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Observing Shifting Perspectives on Art in Engineering during a High School Maker Camp (Evaluation)

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Dr. Lucas' primary goal as a professor is to engage with students in the classroom and inspire them to develop their passion, understanding, and appreciation for STEM-based research and industry roles. This is accomplished by providing well-crafted and innovative learning experiences in engineering technology courses and through extracurricular outreach. His current teaching load primarily consists of courses related to advanced embedded digital systems and is intertwined with ongoing community engagement in support of Humanities-Infused Engineering Education.

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1. Introduction

Engineering is often perceived as a purely science and math-based discipline that is not creative or artistic. This perception is due in part to the fact that engineering is often associated with mathematical problem-solving and technical skills, which are not typically seen as artistic qualities. However, engineering is a creative discipline that requires a great deal of artistry. Engineers must be able to think outside the box, come up with new and innovative solutions to problems, and communicate their ideas effectively. They must also be able to understand the aesthetic qualities of their work and how it will impact the world around them. In recent years, there has been a growing recognition of the artistic side of engineering [1], [2], [3].

The challenge is that engineering is often taught in a very structured and formulaic way, which can discourage creativity. This presents a problem in that as the world becomes more complex, the need for creative engineers continues to grow. Engineers will need to be able to think critically, solve problems creatively, and communicate their ideas effectively. Not only will they need to be able to understand the immediate economic and social impact of their work but also perceive how their decisions will impact the world around them at short and long-time scales.

1.1 Current Approaches to the Problem

There are ongoing efforts to incorporate art into engineering education [4], [5], [6]. Many engineering schools offer art appreciation courses as part of their curriculum. These courses can help engineers learn about different art forms, such as painting, sculpture, and architecture. They can also help engineers develop their critical thinking skills and learn to appreciate the aesthetic qualities of art. This can be supplemented by taking engineers to museums and galleries can help them see art firsthand and learn about different cultures and time periods, or by having artists come and speak to engineering students to discuss the creative process and the challenges of being an artist. Finally, encouraging engineers to create art themselves can help them develop their own artistic abilities and appreciation for art.

1.2 Gaps in Current Approaches

Most top universities do require students to take elective courses on art and communication, and these areas have been identified as key components in innovation and creative problem solving [7], [8]. However, only a limited set require that the instruction be presented in an engineering context [9], [10]. Despite limited availability and scope, positive outcomes have been reported by participants in preliminary human and art-centric engineering experiences [11] that support initiatives to integrate the arts into engineering and technology education. Additionally, students engaged in a STEM-focused program benefit from an arts-related component as a motivator to succeed in their chosen field [12].

1.3 Proposed Solution

It is well established that education in STEM disciplines is essential for preparing students for the future workforce. However, it is also important for students to have a strong foundation in the arts. The arts teach students highly complementary and overlapping skills, such as to think creatively, solve problems, and communicate effectively [13], [14], [15]. The proposed solution in this study is to educate high school students on the benefits and opportunities available through creating art via a Maker Camp experience so that they may gain awareness of art's role in engineering, society, and general wellness. This knowledge can empower them to discern and self-advocate for a human-centric education and career path that will bring the satisfaction and fulfillment that comes from living a meaningful and purpose-driven life. In support of these goals, this study seeks to address the following research question:

> *What is the impact on high school student perception of Making as an Art form after experiencing a STEAM summer camp with an applied engineering workshop component?*

2. Background

This section describes three topics that are fundamental to understanding the work described in the remainder of this document.

2.1 Kentucky Science Center

Kentucky Science Center (KSC) is located in Louisville, KY, and is the largest hands-on science center in the state. KSC works to provide informal STEAM (Science, Technology, Engineering, Art, Math) education by offering a vast array of experiences for all audiences at its flagship location and throughout the city and surrounding region. Its mission is to encourage people of all ages to "Do Science" and is motivated by the notion that "Science Matters" to society, the workforce, and to individuals and families.

2.2 School's-Out Science Camps

Kentucky Science Center's School's Out Science Camps are a STEAM focused summer enrichment program that provides K-12 students with hands-on experiences in a variety of scientific disciplines located at the flagship facility in downtown City. The camps are designed to meet the Next Generation Science Standards and are led by experienced educators who are passionate about science. In addition to the academic content, the camps also focus on developing students' 21st century skills, such as problem-solving, critical thinking, and teamwork. Campers will also develop their creativity and innovation skills through activities such as coding, robotics, and design thinking. Kentucky Science Center also provides Offsite School's-Out Science Camps that take place throughout the region.

2.3 TECHnique Week

TECHnique week is an Offsite School's Out Summer Camp collaboration between Kentucky Science Center and Purdue University. The week-long event was held at a satellite campus of the partner university in the same region as the science center. Camp attendees spent the first half each day engaging in multiple maker activities that encouraged creativity and critical thinking. After a break, each afternoon was dedicated to a 5-day workshop curriculum designed to encourage campers to consider the personal, social, and professional benefits of Making, and to make use of advanced tools to create a personalized art project.

3. Methods

The following sections outline the design of the summer camp by showing the schedule over the five days of the maker and workshop components, describe the participant demographics, and present the prompts and response format used to collect data from participants.

3.1 Study Design

The TECHnique week camp was structured as a 5-day camp consisting of two parts each day. The morning section (8:00 AM to 12:00 PM) contained three maker activities each day that exposed students to various maker techniques and projects and challenged the participants to think critically and creatively solve problems. The schedule of daily activities is listed in Table 1 in section 3.1.1. The afternoon session (12:30 PM to 2:30 PM) was used for the workshop. Each afternoon started with an activity and introduction to a philosophical concept behind Making, presented in an engineering context, followed by a survey about the concept before shifting to work on the personalized art project. The schedule of the afternoon sessions is outlined in Table 2 in section 3.1.2.

3.1.1 Maker Camp

The morning of each camp day was designed to introduce campers to a variety of science, technology, engineering, art, and math concepts through hands-on activities. Each day, campers participated in different activities, as outlined in the following Table 1.

Day	Activity	Description
Monday	Mystery STEAM Bag	Participants will collaborate to design and model solutions to various real-world problems
	Rube Goldberg Machine	Campers will work with a partner in order to create the design for a Rube Goldberg machine that they can build with limited supplies.
	Origami Creations	Campers will work alone or in pairs to make something out of origami folds.
Tuesday	Squishy Circuits	Campers will learn about the components of a circuit.
	Bristle Bots	Campers will learn about the circuitry through application and about mechanical movement.
	Intro to Soft Circuits	Campers will apply what they have learned about circuits to create an e-textile.

Wednesday	Dino Automates	Explore the principles of mechanical engineering by creating one of three dinosaur automates, each with a unique movement mechanic.
	3D Pens	Explore new technology by using 3D pens to create their own 3D structures.
	Kintsugi Key Chains	Explore the process known as kintsugi in a unique way. Taking broken agate slices, copper tape, and a soldering iron, piece together a wonderful art piece that will bring beauty to the once broken pieces.
Thursday	Screen Printing	Campers will design a unique template and will screen print the template on a tote bag.
	Felting	Campers will learn about the textile art of felting and engage your creativity with different felting challenges.
	Duct Tape Creations	Campers will construct Duct Tape accessories including purses and wallets with plenty of pockets for organization.
Friday	Wood Burning	Chemically burn a custom design onto a cellulose based board.
	Leather Working	Participants will stamp their own designs into leather.
	Hydro Dipping	Explore the art technique known as hydro dipping, or water marbling. Float ink on the surface of water and transfer to a new object.

Table 1 - Maker Camp Morning (9:00 AM to 12:00 PM) Schedule

Through these activities, campers learned various techniques related to the application of science and engineering. In addition to learning new skills, campers also had the opportunity to collaborate with others, solve problems creatively, and express themselves through art.

3.1.2 Art and Technology Workshop

The afternoon time was dedicated to a connected workshop experience that spanned the entire five days and had two primary goals each day. First was to discuss and demonstrate one of the foundational goals of making art in an engineering context. The second was to make progress towards the project designed to facilitate the use of advanced tools and engineering principles, while leaving room for personal creativity and expression. The project was for campers to design, fabricate, and assemble an Icon Box that shows the time by the color emitted from a window/symbol instead of by numbers or clock hands, as shown in the student example works displayed in Figure 1.

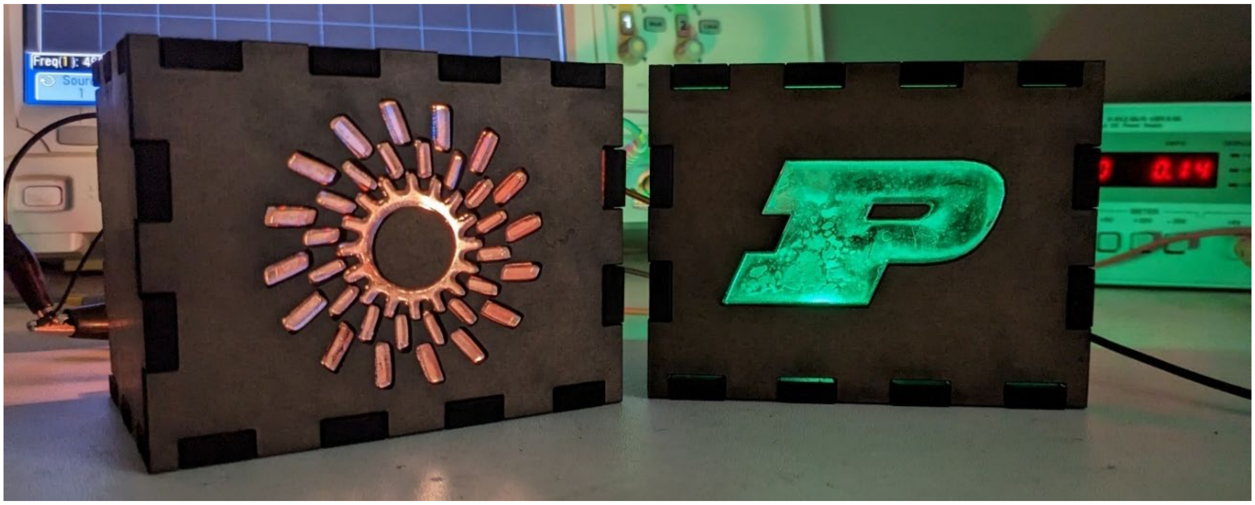

Figure 1 – Example Kaleidoscopic Icon Box

The following table outlines the conceptual elements and project progress steps planned for each day of the workshop. The survey question numbers are in reference to Table 3 in section 3.3.

Day	Activity	Description
Monday	Motivator	“What is Engineering” activity, identifying engineered objects within a fast-paced action-filled video segment
	Discussion of Making as Communication	Guided discussion on why humans make, are we the only animals to do so, and what elements are required to classify making as engineering
	Data Collection (Survey)	Pre survey of all concepts (#1-10)
	Project Progress	Prototype Analysis 1. Ask everyone to gather 2. Instructor gives verbal description of the prototype functions a. Icon Box b. 12 seconds or 24-hour cycle time 3. Students may ask the instructor about how it works at any depth, and then in a provided notebook, write a. 5 questions about how it is made b. 3 places where they think it could be improved 4. Everyone reports their questions, keep track on the board, discuss
Tuesday	Motivator	Think, Pair, Share prompt: Something you are PROUD to have made? WHY? 1. Students develop a list of 5-7 reasons WHY independently in a notebook 2. Pair, narrow it down to four common reasons to be proud of a creation 3. Pair teams, narrow it down to two 4. Groups share results with the class

	Discussion of Making as Creative Personal Realization	Instructor-led discussions of topic examples: 1. Industrial Faucet Design (Art informs Engineering Design) 2. Origami and Material Design (Engineering interconnected with Art)
	Data Collection (Survey)	Post survey of concepts #1-4
	Project Progress	Circuit Experimentation 1. Discuss Circuit Basics for RGB LED a. Circuit is a loop b. Conductive vs insulating c. Power Supply d. LEDs, RGB LEDs e. Resistors and Potentiometers 2. Create RGB LED circuit on breadboards
Wednesday	Motivator	Discuss Nature-inspired inventions, listen to Nature-inspired Manufacturing Podcast (Most Significant Bit [16]) episode about Biomimicry and Cat Claws
	Discussion of Making as Culture, History, and Connectors	Discussion of why study art from the past 1. Introduce perspective from The Metropolitan Museum of Art on this topic 2. Discuss "What do you think we can learn from looking at works of art from the past?"
	Data Collection (Survey)	Post survey of concepts #5 and #6
	Project Progress	Create wooden box and acrylic designs in AutoCAD 1. Generate box graphic from specifications using an automated tool 2. Draw acrylic design with polylines and set linewidth for laser cutting 3. Laser-cut all parts with remaining time and as needed for use on the next day
Thursday	Motivator	STEAM project demonstrations
	Discussion of Making as Means to Wellbeing	Guided discussion of art and engineering impact on wellbeing, with example media 1. "What is art therapy?" 2. Art in Engineering: Aeronautics Painter
	Data Collection (Survey)	Post survey of concepts #7 and #8
	Project Progress	Circuit Layout, Soldering, and Testing 1. Download code to ATTiny4323 2. Layout and solder perforated board circuit 3. Test with power supply
Friday	Discussion of Making as Community Engagement	Motivation Topic 1. Making vs Engineering vs Art 2. Collaborative Making 3. Societal Impact
	Reflection on Camp Activities	Guided Discussion 1. RGB LED Clock results share a. What did we contribute?

		b. What was hidden or expedited? 2. Technique Week Applications a. Future of technology and work b. Your value as an individual
	Data Collection (Survey)	Post survey of concepts #9 and #10
	Project Progress	Workshop project completion 1. Combine circuit and laser-cut components into final assembly 2. Add portable power supply 3. Verify operation

Table 2 - Maker Camp Afternoon (12:30 AM to 3:00 PM) Schedule

Table 2 also notes when participants were surveyed to collect data. Discussion of the survey details and data format is included in the following sections.

3.2 Participation Information

This participants in this study were part of the 2023 and 2024 cohort of campers, which consisted of ten males and three females, all from the Louisville, KY and the nearby Region. The participants' ages ranged from 14 to 18. Three educators from Kentucky Science Center were present for all activities on each day, and one faculty member from Purdue University joined daily for the afternoon workshop section.

3.3 Data Collection

Data was collected from participants with the following 10-question survey at the start of the workshop on the first day of the camp. Prior to the survey, the instructor facilitated a discussion establishing that engineering is a form of Making, and Making is a form of Art. The survey instructions and text for each question are shown in Table 3, and the "fill-in-the-bubble" response field for each is shown in Figure 2.

#	Concept	Category	Question Text
1	Making as Communication	Philosophical Foundation	Making provides unique symbols, systems, and metaphors that convey and inform life experience (i.e., the arts are ways of knowing).
2		Lifelong Goals	Makers use a variety of artistic media, symbols, and metaphors to independently create and perform work that expresses and communicates their own ideas, and are able to respond by analyzing and interpreting the artistic communications of others.

3	Making as Creative Personal Realization	Philosophical Foundation	Making enables individuals to discover and develop their own creative capacity, thereby providing a source of lifelong satisfaction.
4		Lifelong Goals	Makers may find at least one discipline in which they develop sufficient competence to continue active involvement in creating, performing, and responding to art as an adult.
5	Making as Culture, History, and Connectors	Philosophical Foundation	Making provides an essential means for individuals and communities to express their ideas, experiences, feelings, and deepest beliefs. Understanding the maker provides insights into individuals' own and others' cultures and societies, while also providing opportunities to access, express, and integrate meaning across a variety of content areas.
6		Lifelong Goals	Makers know and understand work from varied historical periods and cultures, and actively seek and appreciate diverse forms and genres of work of enduring quality/significance. They also seek to understand relationships among the arts, and cultivate habits of searching for and identifying patterns and relationships between the making and other knowledge.
7	Making as Means to Wellbeing	Philosophical Foundation	Participation in the making as creators, performers, and audience members (responders) enhances mental, physical, and emotional wellbeing.
8		Lifelong Goals	Makers find joy, inspiration, peace, intellectual stimulation, meaning, and other life-enhancing qualities through participation in making.
9	Making as Community Engagement	Philosophical Foundation	Making provides a way for individuals to collaborate and connect with others in an enjoyable, inclusive environment as they create, prepare, and share artwork that brings communities together.
10		Lifelong Goals	Makers seek creative experiences and support making in their local, state, national, and global communities.

Table 3 – Details (Concept and Category) and Text of the Survey Prompts

Participants were asked to respond to each prompt on a 7-point Likert scale. This format was chosen due to its more granular amount of options when compared to a 5-point scale, and optimal amount of choices to capture accurate data without overloading the subject [17]. This structure can lead to more accurate and reliable data due to its range of choices that are more likely to align with the respondents' true opinion [18], [19]. A 7-point Likert scale can help to reduce the problem of forced choice that can occur with 5-point Likert scales by including options that are between the two most undesirable options on a 5-point scale [20], [21], [22]. The following scale was provided with each question on this user survey:

Fully Disagree	Mostly Disagree	Minimally Disagree	Neutral	Minimally Agree	Mostly Agree	Fully Agree
O	O	O	O	O	O	O

Figure 2 – Survey Statement Agreement Scale

As noted above, the complete survey was conducted on the first day of the workshop. The set of questions under each concept in Table 1 was then repeated after the discussion and activities related to that concept were experienced. Results were collected from the participants in the camp and compiled for analysis.

3.4 Data Analysis

The seven-point Likert scale responses were averaged and analyzed by assigning numerical values to each response option and then calculating the mean of all the responses for each question. The mean score for each question can then be interpreted as follows in Table 4:

Weight	Definition
0	Fully Disagree
1	Mostly Disagree
2	Minimally Disagree
3	Neutral
4	Minimally Agree
5	Mostly Agree
6	Fully Agree

Table 4 – Agreement Scale Weights

Based on this scale, participants' responses were interpreted within the range of 0 to 6. A mean score of 0 indicated a full disagreement with the statement, stepping up towards a mean score of 3 which indicated a neutral opinion, and further stepping up to a maximum mean score of 6 which indicated full agreement with the statement.

4. Results

The findings of this work can be interpreted with respect to the research question: *What is the impact on high school student perception of Making as an Art form after experiencing a*

STEAM summer camp with an applied engineering workshop component. The resulting survey data has been sorted into the following three sections: pre-intervention survey results, post-intervention survey results, and a comparison of the change between the two.

4.1 Pre-Intervention Survey Results

The post-intervention data was taken after a discussion of the coinciding topic for that particular day as indicated in Table 2, with the question text provided in Table 3. Each horizontal bar contains the result of all seven respondents. The response level is indicated by the color segments of the bar, and the quantity that responded with that value dictated the length of that color segment.

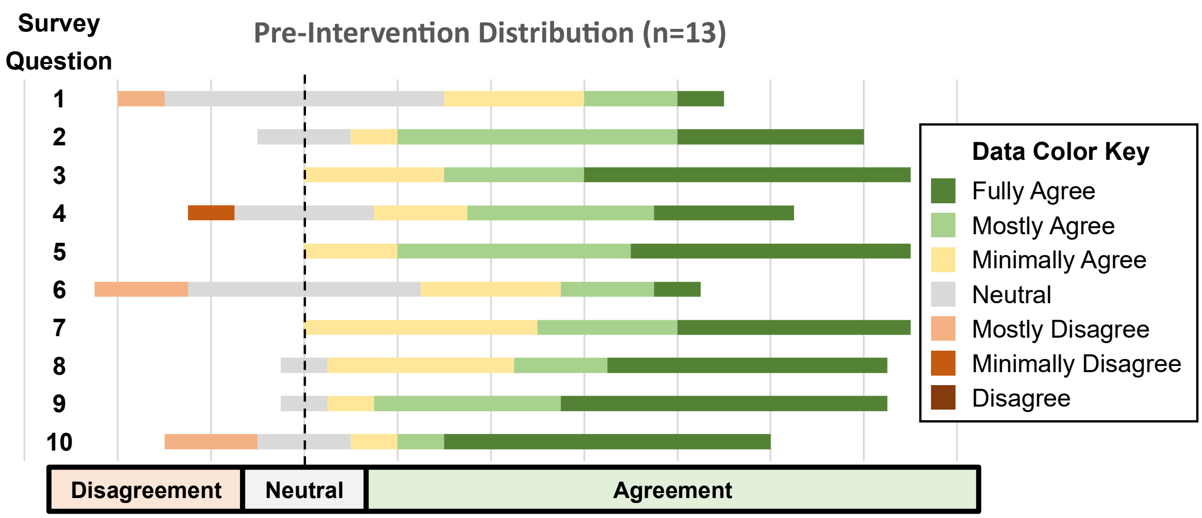

Figure 3 – Pre-Camp Survey Data

4.2 Post-Intervention Survey Results

After participants engaged in a discussion focused on the topic listed in Table 2 for that specific day, post-intervention data was gathered using the questions detailed in Table 3. As with the previous section, each horizontal bar contains the result of all seven respondents. The response level is indicated by the color segments of the bar, and the quantity that responded with that value dictated the length of that color segment.

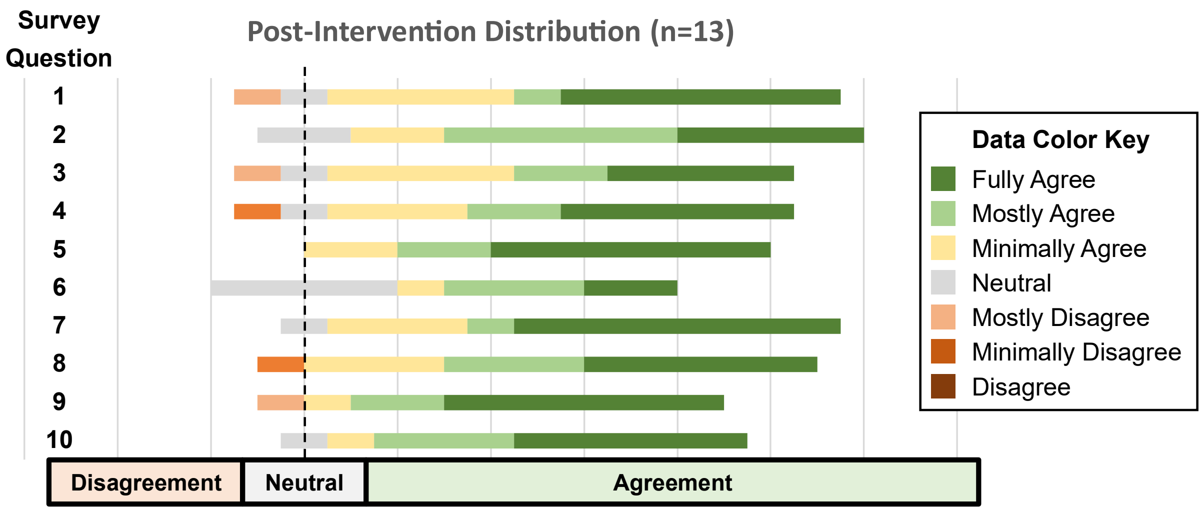

Figure 4 – Post-Camp Survey Data

4.3 Comparison of Pre and Post Data

Average Response (0 to 6 scale)			
Question	**Pre**	**Post**	**Δ**
1	3.692308	4.769231	1.076923
2	4.923077	4.846154	-0.07692
3	5.269231	4.583333	-0.6859
4	4.307692	4.625	0.317308
5	5.307692	5.4	0.092308
6	3.615385	4.3	0.684615
7	5	5.166667	0.166667
8	5	4.833333	-0.16667
9	5.307692	5.2	-0.10769
10	4.692308	5.2	0.507692

Table 5 – Shift in Survey Statement Agreement

The data shows that six of the ten concepts had increasing agreement. This may indicate that the discussion on those days was more impactful than others, or that the incoming understanding of those topics was less. Question one showed the largest movement towards strong agreement, which indicates that students were impacting by the notion that "Making provides unique symbols, systems, and metaphors that convey and inform life experience (i.e., the arts are ways of knowing)."

Of the four that had a deceasing agreement, question number three was by far the most notable. This may indicate that outgoing students were still skeptical of the notion that "Makers may find at least one discipline in which they develop sufficient competence to continue active involvement in creating, performing, and responding to art as an adult." There may also be improved agreement with modification to the explanation of this concept as it relates to engineering. Also, it can be difficult to conceptualize the benefit of doing something over a lifetime from the perspective of a teenage student.

5. Summary and Conclusions

The following sections describe a practical summary of the work, discuss the limitations of this study, and suggest opportunities to improve the quality of future research on this topic.

5.1 Practical Summary

The purpose of this work was to educate high-school age individuals on the presence of art in engineering and demonstrate the role of art in personal wellness and societal connection. The TECHnique Week Maker Camp experience has helped students to gain awareness of art's role in engineering, society, and general wellness, and empower them to discern and self-advocate for a human-centric education and career path. The results from this study indicate that the camp was influential on the perspective of the participants on these issues. Furthermore, this camp serves to highlight the value of individual creativity and perspective that all people can contribute to the engineering field, which is a critical component to increasing diversity, equity, and inclusion in the engineering discipline.

5.2 Limitations

This exploratory study must be considered within the context of relevant limitations. First, this early work was created from data from the first two instances (2023 and 2024) of the camp experience, and with a small student sample. Refinements to the content and delivery have been implemented in recent camps as the educators reflect on the lessons learned. The authors also seek to recruit a higher number of participants in future iterations of the camp curriculum to strengthen the data. The camp administrators also tentatively plan to collect short-answer reflections which may offer more context for the survey responses provided by the participants.

5.3 Future Research

Future iterations of this camp will seek to refine the workshop content to strengthen the messaging behind the content selection. Furthermore, repeated offerings of this camp are anticipated to garner more interest and increase the cohort of participants. It will be beneficial to analyze the effect of the camp with a larger sample size. The preliminary data in this study reinforces the perspective that by integrating art into engineering education, students can develop creative thinking skills and problem-solving abilities that they will need to succeed in their future endeavors. This exposure can also introduce techniques to boost overall wellness and help them to develop a deeper appreciation for the ways that engineering and the arts intersect in our world.

6. Appendix

Art: Philosophical Foundations and Lifelong Goals, National Core Arts Standards [23]

Philosophical Foundation	Lifelong Goals
The Arts as Communication	
In today's multimedia society, the arts are the media, and therefore provide powerful and essential means of communication. The arts provide unique symbol systems and metaphors that convey and inform life experience (i.e., the arts are ways of knowing).	Artistically literate citizens use a variety of artistic media, symbols, and metaphors to independently create and perform work that expresses and communicates their own ideas, and are able to respond by analyzing and interpreting the artistic communications of others.
The Arts as Creative Personal Realization	
Participation in each of the arts as creators, performers, and audience members enables individuals to discover and develop their own creative capacity, thereby providing a source of lifelong satisfaction.	Artistically literate citizens find at least one arts discipline in which they develop sufficient competence to continue active involvement in creating, performing, and responding to art as an adult.
The Arts as Culture, History, and Connectors	
Throughout history the arts have provided essential means for individuals and communities to express their ideas, experiences, feelings, and deepest beliefs. Each discipline shares common goals, but approaches them through distinct media and techniques. Understanding artwork provides insights into individuals' own and others' cultures and societies, while also providing opportunities to access, express, and integrate meaning across a variety of content areas.	Artistically literate citizens know and understand artwork from varied historical periods and cultures, and actively seek and appreciate diverse forms and genres of artwork of enduring quality/significance. They also seek to understand relationships among the arts, and cultivate habits of searching for and identifying patterns and relationships between the arts and other knowledge.
The Arts as Means to Wellbeing	
Participation in the arts as creators, performers, and audience members (responders) enhances mental, physical, and emotional wellbeing.	Artistically literate citizens find joy, inspiration, peace, intellectual stimulation, meaning, and other life-enhancing qualities through participation in all of the arts.
The Arts as Community Engagement	
The arts provide means for individuals to collaborate and connect with others in an enjoyable, inclusive environment as they create, prepare, and share artwork that brings communities together.	Artistically literate citizens seek artistic experience and support the arts in their local, state, national, and global communities.

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