# Multidisciplinary Art and Engineering Collaboration in the Design of "Bee My Guide: An Interactive Journey Back Home"

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**Abstract**: *Bee My Guide: An Interactive Journey Back Home* (BMG) is human-sized video game with mechatronics, being developed by senior capstone design students, Vertically Integrated Project (VIP) students, high school students, elementary school students, a professional composer, elementary school teachers, and university faculty; to be shown to the public in early 2025. This paper details the evolution of the continuous BMG project as it evolves to engage and challenge elementary school through university students in a collaborative and hands on nature. BMG is an interactive game that uses the player's body pose to control the game and changes the displayed video, mechatronics, lighting, music, voices, and sound effects. This paper highlights the educational value and expected student gains for elementary, high school, and college students. Additionally, the paper discusses the organizational methods used in the BMG project, which include narrative design, identification of key scenes & narrative elements, and ideation & design for the various video, mechatronics, and sound components of the game. The paper discusses how second-grade elementary students learned about and created patterns that the college students incorporated into the video animations. The paper discusses methods to quickly bring up to speed the many new college students added in the second semester and methods to encourage system integration. Through this descriptive work, the authors hope to demonstrate the possibilities of STEAM engagement through multidisciplinary engineering education, as well as how it can inspire students to collaborate on innovative problem solving and community development.

## Introduction

In this paper, we discuss the project and its context, team composition, learning outcomes, project stages, key educational and organizational methods, and a description of how elementary students are contributing to the exhibit. Together, these sections underscore the educational possibilities at the intersection of art and engineering, where students learn to develop innovative solutions to the challenges that they encounter when bringing a multidisciplinary project to life.

The paper is a continuation of prior work by the authors that described the first iteration of an interactive exhibit, in which vision tracking on a person's face and body controlled visual, auditory, and mechatronic elements [1]. A focus of the first paper was the project management that enabled the coordination of high school and university student groups within the expectations of academic coursework and extra-curricular environments. This paper addresses some aspects of project management new since the last paper, including methods used to encourage system integration, which is inherently multidisciplinary, and methods used to quickly bring new students up to speed. We also expand to discuss how second graders were engaged, including a detailed learning plan. An appendix goes into technical detail about an interesting collaboration between a high school student and university students.

Pervasive stereotypes portray engineering work as completely objective and technical, despite many engineers operating in social, creative, and innovative spaces [2, 3]. Publications have highlighted the value of integrating art and humanities into engineering education [4], although bringing these perspectives together is not without its challenges [5, 6]. Educators and researchers have described various programs that integrate engineering and the arts, as well as how the experiences of these programs can affect students' beliefs about engineering [7]—[10]. This paper contributes to that effort and offers insights into project management and integration strategies to bring together individuals from multiple backgrounds, life stages, and disciplines to work towards a shared goal.

A power of arts-based engineering is the ability to inspire future generations of engineers. While all students can benefit from this inspiration, it may be especially meaningful to students who are underrepresented in engineering (e.g., girls/women, students of color, first-generation college students), because these students may not feel included in traditional depictions of engineering work [11, 12]. In feedback we collected from users in the first iteration of the exhibit, one guest said, "I loved the encouragement to raise my hand and take up space with my body. As a woman I am too often encouraged to be small, take up less space. It was also really affirming to have the environment respond in a positive way. The Georgia Tech campus often feels impersonal and cold." In the context of the current stage of the project, we conceptualize inspiration in two ways. First, the use of real-world, project-based learning serves as motivation for high school and college engineering students to figure out solutions to novel challenges and think deeply about how they want users to connect with the exhibit. Second, by creating a public exhibit and by establishing outreach efforts with local elementary schools, the project can inspire awe and spark interest in a variety of audiences. Children and adults alike can benefit from reimagining the kinds of work that engineers do and the effects that engineers can have on the world around them.

**Project Overview**

The project *Bee My Guide: An Interactive Journey Back Home* (BMG) is the current focus of the Electronic ARTrium lab at Georgia Tech. Georgia Tech is a large, public university in the southern United States with a strong focus on science, technology, engineering, and math (STEM). The project will culminate in a public exhibit in the Ferst Center for the Arts in early 2025 on the Georgia Tech campus. The team working on the project includes two faculty, a professional composer, art and science teachers from an elementary school, and students in ranks ranging from elementary school to master's, with the large majority being undergraduates. The students involved participate in several courses and programs, including Vertically Integrated Projects (VIP), ENGAGES (Engaging New Generations at Georgia Tech through Engineering & Science), and interdisciplinary senior capstone design. BMG follows the first exhibit by the Electronic ARTrium lab, *Raise Your Hand*, which was shown for two weeks in November 2022, in the Ferst Center for the Arts, and was described in a paper last year in this conference [1].

*Raise Your Hand* was in the form of a rectangular tunnel that participants would walk through, and it comprised many video, audio, and mechatronic elements that reacted to the participant raising their hand and making a few other body poses. The responses of the *Raise Your Hand* participants in an online survey (collected as part of an IRB-approved study) were very positive and indicated that the mechatronic elements of the exhibit were the most interesting. However, a focus group from the study said that the exhibit lacked a narrative for participants to make meaning out of what they were experiencing in the exhibit.

In considering that feedback, the faculty leaders of the VIP course decided that the next exhibit should have a narrative and have mechatronic elements throughout. The VIP students designed the following narrative in Spring 2023. A young bee, who exists only in video, "Mr. Bee," (named by the students) is shown in *Figure 1*. Mr. Bee becomes lost because of a storm and needs the player's help to get back to the hive. An early storyboard for the BMG exhibit, shown in *Figure 2*, divides the exhibit into four sections, to be described in detail in the next section. Each of the first three sections has a different minigame and a different animatronic narrator who converses with Mr. Bee and explains the minigame to the player. Upon completing a minigame, the player will be given a number clue. In the fourth section, the player must use the three number clues collected to unlock the hive to allow Mr. Bee to rejoin his friends and family in the hive.

Figure 1. The main character, Mr. Bee.


Figure 2. Early storyboard of the BMG exhibit.

## Detailed Description of the BMG Exhibit

A plan view of the exhibit is shown in *Figure 3*. Upon entering the exhibit, the player will take a barcode ticket, like a parking deck ticket. When the ticket is taken, an entry for the player is created in a SQL database and a python program will generate the random parameters needed to define the game for this player. The player will be instructed to enter, in order, each of four sections, which are small rooms. To enter a section, the player will scan their ticket, which initializes the game in that section. Various metrics about the player's performance, such as how long the player took to complete the game in that section, will be recorded anonymously. LIDARs in each section detect occupancy and if anything passes through a vertical plane separating the player and the

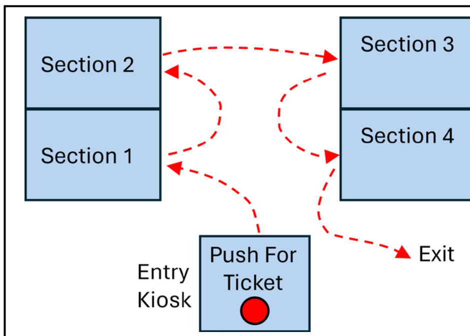



Figure 3. Plan view of the BMG exhibit.

mechatronics. The latter will automatically halt the mechatronics (to not harm the player) and display a warning message in the video.

The scene in Section 1 is dark and stormy, where lightning using strobe lights flashes from artificial gray clouds overhead with thunder rumbling. The player faces three 65” TVs, in portrait orientation and side-by-side, as shown in *Figure 4*. The ceiling has artificial dark clouds like the video ones, with other lightning flashes (strobe lights). The mechatronic narrator, Snowy Owl, in a female voice, explains, with a beak that moves in lip sync, that the player must use their body like a human joystick to steer Mr. Bee up or down and right or left to avoid “attack clouds” and falling trees, as Mr. Bee attempts to fly to a hut at the end of the path. Upon reaching the hut, the number clue is projected onto the artificial clouds.

Figure 4. Orientation of TV screens in Sections 1 and 3.

The video scene in Section 2 is one of bright sunny flowers. *Figure 5* shows a mockup of the scene, which includes colorful flowers, a few white fluffy clouds, and a gentle breeze blowing the grass and flowers, although there is a dark storm in the far distance to the right. There are four mechatronic double-bloom lilies in bud form on the floor just in front of a vertically oriented 75” TV. Cappy, the mechatronic caterpillar, explains that the mechatronic flowers on the floor will bloom and light up in a certain order and then close again, after which the player must point to direct Mr. Bee, like a cursor, to fly over each flower in the same order. When Mr. Bee is over the correct flower, he drops pollen over the flower, and the flower blooms and lights up. Meanwhile, the storm is approaching. If the player completes three rounds of this game before the storm overtakes the entire field, ladybugs fly up to provide the number clue.

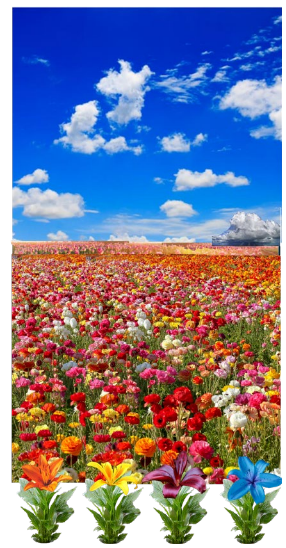


Figure 5. Mockup of Section 2.

Section 3 is a pose-matching minigame, as shown in *Figure 6*, with the same arrangement of TVs as in *Figure 4*. The game camera (which defines the player’s view in the video) steadily moves toward the white figure at the end of the path. The figure defines the pose the player must match to complete a round of play. The dots in the figure correspond to the player’s key points, or major joints, so the player

Figure 6. Mockup of Section 3.

gets feedback on the quality of the match. The player must match the figure before arriving at the white figure. Sandy, the mechatronic snake, in a periscope position on a fake rock, demonstrates the pose matching, followed by the player doing a guided round. After the player completes three more rounds, the third number clue is given.

In the fourth and final section, the player faces honeycomb cells on a pair of sliding doors, with cells numbered zero through nine and with a TV on the upper left, as shown on the left of *Figure 7*. Mr. Bee is the narrator for this section, and he instructs the player to point to three cells, in order, corresponding to the three number clues obtained in Sections 1 through 3. Mechatronic bees fly in circles to the upper right of the player try to distract the player with taunts or encouragements in high-pitched voices with giggles. When the player points to the numbers in the correct order, the doors open, and Mr. Bee joins his friends and family in the 75” vertically oriented display.

Some efforts were made for the project to be inclusive.  The VIP class chose the name “Mr. Bee” for the main character, however, the character’s voice is childlike and not gender specific. Intentionally, to provide some diversity to the characters, the voice of the first robotic narrator, Snowy the Owl, is obviously female, and the face and voice of the second robotic narrator were modeled on a southern black male.  The voice and name “Sandy” of the third robotic narrator are both gender non-specific. The figure in the pose-matching game was changed to be gender non-specific.

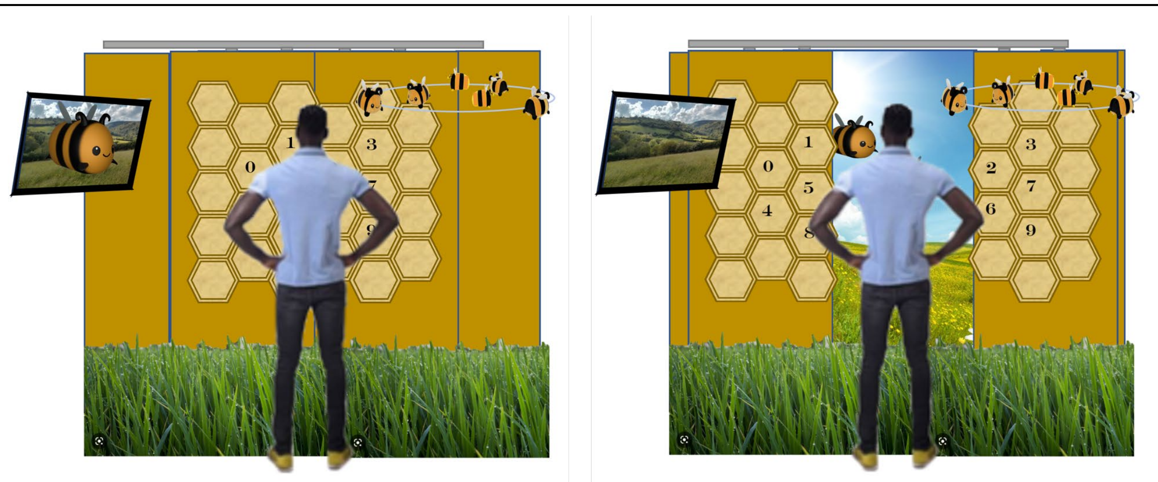


Figure 7. Mockup of Section 4, with doors closed (left) and open (right).

**Composition and Organization of the Project Team**

The BMG project is extremely diverse in many dimensions: in terms of courses, student ranks, disciplines, and how much time the students have for project work. This section describes the composition in these dimensions and how the students are organized within the project.

In a typical fall or spring term, the team consists of two faculty instructors (both electrical and computer engineers), undergraduate students from the VIP course and senior capstone design course, and one or two high school students from project ENGAGES. The capstone students are usually with the single-semester interdisciplinary capstone program. Through the sponsored program ENGAGES, Georgia Tech partners with seven minority-serving public high schools in Atlanta. The ENGAGES students are paid through the ENGAGES program to work nominally 15 hours per week in a Georgia Tech lab. The project faculty have partnered with a science teacher and an art teacher at Hope-Hill Elementary School, a Title 1 school in the Atlanta Public School System, to produce some paintings from their second-grade students. In addition to these activities that occur during the regular school year, in the summer there are usually ENGAGES students, one or two SURE (Summer Undergraduate Research in Engineering/Sciences) students, and a paid undergraduate student assistant to help with set construction and assorted other tasks.

The Vertical Integrated Projects (VIP) team named Electronic ARTrium accounts for the most students in the project by far. VIP is a multidisciplinary project-based learning, for-letter-grade-credit program available at approximately 44 colleges and universities in 13 countries [13]. VIP projects are long term, lasting four years at least. To start a team at Georgia Tech, a faculty member proposes the team to the VIP program, and the VIP program approves it. Then the VIP program promotes the team on their website and invites the professor to recruit students at poster sessions preceding each term. Having a VIP team affords a professor access to students of any major on campus and the students can stay with the VIP team for multiple semesters. VIP teams typically have 10 to 20 students. Many, if not all, the computer science (CS) students on the VIP team use VIP to satisfy their junior capstone design requirement, which means they stay with the project for three semesters, with few exceptions. Mechanical engineering students can use it to satisfy their “Design Concentration” [14]. VIP students typically sign up for one or two credit hours. VIP students are expected to attend in-person both the main meeting and the sub-team meetings. The main team meeting is in a scheduled class period, while a sub-team meeting is at a time agreed upon by the sub-team members.

*Table* 1 shows the enrollments of college students in these different courses and programs, per term, on the BMG project. It can be observed that the enrollment in the VIP course more than doubled from Spring 2023 to Fall 2023, and the enrollment in Spring 2024 was almost the same as Fall 2023. This may be because an internet article and various videos about the first exhibit that appeared in Spring and Summer 2023 increased student interest. It may also be observed that the VIP course attracts relatively fewer engineers, compared to Computer Science (CS) and Computational Media (CM) majors. This may be attributed to CS and CM degrees having a junior design requirement that may be satisfied by three semesters of VIP, while Electrical Engineering (EE) and Computer Engineering (CMPE) give only free elective credit for VIP. The slightly higher number of Mechanical Engineers (MEs) compared to EE and CMPE students may be because the ME degree allows VIP hours to apply to the “Design Concentration” [14].

The involvement of single-semester senior capstone design students is greatly beneficial for the project, because they make up for the lack of engineers in the VIP team and they are older and more experienced than most of the VIP students. On the other hand, the capstone students appreciate that their work will end up in a public show, which would not be possible without the VIP team.

Getting capstone design students, VIP students, and high school students to work together is challenging. The instructor usually must facilitate it by messaging selected students about specific tasks and explaining how they will benefit from the interaction and sometimes arranging meetings between the selected students and the instructor.

The second graders do not work directly with any of the other students on the project. Their engagement is managed completely through the instructors. However, we note that the high school and college students display interest in the engagement of the second graders, as evidenced by the high school and college students voluntarily including STEM outreach to the second graders as part of their motivation for the project in their presentations.

The diversity of majors in the VIP class can be observed, especially in Fall 2023, when there were 10 majors. The students must apply and be accepted (by the instructor) to the Electronic ARTrium VIP team before they can register for it. For this team, the instructor accepts all applicants, regardless of prior experience. In their VIP applications, the students write why they want to join the team. It seems that most students join because they are interested in art; some examples are, “I am very interested in how we can use technology to create art. Being in a performing arts school for most of my life I have always wanted to combine my two passions of using technology to generate art”, “I am interested in themed entertainment applications and this seems like a really good project to get more experience in themed entertainment.”, and “I am passionate about exploring art through many mediums, and as I begin my degree, I want to explore the overlap of art and engineering. I want to join a team to learn applicable skills both in mechatronics and collaboration through the VIP model.” and, “I’m a fifth-year physics major here at Georgia Tech, but I come from a family of artists and have always had great interest in the arts. I’ve always wanted to find a way to integrate my passion for science and the arts in a meaningful way.”

The VIP team is organized into sub-teams, and when the enrollment doubled it became necessary to further divide them into task groups. When the sub-teams are too large to find a common time for sub-team meetings, they are divided into meeting groups, so that task group members are together in the sub-team meeting groups. There are sub-team leaders and meeting group leaders. The sub-teams, their descriptions, and key software and hardware are:

- Electromechanical (EM): Building and animating mechatronic characters and objects with servo and DC motors; programming Arduinos to control the motors and lights, read motor angle sequences from SD cards, and receive Ethernet packets that trigger certain motions and light changes.
- Sensor Processing and Networking (SPN): Python programming to process camera feeds, do pose detection and track player progress; LIDAR and bar code printer and scanners; SQL for storing player status; Ethernet programming (UDP and TCP/IP).
- Sound Design (SD): Using software to trigger music stems, voices, and sound effects. At first the software was FMOD, but we pivoted to VoiceMeeter for voices of robotic narrators and Unity for all other audio.
- Visual Art Design (VAD): Blender to create 3D computer graphics and Unity to create computer animation and for game control in C#.

- Web (and Narrative) Development (WND or WD): WND in the Spring 2023 semester only: completing the narrative in the first part of the semester. Thereafter, this team is only WD and uses WordPress to present our past and present work on the Internet.

Table 1. Breakdown of BMG students by semester, course, major and rank.

| Term | Course | Enrolled | Majors | Rank |
|---|---|---|---|---|
| Spring 2023 | VIP | 24 | CS (16), CM (5), EE (2), CMPE (1) | So (4), Jr (11), Sr (9) |
| | Interdisciplinary Capstone | 5 (1 team) | ME (4), EE (1) | Sr (5) |
| | ENGAGES | 1 | N/A | High School Sr |
| Summer 2023 | ENGAGES | 2 | N/A | High School Jr (1), Sr (1) |
| | Undergraduate Student Assistant | 1 | CS | Sr |
| Fall 2023 | VIP | 49 | CS (24), CM (11), ME (4), CMPE (3), EE (2), and MATH, AE, IE, BMED, and PHYS (1 each) | So (12), Jr (19), Sr 17), Master's (1) |
| | Interdisciplinary Capstone | 11 (2 teams) | ME (6), EE (5) | Sr (11) |
| | ENGAGES | 1 | N/A | High School Sr |
| Spring 2024 | VIP | 46 | CS (23), CM (14), CMPE (4), ME (2), EE (2), and MATH (1) | So (11), Jr (24), Sr (11) |
| | ENGAGES | 1 | N/A | High School Sr |

Note: The abbreviations for majors are AE = Aerospace Engineering, BMED = Biomedical Engineering, CS = Computer Science, CM = Computational Media, CmpE = Computer Engineering, EE = Electrical Engineering, IE = Industrial Engineering, MATH = Mathematics, ME = Mechanical Engineering, PHYS = Physics.

**How Elementary School Students Contributed to the Project**

In each of the first three sections, animated video creatures, such as turtles, snakes, lizards, and birds, will crawl or fly across the path or view of the player, for the purpose of distracting the player. These creatures will be colored by oil pastel and tempera paintings created by second graders at Hope-Hill Elementary School, as part of their unit on pattern. There are approximately 34 paintings. The project goals include having one creature for each painting, providing a guide for the children and their parents so they will know when and where their creature will show itself, and mapping the painting onto the creature in such a way that the child can recognize it.

Importing an image into Unity and simply mapping it onto an object is very straightforward and quick. However, making the image recognizable on the creature can be challenging. The high school student and the instructor selected Blender assets (many are free) to be used as creatures to best display the child's painting and have the potential for animation. In a few cases the assets came with rigging for animation. However, in most cases, the high school student added the rigging and programmed the animation in Blender. For example, one child's painting is shown on the left in *Figure 8*. The crane was chosen for this painting because it was already rigged and the area of the wings was a good match to the feature size of the pattern in the painting. The high school student animated the crane in Blender to fly a banked path so the wings and breast are displayed broadside to the player, making the image more recognizable.

Figure 8. One of the paintings by the elementary school children (left) and the creature that wears the painting (right).

**Learning Outcomes for the College Students**

The learning outcomes for each college student in this project are based on the specific course the student is enrolled in, and the outcomes for different courses are different, even between ME and ECE (EE and CMPE) capstone. The outcomes were reported in detail in the authors' previous paper [1] and their differences will be briefly summarized here. The VIP course emphasizes professional skills, such as communicating in a timely manner and engaging in meetings, and generally contributing to the project. The capstone course emphasizes engineering skills, for example, "Identify and specify design requirements, from general problem descriptions within the applicable realistic constraints". The instructor has tried to compensate for the differences by requiring the VIP reports to have similar elements as the capstone reports, such as sections on the requirements and specifications, the research and ideation, and the justification for selection of approach, and requiring those sections to be submitted in Week 8. The instructor provides learning activities for the VIP students in the areas that capstone students get through the capstone course or its prerequisite, such as one period that includes a short lecture and an in-class small-group exercise about the early stages of the design process. On the other hand, the instructor requires the capstone students to use Microsoft Teams for communication, in the Electronic ARTrium Team, along with all the other students involved with the project, so that they get all the broadcasts and can participate in the special interest channels, such as "Motor Control" and "Power Supply", and that they upload their software into the Electronic ARTrium GitHub site.

The Electronic ARTrium project also has learning objectives for the elementary school students. Much research has been conducted on the "leaky pipeline" which is the point at which females and minorities drop out of STEM fields [15]—[18]. Specifically, [15] examines first graders and found "first-grade children held stereotypes that boys were better than girls at robotics and programming". The objective for interacting with Hope-Hill Elementary School, a title 1 school with 85% African American student population, we hope to:

- Engage early learners via Art and Innovative Technology
- Increase equity in STEM fields

One of the most impactful means of accomplishing this is to provide role models and mentorship [19]. As the BMG project continues, we look for a means of encouraging university students to engage with elementary school students. Over the course of the next year, we are going to look for engagement via, videos and virtual interaction, in-class visits from the university students, and the November show where we will encourage the elementary school students to attend.

**Learning Objectives, Plan, Materials, and Reflection from the Second Grade Art Teacher**

The second graders created splendid artwork that will be "worn" by various creeping and flying creatures in the video component of the exhibit, like the right side of *Figure 8*. In the process of making the art, the students learned about creating pattern using line, shape, color, and different types of media. Some excerpts of the material presented to the students are shown in *Figure 9*. Specifically, the learning objectives for the second graders were:

- Students will be able to create a pattern using oil pastel and paint for an interactive art installation/game at Georgia Tech.
- Students will be able to see real-life applications of their artwork, making connections between artists and other fields/careers.

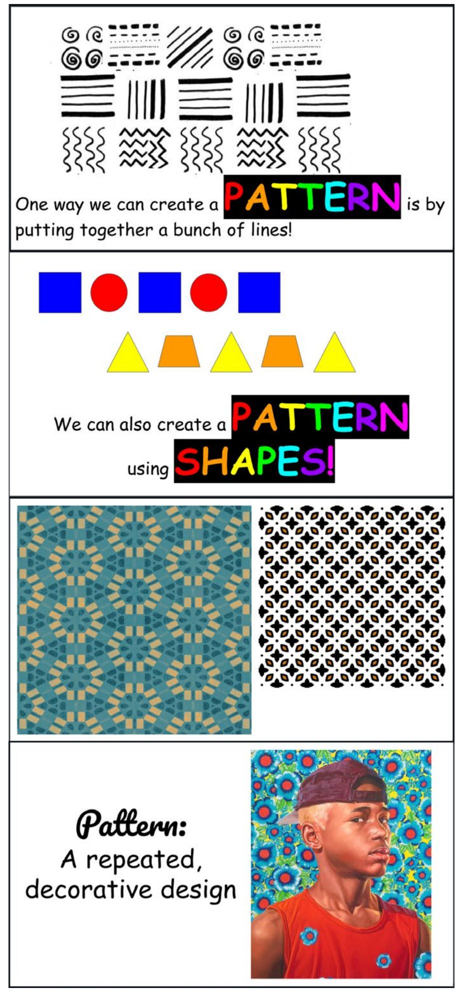



Figure 9. Excerpts of materials used by the second-grade art teacher in the unit on pattern. Sources: lines [20], green pattern [21], black and white pattern [22], painting [23].

The second-grade art teacher crafted a detailed learning plan, shown in *Figures 10, 11, and 12*, and is summarized as follows. Students learned about interactive art through the work of Rafael Lozano-Hemmer and the Electronic ARTrium project at Georgia Tech. The students then developed a definition of "pattern" and looked at how artists create and use pattern in their work. Students created their own patterns using oil pastel and paint, paying attention to line, shape, color, and texture. The students' patterns will then be used in the interactive art at Georgia Tech.

The most valuable takeaway from this experience was that students were able to make real-world connections. The Electronic ARTrium showed students how art has different applications across different fields. The upcoming visits with Georgia Tech will help the 2nd Grade students see these connections more closely. As many students play video games, they were excited about the game and interaction aspect of the project. As Georgia Tech shares more progress, the students will see their work in action and the real-life application should become clearer to them.

As this was the first iteration of the project, the art component focused mainly on pattern. However, as the program and relationship with Georgia Tech grows, we may be able to expand the art component to explore designing for a game or for interactive art more in-depth. The pattern lesson does also allow for experimentation with materials, it could be interesting to have different groups of students create their patterns in different mediums besides oil pastel and paint.

**Stages of the Project**

The project began in Spring 2023 and is still in progress at the time of this writing (Spring 2024). *Table 2* gives a high-level view of what has happened over the semesters until now and what is planned for the next two semesters. The spring and fall semesters of 2023 were spent in ideation and is focused on testing, debugging, and putting on the show.

The instructor is handling presentations and final demonstrations differently in the Spring 2024 VIP class compared to the previous semesters of this class (including in the previous project reported in [1]), to put more emphasis on system integration. In past semesters, sub-teams took turns giving oral presentations in the main meeting throughout the semester. In contrast, in Spring 2024, the oral presentations will transition from sub-team reports in the first half of the semester to section reports in the latter half of the semester. A “section report” gives the status of a particular section in the exhibit. Each section has all the types of elements in the exhibit: pose detection, LIDAR, bar code printer and readers, game control, video, audio, mechatronics, and player status updates to the SQL database. In the instructor’s experience, integration is extremely challenging for the students. Simply requiring an oral section report forces the students to collaborate across disciplinary boundaries. The change was done in part in response to student feedback at the end of Fall 2023 semester: “More working together on a section” was feedback from a student in the last class meeting and the request for “More inter-disciplinary communication” was in the anonymous course evaluation. To make time for the students to have this inter-disciplinary collaboration, four class periods will be devoted exclusively to section group meetings, specifically in Weeks 10, 11, 13 and 14 (Week 12 is Spring Break). To help the students be effective in these meetings, the instructor provided expectations prior to the meetings and rotates joining each of the section group meetings. Since the Web Development sub-team is responsible for documenting project development, they serve as scribes for capturing section meeting notes.

A challenge with the section meetings has been that some task groups, such as Section Control (this group writes the C# code in Unity that cues actions in response to game events) and the Ethernet Networking group, do not have enough people to have representatives in each section meeting. Therefore, some of them shift from one section meeting to another at the halfway point. This has worked reasonably well.

The section meetings have had noticeable impact.  The instructor has not needed to prompt specific students to reach out to others not in their discipline to get something done for the section. Also, two students on different occasions gave unprompted feedback to the instructor that the section meetings gave them a better understanding of their role in the whole project.

Final demonstrations will also be done differently. In the past semesters, each student did a solo final demonstration of their project.  In contrast, in Spring 2024, there will be just four final demonstrations, one for each section.  A Canvas quiz with two questions has been added. The first question asks what the student did together with other students and what should the professor look for to see evidence of this contribution.  The second question asks what the student did alone and what the professor should look for to see evidence of this contribution.

| **Course:**<br>Art - Sareva | **Grade level:**<br>2 | **Length of lesson:**<br>2-50 min lessons | **Unit:**<br>Pattern | |
|---|---|---|---|---|

| |
|---|
| **LESSON TITLE:** Interactive Art - Patterns for Georgia Tech<br>SW=Students will TW=Teacher will |
| **GSE TO BE ADDRESSED:**<br>**<u>CREATING</u>**<br>● VA2.CR.3 Understand and apply media, techniques, and processes of two-dimensional art.<br>a. Create drawings and paintings with a variety of media.<br>**<u>PRESENTING</u>**<br>● VA2.PR.1 Participate in appropriate exhibition(s) of works of art to develop identity of self as artist.<br>**<u>CONNECTING</u>**<br>● VA2.CN.1 Investigate and discover the personal relationships of artists to community, culture, and the world through making and studying art.<br>d. Recognize ways that artists are involved in communities and careers (e.g. architects, painters, photographers, interior designers, educators, museum educators) |

| **ASSESSMENTS** | |
|---|---|
| **DIAGNOSTIC**<br>(Gauge where students are in their learning prior to beginning the lesson.) | ● SWI look at examples of patterns and share what they see (Slide 3). TW be able to gauge what students already know about pattern. |
| **FORMATIVE**<br>(Gauge student progress/growth through ongoing and periodic observation and/or checks for understanding.) | ● Artist Examples (Slides 6-8): SW describe how artists Karin Miller, Lucienne Day, and Kehinde Wiley used pattern in their artwork. Are students able to describe how artists use and create patterns in their work?<br>● What Comes Next? (Slides 11-15): SW share what comes next in the pattern. This will give students more practice on how to create a pattern using line, shape, color, or texture. What needs to be repeated to create a pattern?<br>● TW circulate around the room as students work on their oil pastel patterns |
| **SUMMATIVE**<br>(Gauge student mastery of standards.) | ● Final artwork: Did students create a pattern? |

Figure 10. Learning plan for second graders for the unit on pattern (page 1)

## MAJOR COMPONENTS

**KEY CONCEPTS:**
- I can create a pattern using oil pastel and paint for an interactive art exhibit at Georgia Tech.

**VOCABULARY:**
- Interactive art: art where the viewer participates or the artwork responds to the viewer.
- Pattern: a repeated, decorative design.

**LINKS:**
- https://www.tate.org.uk/art/art-terms/i/interactive-art
- https://www.youtube.com/watch?v=gNNTN0vpFAM

**STUDENT EXAMPLE:**

## DIFFERENTIATED LEARNING

**INCREASED RIGOR:**
- Students can create a more complex pattern: Can you create a pattern that combines line, shape, color, and texture? Think further about how the patterns are going to be used and design a pattern that might help an animal camouflage.

**ADAPTED ASSIGNMENTS:**
- Teacher can start a pattern for a student and they can complete it. Student can use one of the patterns we looked at as an example. Student can trace shapes or lines to create their pattern.

## MATERIALS

Presentation, oil pastel, cardstock, tempera cakes, brushes, water, pencils

| **OPENING**<br>(Getting students ready to learn) | **Length of time for this portion of your lesson:**<br>10 min |
|---|---|

**ESSENTIAL QUESTIONS:**
- How do artists use pattern?

**HOOK/INTRODUCTION ACTIVITY:**

Introduction to Interactive Art
- TW ask students who plays video games.SW describe some video games that they play. TW explain that in this next project, students will be creating artwork for an artwork that is similar to an in-person video game.
- TW introduce partnership with Georgia Tech and the Electronic ARTrium, using images provided (Slide 1).
- Students will watch a short video clip of Rafael Lozano-Hemmer's artwork, "Pulse Topology." How does the artwork change as the viewer walks through it?
- SW understand that interactive art is where the viewer participates in the art or the art changes somehow depending on what the viewer is doing.
- SW understand that for the next project, their artwork will be used in an interactive art installation.

Figure 11. Learning plan for second graders for the unit on pattern (page 2)

| **ARTISTIC PROCESSING**<br>(Active art making with guided practice) | **Length of time for this portion of your lesson:**<br>30 min |
|---|---|
| Day 1: Oil Pastel Patterns | |
| ● SW analyze several artist examples (Karin Miller, Lucienne Day, Kehinde Wiley, Slides 6-8) and describe how the artist created/used a pattern in their artwork.<br>● SW learn that you can create a pattern using line, shape, color, or texture. SW look at examples of each type: line, shape, color, and texture.<br>● SW look at simple examples of pattern and guess what comes next in the pattern.<br>● TW explain that SW be creating their own patterns, which will then be used for the animals in the Electronic ARTrium. TW demo creating a pattern using oil pastel, asking students for suggestions based on the patterns we just reviewed.<br>● SW create patterns using line, shape, color and/or texture using oil pastel. TW circulate, providing feedback and support as needed.<br>Day 2: Painting<br>● SW finish patterns with oil pastel if they did not finish last week.<br>● TW demo adding tempera paint to their oil pastel patterns. SW share what they notice when oil pastel and paint combine: the oil pastel creates a resist, blocking the paint.<br>● SW use tempera cakes to add color to their patterns. | |
| **CLOSING**<br>(Review/assess and preview) | **Length of time for this portion of your lesson:**<br>10 min |
| ● Students will reflect and share: How did you create your pattern? Did you use line, shape, color, or texture? What types of lines did you use? What types of shapes? What colors? | |

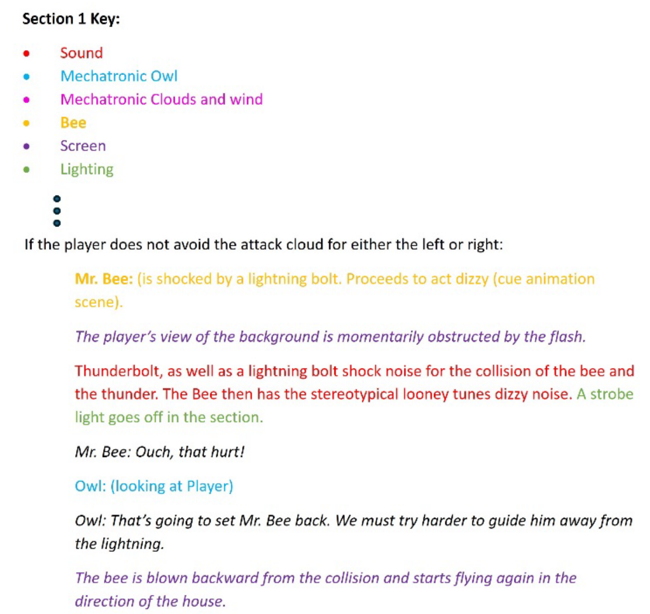
Figure 12. Learning plan for second graders for the unit on pattern (page 3).

Table 2. Highlights of the activities of each course or program, by semester, over the entire two-year span of the BMG project.

| Semester | Activity |
|---|---|
| Spring 2023 | VIP class: Narrative Design, determination of all the elements of the exhibit, requirements, and specifications for most of the elements, ideation, and low fidelity prototypes of those elements.<br>Capstone Design: design and build of the first version of Cappy the Section 2 narrator, focusing on mechanical structure. |
| Summer 2023 | Student assistant and professor: Base set construction, hanging of TVs, lab organization.<br>ENGAGES Student 1: Add rigging to the 3D video model of Mr. Bee.<br>ENGAGES Student 2: Design a fixture in SolidWorks to hold the servo motors that move the wings of the Circling Bees and write an Arduino program to flap the wings. |
| Fall 2023 | VIP class: focus on prototyping all the interactive elements, separately.<br>Capstone Design Team 1: design and build the honeycomb sliding doors<br>Capstone Design Team 2: redesign and build the head of Cappy to have a moving jaw and eyes that move in two dimensions.<br>ENGAGES Student: Research and test lip sync along with VIP students, and sculpt the old man face of Cappy in Blender. |
| Spring 2024 | VIP class: focus on finishing and reproducing prototypes and integrating them, culminating in section demonstrations.<br>ENGAGES Student: make animated video creatures that wear the paintings by the elementary school children and insert the animations into the video. |
| Summer 2024 | At least one SURE student to create a robotic “Hip Hop Sloth” to hang from a tree in Section 3 and distract the player with dance moves. Two undergraduate research students to continue any critical tasks not yet completed. |
| Fall 2024 | VIP class: Finish all critical elements and add additional non-critical elements as time allows. Test and debug the entire exhibit until mid-October. Create “Startup and Recovery Scripts” for inexperienced students to operate the exhibit and recover if something goes wrong. |
| Spring 2025 | VIP class: quickly, bring new students up to speed on how to operate the exhibit and test recoveries. In February, transport the exhibit to the show venue and test the exhibit again. During the exhibit, guide visitors and maintain the exhibit over the two-week show period. After the exhibit, transport the exhibit back to the lab, assess the performance of the exhibit, and organize the files and resources for the team to use in the next project. |

**Methods Used to Accelerate Engagement of New Students**

In Fall 2023, only nine of the 49 students enrolled in the VIP class were returning from the Spring 2023 VIP class. The Spring 2023 class designed the narrative and wrote the story script. The 31-page story script is like a screen play; it describes everything that happens in the game in response to what the player might do, for example, *Figure 13* shows excerpts of the text color key and what happens if Mr. Bee is attacked. The instructor needed ways to quickly focus the 40 new students on the story script as the authoritative document of the project and to give them a sense of ownership of the project.


Section 1 Key:

- Sound
- Mechatronic Owl
- Mechatronic Clouds and wind
- Bee
- Screen
- Lighting

If the player does not avoid the attack cloud for either the left or right:

**Mr. Bee:** (is shocked by a lightning bolt. Proceeds to act dizzy (cue animation scene).

*The player's view of the background is momentarily obstructed by the flash.*

Thunderbolt, as well as a lightning bolt shock noise for the collision of the bee and the thunder. The Bee then has the stereotypical looney tunes dizzy noise. A strobe light goes off in the section.

*Mr. Bee: Ouch, that hurt!*

Owl: (looking at Player)

*Owl: That's going to set Mr. Bee back. We must try harder to guide him away from the lightning.*

*The bee is blown backward from the collision and starts flying again in the direction of the house.*

Figure 13. Excerpts of Story Script.

A Canvas multiple choice quiz with 10 questions, worth 2 points of the overall grade, was assigned on the script and due in Week 2. The quiz had no time limit and unlimited tries allowed. An example question is, "4. What does Mr. Bee do in Section 2 when he is happy? a. grin, b. jiggle, c. dance." The instructor's attitude was, even if the students search the script while they are taking the quiz, at least they become aware of the script and where to find things.

A more fun activity that gave the students a sense of ownership was the exhibit naming. This began in the form of a Canvas quiz in Essay form, worth 1 point of the overall grade, no time limit, and unlimited tries, due the day before class in Week 4. The question was, "In the field below, list at least one proposed name for the planned exhibit in Fall 2024." The full point was given for anything.

In the class in Week 4, two rounds of a quick and silent voting technique were used, like the technique reported in [1]. The idea is that in the first round of voting a student is not voting for their own proposed title. To prepare, the instructor partitioned the students' names into two sets, according to the first letter of their last names, into the "Apples" group and the "Oranges" group. Then the instructor pasted the titles proposed by the Apples group into a PowerPoint file named "Oranges" and pasted the others into a PowerPoint file named "Apples". Each slide had up to four proposed titles on the left and corresponding voting grids on the right, as shown in *Figure 14*. The PPTs were printed on paper, one

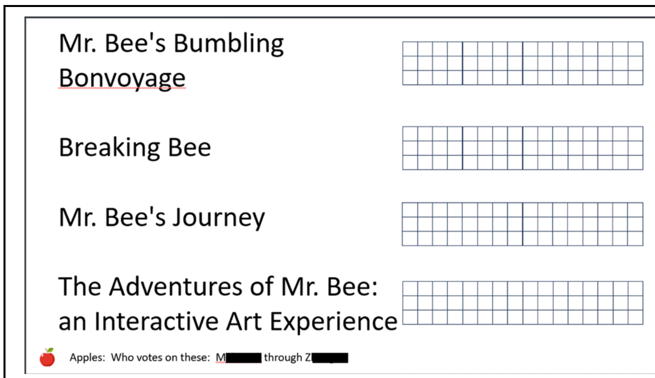



Figure 14. One PPT slide in the first round of voting on the name of the exhibit.

slide per page and the slides were taped to the white boards, Apples slides on one side and Oranges slides on the other.

When the students walked into the class, they were given six small blue dot stickers and three small green dot stickers. They were told that they were Apples if their last name begins with A through L, and Oranges if their name begins with M through Z, and the voting process was explained. 10 minutes were given for the students to silently vote on the titles according to their group, by sticking their blue dots into the voting grids: the Apples group voted on the titles on the Apples side and the Oranges voted on titles on the Oranges side. The students were allowed to stick multiple blue dots on a single title if they wished. With scissors, the instructor cut out the top three vote-getting titles from each of the Apples titles and the Oranges titles, and taped the six titles to a second round voting grid, created from PPT slides, this time, only two titles per page with a larger voting grid. Then the students were given five minutes to vote on these six finalist titles. The result is shown in *Figure 15*. There were three clear winners. As was explained to the students at the beginning of that class, the instructors would choose from among the top three winners. The name "Bee My Guide: An Interactive Journey Back Home," was selected because in the opinion of the instructors, it best conveyed what the exhibit was about and what type of exhibit it is.

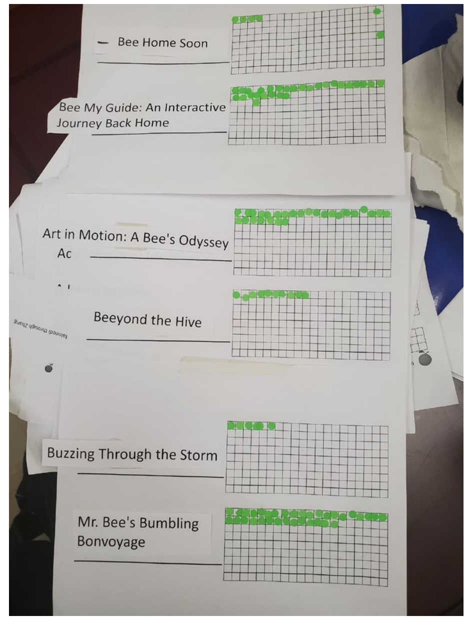


Figure 15. The results of the second round of voting for the exhibit name.

**Conclusion**

This paper provides a roadmap for individuals looking to develop a multi-program/multi-disciplinary collaboration, this work is centered around the creation of an immersive, engaging, gamified exhibit that combines art and engineering. The project focuses on students in elementary, high school, and college students to form a structure of mentoring and inspiration that draws on students and educators from a variety of life stages, interests, and disciplinary backgrounds. Managing the project requires a focus on onboarding new students and enabling them to contribute to the creative collective of interdisciplinary ideas from more than 10 different majors. The college students have also been able to incorporate the drawings of elementary schoolers into the visual displays. Students have developed skills far beyond their schooling level and across disciplinary boundaries, and the growth in the size of the project team demonstrates the value students see in getting to integrate art and engineering into their work. Additionally, project leaders have collaborated with elementary educators, who developed objectives and lesson plans targeting students' ability to recognize and create patterns. By bringing elementary school students' patterns to life as part of the background artwork of the exhibit, we are able to help potential future engineers see the way that their work can integrate engineering and art. Future work will include an increase in the degree to which college students directly interact with elementary and high school students to inspire young students to embrace STEAM.

# Appendix: Multi-disciplinary and Multi-Program Collaboration: Specific Highlights

**Cappy's Head**

The development of the head of "Cappy," the animatronic narrator in Section 2 of the exhibit was an interesting collaboration between a capstone ME student and a high school student, and went across ME and graphic arts domains. SolidWorks is a 3D modeling software designed for engineers and is taught in a required course in the ME undergraduate program; it makes precise 3D models and conveniently takes as inputs 3D models of hardware parts from vendors, such as motors and metal parts. Blender, on the other hand, is a software 3D modeling tool designed for artists; it provides an intuitive interface for sculpting, painting, and animation.

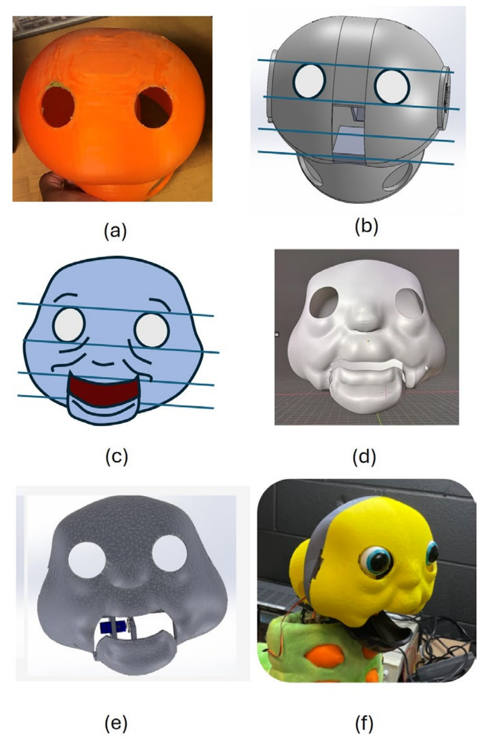


Figure 16. The many heads of Cappy: (a) 3D-printed head by the first capstone team, (b) first Solidworks model of Cappy with a moveable jaw, (c) sketch given to high school student, (d) the Blender version of Cappy, (e) the revised Solidworks model of Cappy, and (f) the 3D-printed and assembled Cappy head.

The Spring 2023 capstone team created the 3D-printed head in *Figure16(a)* with only eye holes. The Fall 2023 Cappy capstone team was tasked with adding motorized eyes, a motorized jaw (so the character could look at the player and lip sync to a recorded voice) and enable the head to be opened to access/maintain the motors and structures inside. The image of *Figure 16(b)* is the first SolidWorks model produced by an ME student in the Fall 2023 capstone team to meet the functional specifications (the superimposed blue reference lines were added to the image by the instructor).

The voice of the Cappy character is that of an older man with a southern USA accent, so the instructor wanted a face that would go better with the voice. The ENGAGES high school student had learned Blender over the summer, as part of her task to create animated video characters. So, the instructor asked her to make an old man face for Cappy. The instructor gave the HS student the sketch in *Figure 16(c)* (which uses the same reference lines) and the capstone student sent the HS student the .obj file exported from SolidWorks.

The HS student imported the .obj file into Blender (easy) and created a mesh that enclosed the volume of the capstone team's Cappy head; this was necessary to preserve the space needed for electronics. She then proceeded to sculpt the mesh to look more like an old man's head, based on an image of a man provided by the instructor. The HS student had to learn how to make lifelike folds and creases in the mesh. She sent her final product, shown in *Figure 16(d)*, back to the capstone student, in the form of a .obj file, to be imported back into Solidworks. Once in Solidworks, the new model had zero thickness and its dimensions were off by a factor of 10. The capstone student gave the model the necessary thickness, fixed the edges of the face and jaw so the jaw could rotate on the servo motor axis without interference, split the head into front and back halves to be attached with a hinge and clasp, and merged it with the motor fixtures for moving jaw and moving eyes, as shown in *Figure 16(e)*. The team 3D-printed and assembled the head shown in *Figure 16(f)*. The collaboration between the HS student and ME capstone senior was crucial in the development of this animatronic narrator.

**Lip Sync and "James" the Jaw Fixture**

This Fall 2023 collaboration involved members from the VIP team, specifically, task groups from the Visual Arts Design (VAD), Sensor Processing and Networking (SPN), and Electromechanical (EM) sub-teams, a member from the Cappy capstone team, and the high school student. Three animatronic narrators will lip sync with moveable jaws to recorded voices, so the instructors decided a single, simple lip sync prototype should be demonstrated first. The general plan was that task groups within VAD and SPN would demonstrate lip sync in the video and physical models, respectively, and then the EM and capstone students who were building the animatronic narrators could copy the technique and code.

Figure 17. Above: visemes created by the high school student. Below: drawings from [24].

The VAD task group (including the high school student) was tasked to research lip sync animation in Unity, using models created in Blender. The high school student had learned Blender the previous summer, so she was more experienced with this software than most of the VAD members and was a respected collaborator within the VAD lip sync task group. They were searching for software that would be compatible with FMOD for audio and enable the exporting of the jaw angles versus time for the Arduinos to control the animatronic jaws. These were difficult constraints. Surprisingly, the high school student was the one who found the solution in a Unity software plug-in called Rhubarb. The high school student practiced making the visemes (visual versions of phonemes) on her version of Mr. Bee, as seen in *Figure 17*.

Since the Cappy capstone team had already created a Cappy head in SolidWorks and they needed help with lip sync, the instructor asked one of the ME students on the team (the same one mentioned in the previous section) to design the test fixture in SolidWorks and send it to the VAD and SPN task groups, a .obj to the VAD task group for animating and the .stl file to the SPN task group for 3D printing and assembly. *Figure 18* shows the final versions of the lip sync test fixture, dubbed "James" by the students, in both physical (above) and in Blender (below).

Starting with viseme jaw angles estimated by a VAD member (CM major), another of the VAD members (MATH major) generated "key frames" in Rhubarb, which are non-uniformly sampled in time, and used by Unity for animation. The MATH major exported a text file of the (time, jaw angle) pairs associated with these key frames and found some software online to interpolate between the jaw angles at 50 samples per second.

Meanwhile, a student (EE major) in the EM sub-team figured out how to load the text file into the SD card of the Arduino Ethernet Shield. He and another EM member then demonstrated the

Arduino reading the 50 samples per second (time, jaw angle) pairs from the SD card and commanding the jaw servo in James to move to those angles, thereby creating the lip sync for James. Simultaneously, the EM members started the playback of the recorded voice and started the Arduino program to move the jaw, and demonstrated that over the duration of the recording, the jaw movements matched the recorded voice.

This last demonstration was a remarkable achievement by this group of students ranging from high school to college seniors, including at least four majors. It remains for the Spring 2024 VIP team to figure out how to trigger the audio and Arduino from the Unity game control C# program.

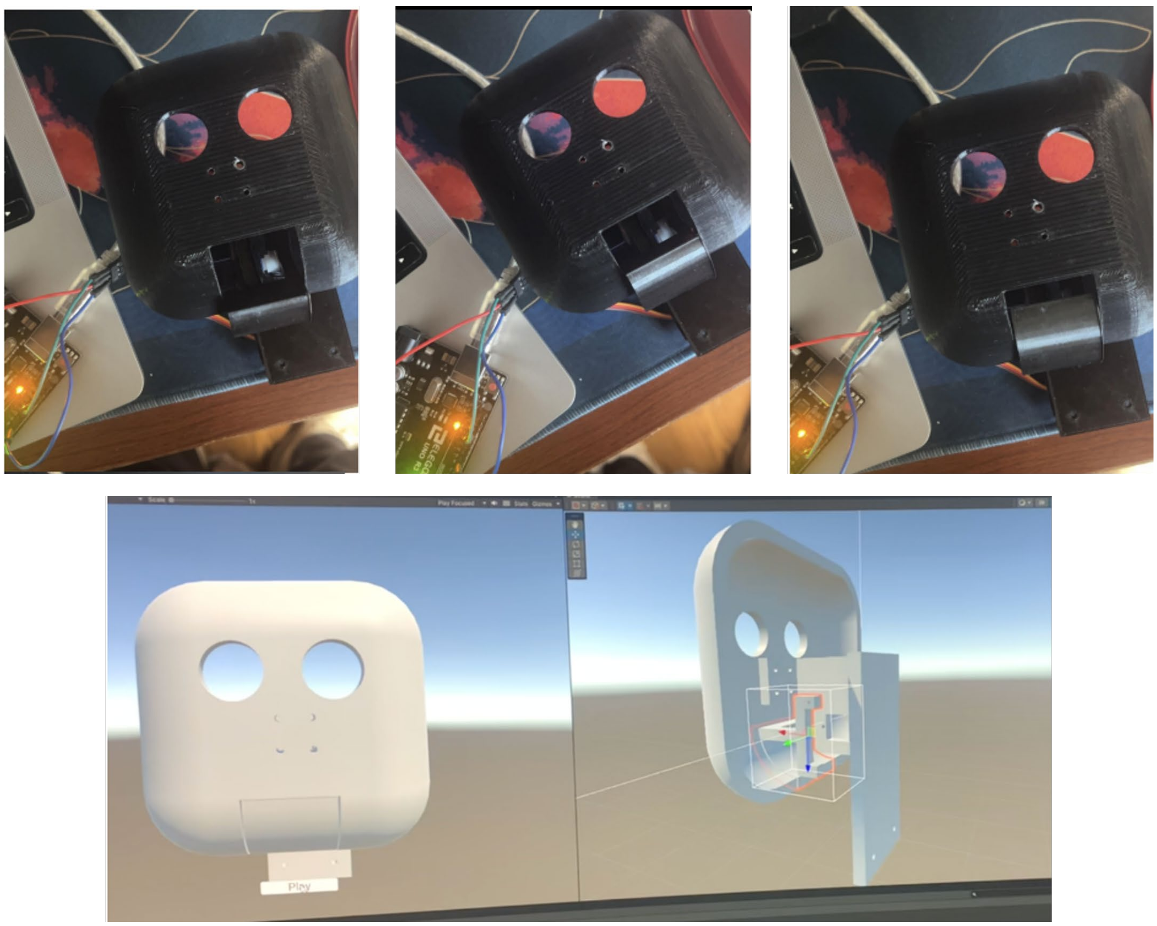



Figure 18. "James" the lip sync test fixture. The above images are of the assembled physical model. The below images are of the Blender model.

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