit themselves. Thus, this constraint would have caused potential timing issues as a fair amount of time would need to be spent on getting participants in and out of the suit, additionally, the suit only came in one size.

Moreover, the Motion Capture Activity Procedure Plan section of Chapter 7, outlines that the volunteer in the motion capture suit was hidden from participants’ view prior to the start of the activity and then brought out and introduced just before
the live demonstration began. Initially, the aspiration for the live demonstration was to have the volunteer hidden for the entire duration of the live demonstration, then revealed and introduced to the participants when it was over. This plan was put in place to create the illusion that the character model was being controlled by prerecorded motion data or animated. We hoped that the illusion would exacerbate the surprise and wonder the participants felt once they were told that the actions were being provided in real-time by a person in the room via an innovative piece of technology. The aim for wanting to evoke wonder in the students arose from the idea that it would increase their enthusiasm to want to learn more about motion capture via the presentation and beyond the workshop. However, the decision to reveal the volunteer before the live demonstration was made due to interference in the KTGY Gallery. Due to the interference, it was best to allow the volunteer to see the screen to ensure that the motion data was reflecting the intended actions in light of the data jitters and skipped frames encountered. Despite the change in activity plans, through observation and the data collected from the questionnaires, the wonder and awe that was anticipated from the participants were still present.

6.3.3 Workshop Constraints

Another constraint encountered later in the development of the workshop was low workshop attendance. The workshop planned to accommodate fifty students, however, due to a conflicting event being held on the same day in Santa Maria and the ongoing COVID-19 pandemic, the total number of students that attended the workshop was thirteen. As a result, the plans for how the workshop was going to operate needed to be altered slightly. Instead of having four groups of students rotating to an activity every hour as initially planned, there were instead two groups of students rotating between the Women in Software and Hardware activity and Society of Civil
Engineers activity in the first half of the workshop, and those same groups rotating between the Motion Capture activity and Mobile Audio Experience activity in the second half of the workshop. The cutback in participant attendance negatively impacts the amount of data collected via the questionnaires as it limits the number of perspectives, opinions, and the presence of trends or shifts in the data.
Chapter 7

IMPLEMENTATION

Motion capture has gained popularity in many industries due to advancements in technologies that have facilitated the use of motion capture and minimized the cost. This section discusses the technical specifications of the Rokoko Electronic motion capture suit as well as a step-by-step guide to how to set the suit up for recreating the mocap activity. Also found in this section is an outline of how the Rokoko suit and the Unity game engine cooperate to execute the motion capture live demonstration. Lastly, this section also discusses all preventative measures taken to mitigate unforeseeable disturbances in the activity.

7.1 Rokoko SmartSuit Pro

Traditional motion capture technologies currently on the market can cost upwards of $100,000+, therefore, Rokoko’s Smart Suit Pro I and II stand out due to their ability to accurately capture motion tracking data for an affordable price of $2,495 for the Pro I and $2,745 for the Pro II.

Both suits come with a “Hub” device used to wirelessly connect to a computer to track data and a waterproof suit cover to allow safe travel with the suit [7]. The Hub is placed on the back of the suit and its main job is to collect all the tracking data from the sensors, fusion it, and live stream it to Rokoko Studio via WiFi. Moreover, the suit is powered by an external power bank that is connected to the Hub with a USB power cable included in the box. Figure 7.1 provides a legend for the various
connections and configurations on the Hub. The power button and the WiFi lights were particularly helpful during testing for the motion capture activity.

![Figure 7.1: Rokoko Hub [7].](image)

The SmartSuit Pro tracks the body’s movement via 19 Inertial Measurement Unit (IMU) sensors that are secured by durable nylon-based fabric. Each of the sensors contains a gyroscope, an accelerometer, and a magnetometer to provide full spatial and rotational tracking [2]. A gyroscope is a device commonly used to maintain a reference direction or provide stability in navigation. A gyroscope is used in smartphones to sense angular rotational velocity and acceleration [4]. An accelerometer is a tool that measures acceleration. An accelerometer is also present in smartphones and is the reason why the phone’s display switches when it is flipped [5]. A magnetometer is a device used to measure the magnitude and direction of a magnetic field, the most omnipresent example being a compass [6].

As the person wearing the suit moves, the suit records data locally to the suit’s Hub (secured to the person’s upper back where a pocket specifically for the Hub can be found). The Hub then delivers the data to a computer with Rokoko Studio Live.
software running (assuming both devices are connected to the same wireless network and the suit was paired with an actor profile during setup).

7.1.1 Rokoko SmartSuit Pro I Specifications

Rokoko is very transparent regarding the specifications and capabilities of their suits on their website. These include but are not limited to, a 6-hour battery life, a unisex design that comes in four sizes: S, M, L, XL (the suit being used in the workshop is a size M), 19 9-DoF\(^1\) IMU motion sensors that have a 3D orientation accuracy ± 1 deg that comes connected to the central Hub and pre-installed in the suit [8].

Regarding connectivity, the suit can communicate with a computer with a speed of 2, 4, and 5 GHz via 802.11ac\(^2\) Wi-Fi wireless networking, a frame rate of 200 FPS, with an approximately 15 ms latency, or delay, and finally a range of 100 meters [8].

Along with the suit, Rokoko developed Rokoko Studio Live, a software that supports plugin interactions for real-time data streaming with various game engines and modeling software such as Unreal, Unity, Blender, Maya, Cimena4D, and more [8]. Figure 7.2 demonstrates the flow of motion data when using a Rokoko Smartsuit to stream data into another application. The Rokoko Smartsuit sends data into Rokoko Studio through the Hub, the data can then be cleaned up manually or by built-in filters, then, with a Rokoko Live plugin, the motion data can be streamed to another computer application. This flow was followed for streaming the motion data from the Rokoko SmartSuit into Unity for the live demonstration of the motion capture activity.

\(^1\)Degrees of Freedom

\(^2\)A WiFi standard established by the WiFi-Alliance to deliver improved speeds, WiFi performance, and better range to keep up with the growing number of users, devices, and data consumption [50].
Lastly, the electronic parts of the suit, such as the Hub and sensors, can easily be removed from the suit making the nylon-based textile suit washing machine safe.

7.1.2 Rokoko SmartSuit Pro I Setup

For stable and constant communication between the SmartSuit Pro and a computer, both devices must be connected to the same WiFi network properly. To do so begin by connecting the USB cable that comes with the suit to a computer that has Rokoko Studio Live running and in Rokoko Studio Live open the WiFi settings panel and verify the information being displayed such as the WiFi network and Receiver IP. Once this information is verified, click “Apply WiFi settings to Smartsuit,” disconnect the USB, and a default actor model should appear. An actor profile is needed to interact with the suit because an actor profile allows Rokoko Studio Live to scale the movements to the actor’s body measurements. To create an actor profile, click the “add object” button located at the bottom right of the project window, then set the measurements with those of the person wearing the suit, assign the actor profile a color to allow for easier tracking, and lastly drag the unpaired SmartSuit
input on the actor profile object to tie them together. Still in Rokoko Studio Live, verify that the location settings are also accurate, if not update them by navigating to account settings, then location settings, and finally verify country and city and apply any changes made. This verification is important to guarantee accurate motion data because the sensors use the Earth’s magnetism via the magnetometer.

To begin utilizing the Rokoko SmartSuit Pro it is important to put on the suit so that it fits tight and the sensors are sitting securely on key locations of the body during movement. It is recommended to be near a wall or an object that can be used for stabilization since there are sensors on both feet that one should be careful not to step on. Once the suit is equipped, have the person wearing the suit standstill in a “straight pose” also known as an I-Pose to calibrate the suit in Rokoko Studio Live. A straight pose consists of standing upright with one’s arms down to the side of the body touching one’s thighs, head pointing forward, and feet pointing straightforward and parallel, this is depicted in Figure 7.3 below. Once the person in the suit is performing the straight pose, one can then press the “perform straight pose” button in Rokoko Studio Live to calibrate the suit. It is the left-most button on the project screen.

A critical step to setting up and calibrating the suit is making sure there is no magnetic interference. Once the calibration is performed the Smartsuit Pro will provide feedback on potential magnetic interference for each of the nineteen sensors. In the Studio Diagnostics panel, interference will be indicated by a red sensor and no interference will be indicated with a green sensor. It is recommended to aim for 75% or more green sensors for data accuracy. This can be achieved by avoiding being within 3-6 feet of large steel or iron objects and devices that create local magnetic fields, see Figure 7.4.
Figure 7.3: Straight pose (I-Pose).
After the SmartSuit is set up and communicating with Rokoko Studio Live, data capturing can begin and the captured data can be exported for use in the game engines or modeling software mentioned above.

7.2 Live Demonstration Scene Implementation in Unity

The Unity game engine was utilized to create the scene for the live demonstration. Unity was the preferred game engine to achieve the activity’s goal because it supports a Rokoko Live plug-in for syncing and streaming Rokoko Studio real-time data into a Unity scene. All that was needed was a Rokoko Studio Plus subscription, enabling Live Streaming in Rokoko Studio, and importing the Rokoko Live plugin into the Unity Project from the Unity asset store. The Rokoko Live plugin makes getting started with live streaming motion data extremely easy as it contains two sample scenes, character models, a scene manager game object, and scripts containing wrap-
pers for mapping all parameters and data from Rokoko Studio to Unity, removing the need for the user to do further set up beyond importing the asset. However, if the user did want to inspect the wrapper code, Unity facilitates this and reflects changes made by the user. Figure 7.5 depicts one of the sample scenes, `RokokoPluginExampleScene`, that is provided by the Rokoko Live plugin, it maps the actor model from Rokoko Studio into the Unity scene via a `SceneManager` game object and script. The `SceneManager` game object can be seen in the Hierarchy tab on the left and the `SceneManager` script can be seen in the Inspector tab on the right. The `SceneManager` script includes parameter fields for specifying which actor model the motion data from Rokoko Studio should map to (in the sample scene the default is a sample actor model named “Netwon” provided by the plugin). Lastly, in the Project tab on the bottom left of the figure the content of the Rokoko Live plugin can be found.

![Image](image)

Figure 7.5: Rokoko Studio data mapped into Unity scene via the Rokoko Studio Live Unity Plugin.
The scene features a skybox, a humanoid character model, environmental and park assets, start and end game screens, and a timer all pictured in Figure 5.3. All game assets present in the Unity scene were free assets found online from various 3D modeling websites, but mainly the Unity asset store. Similarly, code samples were also used to create some of the game mechanisms in the scene and they are credited via comments at the bottom of the C# script, the code samples can be found in Appendix G.

7.3 Motion Capture Activity Procedure Plan

A motion capture activity procedure plan was designed to confirm that everything needed for the activity was properly set up, to minimize the workload during the activity, to guarantee the activity ran smoothly, and to properly collect and analyze participant data. The procedure plan was executed in three phases, a pre-activity phase, an activity phase, and a post-activity phase to organize and break down tasks.

7.3.1 Pre-Activity Experiment Phase

The motion capture activity is heavily reliant on various pieces of computer software and technology. Therefore, many tasks that can be categorized as setup and not the part of the activity itself were done prior to the activity in preparation. These tasks are outlined below and they include downloading the necessary Rokoko and Unity software and performing calibrations and testing the motion capture suit.

- Download Unity
- Download Rokoko Live Studio
• Import Rokoko Plugin into Unity Project from the asset store and import Unity Live plugin in Rokoko Studio.

• Create a Unity scene for the volunteer in the motion capture suit to interact with, also where participants can observe a character model on which the motion data is mapped to

• Open the specified Unity Project with the Unity scene

• Open Rokoko Studio Live application and enable Unity Live Stream

• Set up WiFi and connect the computer running Rokoko Live Studio to it

• Get the student volunteer in the suit

• Perform a calibration

7.3.2 Activity Experiment Phase

The tasks that were carried out during the activity, meaning from the moment participants walked into the KTGY gallery until the moment they exited to attend another workshop activity, are outlined in this phase of the procedure. These include the introduction of the interactive presentation and the performance of the live demonstration.

• Have participants fill out the pre-activity questionnaire

• Present the activity storyline

• Reveal and introduce the student volunteer in the suit

• Transition to the motion capture scene; Let the participants take in what they are observing and perform a live demonstration with the motion capture suit.
• Present interactive presentation to the participants introducing motion capture technologies, their applications, and real-world examples.
• Have participants fill out the post-activity questionnaire and thank them for their time and participation.

7.3.3 Post-Activity Experiment Phase

The motion capture activity was accompanied by two questionnaires in order to formally collect data from the participants. Data was obtained through activity questionnaires, overall workshop questionnaires, and visual and verbal feedback collected during and after the activity. How the data was used after the workshop is outlined in this phase.

• Sort and categorize the data collected
• Analyze data
• Make conclusions based on the data analysis
• Discuss conclusions and what they reveal about the research questions and hypothesis made.

7.3.4 Motion Capture Activity Questionnaires

As previously mentioned, the activity was accompanied by two questionnaires for participants to fill out before and after the activity. The questionnaires served as the method through which data was collected and analyzed to gauge how the activity impacted the participants. Explicitly, through the questionnaires, we hoped to detect a positive shift in participant attitudes regarding the kinds of STEM careers and
the possibilities within them. Moreover, they aid in observing participant attitudes, ideas, and motivation before and after the activity in regards to STEM creativity and the impact of emerging technologies as a tool for learning.

7.3.5 Preventive Measures

If any technical complications were encountered with the suit, Unity, or Rokoko Studio Live, then valuable time allocated to the activity would be lost. To combat this, many iterations of testing were performed beforehand to catch any technical complications that may occur and develop a plan to resolve them. An extensive procedure plan was created to follow during the activity and can be found in the Motion Capture Activity Plan section above. Moreover, any downloads that don’t directly add to the activity and learning outcomes were done beforehand in the pre-activity experiment procedure. Lastly, more than one laptop with Unity and Rokoko downloaded and set up was present during the activity in case of technical difficulties and to allow for quick device changes.

7.3.5.1 User Testing

Extensive user testing of the motion capture live demonstration and the suit was done prior to the workshop. Testing occurred in various locations and with different people in the suit to test different actor profiles within Rokoko Studio. Several actions including running, jumping, and colliding with objects were tested to examine the extent of what was possible in the scene that was used for the live demonstration. Additionally, a full run-through of the activity was carried out a week before the workshop which led to the awareness of technical issues exclusive to the location of the activity.
Three different forms of assessment were administered for measuring the impact that the motion capture activity had on the participants. The first set of data was collected via the activity questionnaires which surveyed the participants on topics exclusively related to the activity and STEM education. The second set of data stems from the overall workshop questionnaires which inquired about participants’ confidence to succeed in STEM, interest in pursuing a STEM career, and experience participating in the workshop. Additionally, data was collected through visual and verbal observation in the form of participants’ reactions and by engaging in conversations with them during and after the activity.

8.1 Data Collection

The motion capture and workshop questionnaires were offered to the students in English and Spanish due to the aforementioned focus on making the students feel welcomed and included. The questionnaires filled out by the students during the motion capture activity can be found in Appendix D and photography taken during the activity can be found in Appendix F.

The motion capture pre-activity questionnaire featured four questions in total: one yes/no, two Likert scale questions, and one fill-in-the-blank. Similarly, the motion capture post-activity questionnaire had four questions in total: three Likert scale questions and one fill-in-the-blank. The pre-workshop questionnaire contained seven
Likert scale questions and the post-workshop questionnaire had seven Likert scale questions, two yes/no questions, and three fill-in-the-blank questions.

The purpose of the questionnaires is to gauge student attitudes about STEM as a discipline and aid in observing any shift in perceptions of what a STEM field and career entails.

8.2 Motion Capture Activity Questionnaires Data Analysis

Thirteen students filled out the motion capture pre-activity questionnaire and twelve filled out the post-activity questionnaire, due to this one of the pre-activity questionnaires was omitted from the analysis, resulting in a total of twelve responses being used to draw conclusions about the activity. Thirteen students filled out the Likert scale questions on both the pre and post-workshop questionnaires, but some students excluded responses for the yes/no and free response questions in the post-workshop questionnaire.

8.2.1 Pre-Activity Questionnaire Data Analysis

The first question in the pre-activity questionnaire asked participants whether they were familiar with or had prior exposure to motion capture. This question discloses how much of a foundation regarding motion capture participants had preceding the motion capture activity. Figure 8.1 shows that a majority of participants, 61.5%, were familiar with motion capture, while 38.5% had no prior exposure to the technology before attending the workshop. While formalizing the activity questionnaires, I anticipated that the majority of participants would indicate that they were not familiar with motion capture as it is an emerging technology that is used behind the
scenes in a myriad of industries and it is not one commonly discussed in school. The results may indicate that students are being exposed to innovative technologies that assist in creating the media that they are exposed to daily, meaning when relating motion capture to these same pieces of media in the activity, it might have been more impactful or relatable.

Additionally in the pre-activity questionnaire, participants were asked how much they enjoyed the way STEM is taught in school, this question aimed to determine if students were put off by STEM due to the way it is taught in everyday classrooms. Data shows that all participants were either neutral or liked the way STEM is taught, this can be seen in Figure 8.2. These results demonstrate to us that most participants are not discourage from learning about STEM due to the way it is taught in school.

![Figure 8.1: Level of participants’ prior exposure to or knowledge of motion capture.](image)

8.2.2 Post-Activity Questionnaire Data Analysis

The first question of the post-activity questionnaire solicits participants to rank how interested they are in learning more about motion capture or similar technologies on
Figure 8.2: Breakdown of participants’ satisfaction with the way STEM is taught in school.

a 5-point scale. Five participants indicated that they are very interested in learning more, six indicated they are interested, and one participant expressed almost no interest in learning more. These results demonstrate that at least 91.66% are somewhat interested in learning more. The resulting breakdown can be observed in Figure 8.4. A majority of the participants likely indicated that they were interested in learning more because they were in awe of the technologies and the possibilities it enables. Conversely, one of the participants likely indicated that they were not interested because technology, engineering, or computer science isn’t the facet of STEM they are interested in exploring or the activity did not touch on topics that interest or personally impact the participant.

The second question asks participants to rate their opinion on the following statement, “The motion capture activity piqued my interest in STEM careers in ways that other STEM education activities have not.” Five participants indicated that they agree,
four were neutral to the statement, and two said they strongly agree. Overall, the activity either positively impacted the participants or not at all, but no one was negatively impacted. These results suggest that this workshop incorporated emerging technologies in an activity in a way that it engaged the participants more or the same as other ordinary STEM-based workshops that the participants have attended, but not less. See Figure 8.3 for the data categorization.

![Graph showing data categorization](image)

**Figure 8.3:** Arrangement of participants’ opinions of the motion capture activity compared to other STEM education workshops following the activity.

### 8.2.3 Duplicate Questionnaire Questions Data Analysis

Two questions were featured in both the pre- and post-activity questionnaires to detect any shifts and/or changes in the options and perceptions of the participants.

The first question asked participants how creative they regard STEM to be. In the pre-activity questionnaire, 58.33% of participants marked STEM as very creative and
the remaining 41.67% identified it as a 4 on a 5-point scale which equates to simply being creative. This demonstrates that before the motion capture activity participants already consider STEM as creative based on their prior experiences and exposure. The post-activity questionnaire reveals a shift toward STEM being even more creative as 83.33% of participants denoted it as very creative and 16.67% as creative. This shift suggests that introducing a broader range of STEM careers through the use of motion capture can lead to a positive change in perceptions of STEM in at least 25% of students. The percentages can be found in Table 8.1 and a visual representation of the shift can be seen in Figure E.1.

In the second question, participants were asked to list three jobs that involve STEM. This question aims to observe a shift in responses as it is likely most students will list traditional careers associated with STEM such as engineer, scientist, and programmer considering they have a lot of exposure to these fields in school, but only get intro-
duced to STEAM fields and careers through participation in afterschool programs and workshop such as this one. Responses to this question before participating in the activity were sorted into buckets of traditional, creative, and other careers, these can be seen in Figure 8.5. Similarly, responses to this question after subsequent participation in the activity were sorted into buckets of the same categories, these can be found in Figure 8.6. These buckets provide a visual representation of the data collected and reveal an observable shift of participants’ listing predominantly traditional careers before the activity, to listing a more balanced mixture of traditional and creative careers after the activity.

Table 8.1: Breakdown of how creative participants regarded STEM before and after the activity.

<table>
<thead>
<tr>
<th>How creative do you think STEM careers are?</th>
<th>Not Creative 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 Very Creative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Activity Questionnaire</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>41.67%</td>
<td>58.33%</td>
</tr>
<tr>
<td>Post-Activity Questionnaire</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>16.67%</td>
<td>83.33%</td>
</tr>
</tbody>
</table>

Figure 8.5: Categorization of jobs participants identified as involving STEM before the activity.
8.3 Workshop Questionnaires Data Analysis

Despite the workshop questionnaires not inquiring about any of the activities individually, many of the questions featured in the questionnaires are still relevant to the motion capture activity data analysis as they still provide some insight into the impact and influence of the activity.

One question prompted the participants to select the activity they enjoyed the most and to provide an explanation. Figure 8.7 displays that five participants selected the motion capture activity as the activity they enjoyed the most, five selected one of the other three activities, two participants did not respond, and one indicated that they enjoyed all the activities equally. The responses to this question show that the number of participants that enjoyed the motion capture activity the most, is equal to the sum of participants that enjoyed one of the other activities. Explanations as to why the participants choose the motion capture activity can be compiled into three categories. Some participants stated that they chose motion capture because it was fun and interesting, others stated they chose motion capture because it relates to or
impacts something they enjoy, and others stated they chose motion capture because they learned something new, see Table E.1.

Another pertinent question featured in the workshop questionnaires asks how interested participants are in pursuing a career in STEM. Responses in the pre-workshop questionnaire ranged from a neutral interest to very interested with 76.92% indicating they were interested or very interested in pursuing a career in STEM. This same question in the post-workshop questionnaire had 100% of participants indicate they were interested or very interested. In other words, those participants that were unsure about their interest in STEM before participating in the workshop had their doubts, skepticism, and/or bias positively influenced so much so that by the end of the day they were certain in their interest to want to pursue a career in STEM. A visual representation of this shift is exhibited in Figure 8.8. The heightened interest in pursuing a career in STEM is accompanied by an increase of confidence in their ability to succeed in a STEM career evident by the responses to the question “How confident do you feel in your ability to succeed in a STEM career,” observable in Figure 8.9.

Through the workshop questionnaires, the effects of integrating storyline, culture, and community into the workshop were measured. Participants were asked if they saw their culture and/or community reflected in the workshop, 61.54% responded yes, 7.69% responded no, and 30.77% did not provide a response, see Figure 8.10. These percentages suggest that a majority of the participants recognized some traits of their culture and/or community integrated within the workshop. As mentioned in the introduction, the lack of role models in STEM industries deters underrepresented groups from participating in STEM, hence we incorporated details of the participants’ culture and community in the workshop to guide the participants into perceiving themselves as belonging in STEM roles. Although it is not conclusive whether the
integration of the participants’ culture and community contributed to the responses in the questionnaires, the follow-up question “If yes, did seeing your culture/community reflected in the workshop make you feel more comfortable doing STEM activities,” included in Figure 8.11, does indicate a slight increase in comfort to get involved in STEM activities since 6 out of 8 or 75% respondents chose yes.

![Figure 8.7: Breakdown of which activity participants enjoyed the most.](image)

8.4 Overall Assessment

These primarily positive results perhaps point to the fact that employing emerging technologies such as motion capture in STEM workshops can have a beneficial impact on participants. This is evident not only from the results discussed in this chapter, but from the visual and verbal responses I was able to gather while conducting the motion capture activity. Throughout numerous points of the activity, the participants were in awe discernible by their audible gasps and laughs while they smiled and stated
Figure 8.8: Level of participants’ interest to pursue STEM before and after the workshop.
Figure 8.9: Level of participants’ confidence to succeed in a STEM career before and after the workshop.

Figure 8.10: Disposition of participants’ perception of their culture and community in the workshop.
Figure 8.11: Distribution of whether the integration of culture and community had an impact on participants.

notions such as “This is so cool!” Moreover, due to spare time at the end of the activity, we revisited the live demonstration scene to test what more the motion capture suit was capable of and I was met with a constant stream of questions about the motion capture suit, which further indicates interest.

In general, this activity has shown that conducting STEM workshops that make use of STEAM teaching principles and emerging technologies can encourage participants to see STEM topics as being creative, applied in creative industries, or able to be addressed through creative solutions. Furthermore, these workshops could spark curiosity in learning more about these or similar technologies.

These workshops offer exposure to the different ways STEM can be taught. Participants communicated that they enjoy the way STEM is currently taught in school, but they also indicated that they enjoyed the workshop and want to learn more about the technologies introduced. Therefore if executed correctly, meaning the workshop takes advantage of emerging technologies in a meaningful and impactful way, then they could potentially motivate the participants to begin perceiving STEM as creative or being able to lead to creative careers. Responses to the questionnaires reveal some
of the participants enjoyed the motion capture activity because it was relatable and impacted something meaningful to the students. Hence, to ensure that these STEM workshops are meaningful and impactful it would be valuable to relay how STEM topics impact the participants’ community, hobbies, or daily lives.
Chapter 9

RECOMMENDATIONS

The feedback, data, and results discussed in the previous chapter, promoted recommendations for further improving the effectiveness of the motion capture activity. This chapter outlines points of improvement and recommendations for both the live demonstration and the interactive presentation.

9.1 Live Demonstration

In the days leading up to the workshop, some game design features incorporated into the Unity scene had to be omitted from the final scene used in the activity due to unprecedented difficulty navigating the scene from the point of view of the volunteer in the motion capture suit.

Additionally, due to interference in the room, the motion data collected from the Rokoko suit was not being updated and mapped onto the character model every frame. Thus at times, the model’s motions were delayed resulting in the model’s position being inaccurate. Consequently, when the volunteer in the motion capture suit moved a large distance in the room, the model only moved a few steps in the scene, ultimately preventing the volunteer from colliding with the chamomile at the end of the scene map. This issue prevented the participants from seeing the “End Game” banner. Fortunately, following the live demonstration a storyline visual thanked and congratulated the participants for their efforts in helping the character in the storyline despite not physically reaching the chamomile game object.
While testing and performing the live demo in the gallery, Rokoko Studio repeatedly displayed a “Poor data detected” warning message, see Figure 9.1, and a warning symbol indicating the suit was being exposed to magnetic interference, this symbol is shown in Figure 9.2. This was not expected by the Seeds in STEM leadership team. As mentioned in Chapter 5, the gallery was specifically chosen for the motion capture activity due to its size and vacancy. After receiving this warning message countless times during testing in the gallery it was decided that it would be a good idea to look into using another room. From this, the leadership team considered using Bonderson 104 as it was the second largest room booked for the workshop that wasn’t going to be in use during the event by another activity. Unfortunately, there was a mishap in the room bookings and the leadership team never received the access code to the room, so it was unavailable during the workshop.

![Figure 9.1: Rokoko Studio - poor data detected message.](image)

Despite the live demonstration not going as planned, through observation I can confidently state that it did not take away from the experience or the purpose of the
Figure 9.2: Rokoko Studio - magnetic interference on suit.

demonstration as the participants were still able to see what the motion capture can do and how it impacted the scene.

To prevent unpredictable room interference from impacting an activity, it is recommended to test the suit with a sample scene for possible magnetic interference in a room before finalizing a location for the activity (as well as booking a backup room). Moreover, including a button or feature in the Unity scene responsible for transporting the model immediately to the goal item is recommended to allow the students to experience all intended game features such as the end game banner.

9.2 Presentation

Another aspect of the activity that was not anticipated was that in one of the sections the participants were hesitant to share their ideas or engage with the interactive questions asked throughout the presentation. It is to be expected that some of the participants may have some reservations about participating since they are in a new setting surrounded by students that they do not know. For the presentation, planning alternative ways to engage the students while not compromising the reputation they wish to uphold around their peers is recommended to keep them interested.
Hosting STEAM-based activities at different schools or afterschool programs for various target audiences is recommended based on the observable feedback from the participants and the data collected. If more activities such as the motion capture activity are carried out, it is recommended that the organizers conceptualize more ways in which the students can interact with both the scene and the actor in the suit. In the motion capture activity, the students were sat in their chairs for the entirety of the activity and were restricted to observation, which they still seemed to enjoy. While the results of this activity were still positive it is likely that if the participants played a larger role in the activity the response would be even more telling. For instance, the responses to the question, “The motion capture activity piqued my interest in STEM careers in ways that other STEM education activities have not” could shift towards a more affirmative consensus if the activity was made more interactive.

Workshop data revealed that the incorporation of culture and community through a storyline did not greatly impact how participants engaged in and learned during the activities. Therefore, emphasizing the correlation between the storyline and the activity to further highlight how STEM topics can be learned in an entertaining artistic way could lead to greater engagement and is worth testing in a future iteration of the activity. Additionally, brainstorming how to better integrate culture and community such that it does impact one’s experience in the workshop is highly recommended.
Expanding on the emerging technologies explored in the activity can also potentially lead to notable engagement or interest in STEM topics and/or approaches to learning STEM topics.

Additionally, implementing and making use of a scene that contains more game design features is a recommendation made based on the limited ways the participants and the volunteer wearing the suit were able to interact with the Unity scene utilized for the live demonstration.

Studies have found evidence that having diverse instructors favorably assists in fostering a successful learning environment for students [25]. Although the Seeds in STEM workshop had a diverse set of activity leads for the spring iteration, it was not explicitly stated to the student, and considering the impact was out of scope for this research. Therefore, it would be an indicative factor to explore in a future workshop alongside a STEAM-based learning approach and the application of emerging technologies.

In order to support the integration of emerging technologies in a classroom setting, one should consider the use of professional development programs to improve teacher confidence and tool proficiency, as well as, breaking down restricting views regarding the role of technology in the classroom for learning [31]. This is due to the fact some studies point to poorly prepared or versed teachers as impeding emerging technologies from having a considerable impact on students [35].
There is reason to be concerned with the insufficient number of STEM professionals entering the workforce and the limited skills they are acquiring. Many contemporary STEM workshops and programs with a mission to augment the volume of future STEM professionals to fill the rising number of STEM jobs exclusively use a STEM learning approach, which is insufficient to properly prepare K-12 students with the skills needed for a successful career in STEM. Underrepresented minorities are further disadvantaged because not only are they also lacking critical skills to be successful, but they are also not being acquainted with STEM in a personalized and meaningful manner that evokes self-efficacy in their ability to succeed in a STEM role. Cultivating a diverse workforce and instilling interdisciplinary skills can prepare STEM professionals that are ready to positively affect the current and future economy of the United States.

In aims to address the concerning statistics regarding the lack of individuals interested in and pursuing STEM careers, especially in regards to underrepresented minorities, as well as, the incomplete skillset provided by current attempts in recruiting individuals into STEM, this paper explored the use of motion capture as a method of adopting a STEAM learning approach that makes use of story, culture, and community as tools to engage participants, make STEM topics personable and relatable, demonstrate a broader set of STEM careers, and shift perspectives of STEM in a more positive light. Although no data can be analyzed to determine how many students that participated in the workshop will pursue a major or career in STEM, the results from the workshop
demonstrate an overall interest from students to learn more about STEM facets and careers. Simply planting the seed of wanting to learn more is significant. Now, the students at a minimum have exposure and knowledge of the possibilities and communities within STEM and can make a more informed decision about whether to pursue a career in STEM.

It can be concluded that the research question introduced at the beginning of the paper correctly proposed that presenting how motion capture is used in real-world STEM careers and demonstrating a live motion capture activity does neutrally if not positively, impact the perceptions of STEM careers after introducing applications in creative industries.

Encompassing a STEAM educational approach and integrating emerging technologies into workshops aiming to introduce STEM to students, demonstrates the substantial connection between STEM subjects and the arts, in other words, it conveys to the participants that they don’t need to decide whether to explore STEM or the arts, as there are roles in STEM industries where one interacts with both.
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[53] H. Wu, S. Lee, H. Chang, and J. Liang. Current status, opportunities and challenges of augmented reality in education. *Computers and Education*, 62:41–49, 2013. Funding Information: This study was based upon work supported by the National Science Council of Taiwan under NSC 100-2511-S-003-041-MY3 and the Aim for the Top University Project at the National Taiwan Normal University. We would like to thank Dr. Chin-Chung Tsai for his help and thoughtful comments on the paper.

APPENDICES

Appendix A

MOTION CAPTURE ACTIVITY PROPOSALS

First Motion Capture Activity Proposal

Second Motion Capture Activity Proposal

Third Motion Capture Activity Proposal

Final Motion Capture Activity Proposal
One foggy April morning, we just woke to find that we were in an alternate dimension of home known as Santa Airam. Everything seems to be the same, but something feels a little bit different.

**Figure B.1: Workshop participants are introduced to Santa Airam.** Through this visual we are conveying to the participants that they are no longer in the Santa Maria that they know, but one in an alternate dimension.
After going outside and asking the Santa Airam community members what’s happened, we find out that the Santa Airam farmers were trying to genetically modify the strawberries so that they would grow year-round since it’s our #1 crop, but something went wrong!

Figure B.2: Workshop participants are told about the farming disaster. This visual conveys the farming disaster that occurred in Santa Airam prior to their arrival.
Now there are giant mutant strawberries, goo, and vines everywhere. But oh man, today is supposed to be our prom! Santa Airam’s Mayor Pat said our venue and materials got covered in strawberries and can’t be used anymore.

Figure B.3: Workshop participants are introduced to Mayor Pat and the prom dilemma. This visual introduces Mayor Pat (a play on Santa Maria’s actual mayor, Mayor Alice Patino) and the dilemma that the community has encountered.
We can’t just let all the prom planning go to waste, let’s take today to go around Santa Airam to find out how we can help and if we can save Santa Airam’s prom!

**Figure B.4: Workshop participants are given their call to action.**
The visual sets the theme of the workshop and provides the participants with the call to action of providing aid to the community of Santa Airam in order to save their prom as they make their way through the workshop.
Appendix C

MOTION CAPTURE ACTIVITY STORYLINE VISUALS

Everyone, meet Jamie! Jamie is Santa Airam’s Lead Chemist and ever since the mutated strawberries began encroaching on the town they have been working on a science experiment to find a cure to stop the mutated strawberries from growing, so the community can focus on cleaning up and rebuilding the town in preparation for prom! / ¡Todos, conozcan a Jamie! ¡Jamie es el químico principal de Santa Airam y desde que las fresas mutadas invadieron la ciudad ha estado trabajando en un experimento científico para encontrar una cura que detenga el crecimiento de las fresas mutadas, para que la comunidad pueda concentrarse en limpiar y reconstruir la ciudad en preparación para el baile de graduación!

Figure C.1: Participants are introduced to Jamie and their work.
The problem is that they are missing Chamomile, a critical ingredient for the experiment to work! To make matters worse, they can’t leave the beaker with the rest of the ingredients unattended, it is much too dangerous! That’s why we’re here, we are going to go into the Waller Park forest where Chamomile can be found and retrieve it for them! / ¡El problema es que le falta la manzanilla, un ingrediente crítico para que el experimento funcione! ¡Para empeorar las cosas, no puede dejar el vaso de precipitados con el resto de los ingredientes desatendido, es demasiado peligroso! ¡Es por eso que estamos aquí, vamos a ir al bosque de Waller Park donde se puede encontrar la manzanilla y recuperarla para ellos!

Figure C.2: Jamie explains the goal of the live demonstration to participants.

One last thing to know before we go in... Jamie provided us with a hazmat suit for protection since the forest has been taken over by mutated strawberries, sticky goo, and sprawling vines! / Una última cosa que debemos saber antes de entrar... ¡Jamie nos proporcionó un traje de protección contra materiales peligrosos ya que el bosque ha sido invadido por fresas mutadas, lio pegajoso, y enredaderas en expansión!

Figure C.3: Jamie introduces the volunteer in the motion capture suit.
Great job! You successfully got the Chamomile for Jamie! / Buen Trabajo. ¡Has conseguido la manzanilla para Jamie!

Jamie was able to successfully add it to their antidote and stop the mutated strawberries from growing more! / ¡Jamie pudo añadirlo con éxito a su antidoto y evitar que las fresas mutadas crecieran más!

Figure C.4: Participants are thanked for their help after the live demonstration.
Appendix D

MOTION CAPTURE ACTIVITY QUESTIONNAIRES
Grade Level: ________________

Directions: Please fill this survey out **before** completing the motion capture activity.

1. Are you familiar with what motion capture is?
   
   Yes / No

2. How much do you like the way STEM (science, technology, engineering, and mathematics) is taught in school?
   
   High Dislike 1 2 3 4 5 Highly Like

3. How creative do you think STEM careers are?
   
   Not Creative 1 2 3 4 5 Very Creative

4. List 3 jobs that involve STEM?
   
   1. ________________________________
   
   2. ________________________________
   
   3. ________________________________
Directions: Please fill this survey out after completing the motion capture activity.

1. How interested are you in learning more about motion capture or similar technologies?
   Not interested 1 2 3 4 5 Very Interested

2. Rate your opinion on the following statement: This motion capture activity piqued my interest in STEM careers in ways that other STEM education activities have not.
   Strongly Disagree 1 2 3 4 5 Strongly Agree

3. How creative do you think STEM careers are?
   Not Creative 1 2 3 4 5 Very Creative

4. List 3 jobs that involve STEM?
   1. ______________________________________
   2. ______________________________________
   3. ______________________________________
MOTION CAPTURE PRE-SURVEY

Nivel de Grado: ________________

Instrucciones: Por favor, rellena esta encuesta antes de completar la actividad.

1. ¿Conoces lo que es la captura de movimiento?
   Sí / No

2. ¿Cuánto te gusta la forma en que se enseña STEM (ciencia, tecnología, ingeniería y matemáticas) en la escuela?
   Me disgusta mucho 1 2 3 4 5 Me gusta mucho

3. ¿Qué tan creativas crees que son las carreras STEM?
   No Creativas 1 2 3 4 5 Muy Creativas

4. ¿Enumere tres trabajos que involucran STEM?
   1. __________________________
   2. __________________________
   3. __________________________
Instrucciones: Por favor, rellena esta encuesta después de completar la actividad.

1. ¿Qué tan interesado estás en aprender más sobre la captura de movimiento o tecnologías similares?

   No Interesado  1  2  3  4  5  Muy Interesado

2. Califica tu opinión sobre la siguiente afirmación: Esta actividad de captura de movimiento despertó mi interés por las carreras STEM de una manera que otras actividades educativas de STEM no lo han hecho.

   Totalmente de desacuerdo  1  2  3  4  5  Totalmente de acuerdo

3. ¿Qué tan creativas crees que son las carreras STEM?

   No Creativas  1  2  3  4  5  Muy Creativas

4. ¿Enumere tres trabajos que involucran STEM?

   1. ___________________________________________

   2. ___________________________________________
      ___________________________________________

   3. ________________
Table E.1: Themes to the free responses to why motion capture was enjoyable.

<table>
<thead>
<tr>
<th></th>
<th>Fun/Interesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Motion capture because the ways it worked were very interesting”</td>
<td></td>
</tr>
<tr>
<td>Relates to or impacts something they like</td>
<td></td>
</tr>
<tr>
<td>“Mocap because it is what makes up most movies and video games”</td>
<td></td>
</tr>
<tr>
<td>“I enjoyed the motion capture, presentation was good and relatable”</td>
<td></td>
</tr>
<tr>
<td>Learned something new</td>
<td></td>
</tr>
<tr>
<td>“Motion capture - I learned a lot of new things”</td>
<td></td>
</tr>
</tbody>
</table>
Appendix F

PHOTOS FROM THE MOTION CAPTURE ACTIVITY

Figure F.1: Introducing participants to the storyline.
Figure F.2: Live demonstration.
Figure F.3: Discussing hand motion capture.
Figure F.4: Introducing real-world examples.
Figure F.5: Exploring applications of motion capture in sports medicine.
Figure F.6: Exploring applications of motion capture in video games.
Appendix G

UNITY SCENE CODE

Listing G.1: Enables a hover motion on the item this script is attached to. This script was placed on the chamomile to indicate the goal direction and destination and the water bottle to indicate an opportunity to take a break.

// Collectables.cs
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class Collectables : MonoBehaviour
{
    Vector3 pos;

    void Update()
    {
        Hover();
    }

    void Hover()
    {
        pos = gameObject.transform.position;
        pos.y = pos.y * 0.3f * Mathf.Cos(Time.time) + 2.0f;
        gameObject.transform.position = pos;
    }
}
Listing G.2: Enables the player to collect items by colliding with them. After a player collides with an item the item disappears from the scene to simulate collection and a cheerful music snippet is played to indicate success.

// CollisionDetection.cs
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;
public class CollisionDetection : MonoBehaviour
{
    private Vector3 initPosition;
    private Color OriginalColor;
    [SerializeField] Image WinScreen;
    [SerializeField] Renderer rend;

    void Start()
    {
        // Save starting position and original material color
        initPosition = gameObject.transform.position;
        OriginalColor = rend.material.color;
    }

    void OnCollisionEnter(Collision collision)
    {
        if (collision.collider.CompareTag("Obstacle"))
        {
            StartCoroutine(ChangeMaterialColor());
        }
    }
}

else if (collision.collider.CompareTag("Ingredient"))
{
    // Disable flower gameobject to simulation collection
    collision.transform.parent.gameObject.SetActive(false);
    // Play collected item audio clip
    this.GetComponent<AudioSource>().Play();
    // Freeze scene and Display Win Message
    Time.timeScale = 0f;
    WinScreen.gameObject.SetActive(true);
}
else if (collision.collider.CompareTag("Water"))
{
    // Disable water gameobject to simulation collection
    collision.transform.gameObject.SetActive(false);
    // Play collected item audio clip
    this.GetComponent<AudioSource>().Play();
}
}

IEnumerator ChangeMaterialColor()
{
    // Set material color to red to simulate damage
    rend.material.color = Color.red;
    // Wait for 0.6 seconds
    yield return new WaitForSeconds(0.6f);
    // Set material color to original color
    rend.material.color = OriginalColor;
}
Listing G.3: Enables the game camera to follow the player around the scene.

// FollowPlayer.cs
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class FollowPlayer : MonoBehaviour
{
    private GameObject rig;
    private Vector3 rigPos;
    private float speed;

    void Start()
    {
        speed = 2.0f;
        rig = GameObject.Find("mixamorig:Hips");
    }

    void Update()
    {
        // Move camera target to rig position
        rigPos = new Vector3(rig.transform.position.x,
            transform.position.y, rig.transform.position.z);
        transform.position = Vector3.Lerp(transform.position, rigPos, speed
            * Time.deltaTime);
    }
}
Listing G.4: When the scene is first started up this script freezes it and displays a “Start Game” screen (this screen can be seen in Figure 5.2) to provides the player with hints on how to complete the game goal. Once the player is ready they can press the “Start” button and the scene unfreezes and the start game scene is disabled.

```csharp
// SceneManager.cs
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;

public class SceneManager : MonoBehaviour
{
    [SerializeField] Button startGame;

    private void Awake()
    {
        Time.timeScale = 0f;
    }

    private void OnEnable()
    {
        startGame.onClick.AddListener(StartGame);
    }

    private void OnDisable()
    {
        startGame.onClick.RemoveListener(StartGame);
    }
}
```
private void StartGame()
{
    Time.timeScale = 1f;
}

Listing G.5: The motion data captured by the Rokoko motion capture suit is relative to the real-world, therefore, to allow the volunteer in the motion capture suit to travel forward within the confines of the KTGY gallery movement on the z-axis is simulated by making the scene move towards the character via this script. The scene stops moving once the player is near the chamomile asset.

// SmoothTravel.cs
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class SmoothTravel : MonoBehaviour
{
    private bool Move;
    private Vector3 Destination;
    private Vector3 Origin;
    private float totalMovementTime; //The amount of time you want the movement to take
    private float currentMovementTime; //The amount of time that has passed
    private float speed;

    void Start()
    {
    }
Move = false;
Destination = Origin = transform.position;
Destination.z -= 158;

totalMovementTime = 100.0f;
currentMovementTime = 0.0f;
speed = 1.0f;

}  
void Update()
{
    if (Input.GetKeyDown(KeyCode.Space))
    {
        Move = !Move;
    }

    if (Move)
    {
        moveObject();
    }

    //Increase speed
    if(Input.GetKeyDown(KeyCode.RightShift))
    {
        speed += 0.1f;
    }

    //Decrease speed
if(Input.GetKeyDown(KeyCode.LeftShift))
{
    if (speed > 0)
    {
        speed -= 0.1f;
    }
}

private void moveObject()
{
    if (Vector3.Distance(transform.position, Destination) > 0)
    {
        float updateYPos = transform.position.y;
        Origin = new Vector3(Origin.x, updateYPos, Origin.z);
        Destination = new Vector3(Destination.x, updateYPos,
                                   Destination.z);
        currentMovementTime += Time.deltaTime;
        transform.position = Vector3.Lerp(Origin, Destination,
                                           (currentMovementTime / totalMovementTime) * speed);
    }
    else
    {
        Move = false;
    }
}

public void JumpDetected()
{  
  //Increase speed  
  speed = 1.2f;  
}