Enabling Art: Accessible Art Creation for K-5th Grade Students

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Problem Statement and Background

Special education programs employ a variety of tactics to help their students reach a number of cognitive, emotional, and physical goals. The aim of these programs is to help each individual student to maximize their engagement in the learning curriculum as well as improvement in life skill areas such as motor skills, communication, and a sense of autonomy through adapting the school curriculum and activities to meet each student's needs and goals [1]. Some adaptations can be performed in the classroom, but many special programs, such as art are not fully equipped to adapt to each student's needs and goals and teachers are often left on their own to find ways to maximize student engagement. Adaptive art programs have the potential to facilitate student development in many key areas and some elements of therapeutic visual art making have successfully been integrated into public education [2].

The current options for assisting students using special education services to physically engage with art are severely limited. The primary method that teachers employ while assisting students in creating visual art is the hand-over-hand technique. This method involves a teacher placing their hand over a student's hand to assist in grasping the art implement as the student draws. Despite good intentions, this method makes it hard for students with limited strength to take ownership of the art making process and does little to improve their motor skills. An interview with an art therapist confirmed that the mental connection between physical movements and the resulting art are key to using art as a tool to help students achieve their learning objectives [3]. Art is a creative process and not constrained to the use of tools, as children are often observed finger painting without the use of art implements; however, students with various disabilities are often very sensory conscious and can be overwhelmed by loud noises, intense visual stimuli, or uncomfortable tactile sensations such as the feeling of paint. Therefore, adaptive tools that allow for art creation in which students can independently choose their level of comfort and engagement are needed.

Some adapted art tools do exist, including large grips that wrap around drawing implements such as Abilitations AbiliGrip Hand Grips and adapted easels that can be maneuvered for easy access from a seated position such as the MABEF Painting Workstation Easel M-30. These tools are often prohibitively expensive for educators and elementary school students with limited strength and motor functions find them frustrating or unengaging [1].

Our design is an affordable artboard and paint dispensing system that enables elementary aged students to engage with and create their own art. This project was completed in collaboration with a local art teacher whose goal is to build a robust, adapted art program that can deploy to multiple schools within the district and potentially also be made available to after-school programs.

Solutions Considered

Design approaches considered could be categorized into active and passive devices. Ideas for active devices included robotic devices ranging from freely roaming

robots to x-y plotters that would be able to traverse a canvas with user direction and dispense an art medium such as paint. Robotic devices have the advantage of allowing students a large amount of autonomy and control over the creation process, and interfaces could easily be customized to accommodate the achievable range of motion; however, it was clear in several observation sessions that the students struggled to connect with the art that was being created robotically as their focus oscillated between the technology interface and the robot, rather than the art itself. Passive devices ranged from assist to hold paint brushes that would making grasping easier and simplify the workflow with paint distribution to manually moved art tables which could move marbles around to spread the paint.

A key customer need was identified early on such that this product, should be easily repaired and easily manufactured with basic hand tools so that teachers can make their own systems. The active device concepts did not support this customer constraint of ease of replication well due to concerns regarding ensuring safety, complicated manufacturing, and long-term serviceability. A manual motion table was selected due to the potential to engage the most students and the ability to use off the shelf parts to design a device that could be manufactured with hand tools and thereby an accessible solution for multiple teachers. A secondary device then had to be proposed for distribution of the paint in order to promote as independent of a process as possible. Feedback from the teacher suggested that a stomp paint mechanism would help to engage the students in the art creation. The paint dispensing system also needed to satisfy the constraint of being easily replicated and easy for the students to use without sensory overload. The table would need to be multi degree of freedom in order to allow the students to move and rotate it freely and marbles would be used to spread the dispensed paint across the canvas.

Once a leading concept was selected, the initial design was embodied in an alpha prototype which was built using the design for manufacturing constraints. The alpha design for the artboard used a fused deposition modeling (FDM) method to manufacture a ball and socket joint to provide freedom for the tabletop to rotate and allow marbles to roll freely on the canvas inside a frame. The design utilized wood and minimal hardware to ease manufacturing and the sourcing of components. The alpha prototype of the paint distribution system suspended bottles of paint attached to a foot bellows which the student used to send a puff of air to increase the pressure in the paint bottle and dispense the paint out the nozzle and onto the canvas below. Commercially available components used for this prototype included stomp rocket bellows and PVC pipe (see Figure 1).

Figure 1: Alpha prototype of artboard (left) and paint dispensing system (right)

The alpha was tested at a local school where students were observed, and feedback was collected from the teachers and clinicians about the creative process that was enabled. Several modifications were needed after testing. The most glaring issue came from the FDM manufactured ball and socket joint used in the construction of the artboard, which failed during durability testing prompting a new design that could better reflect the constraints for maintainability and serviceability. The alpha prototype of the paint distribution system also had room for improvement. The PVC stand that was constructed to hold the paint bottles was too bulky and not flexible enough for the students to easily use both on the table and on the floor. The bellows initially used also had issues as the students expected them to refill with air while their foot was still depressing it, illustrating how the final device needed to be more intuitive. Additionally, the final assembly needed to be simple and straightforward for a teacher or administrator could make an entirely new setup with commonly available power tools and fasteners and commercially available components. The team used the feedback to then develop a beta prototype of both systems, which was delivered and is currently in use at the school.

Description of Final Approach and Design

The team decided to use with strictly commercially available components so that teachers or administrators could easily replace any parts that failed during use of the product without having to wait for weeks for a specific part to come in. The final design for the artboard utilized a ball and socket joint to maximize the degrees of freedom that the students were able to use in creating their art. The final design of the paint dispensing system was modified to sit at the same level as the artboard, so that whether the students were better engaged on the table or the floor, the system could adapt quickly.

Redesigning the ball and socket joint with affordable commercially available parts presented several challenges. Ultimately the team decided to go with a doorknob-based design, with the doorknob resting inside of a PVC tee joint. The PVC tee has a chamfer on the inner diameter of the middle connection, which provides a surface for the doorknob to rest on, and the upper walls of the connection keep the knob from translating from side to side. The PVC tee and door knob are screwed into the tabletop

and base, respectively. And finally, in order to keep the PVC and doorknob in contact, a bungee cord runs through the center of the joint and is knotted on either end with hog clamps to keep it in tension.

The canvas frame on the top of the artboard was also modified in the final design to allow for multiple standard sizes and to support both stretched canvases and paper. This was accomplished using two knob-handle screws and threaded inserts in the tabletop. This design solved multiple issues. It allowed the canvas to be easily removed by unscrewing the frame and didn't require any major alterations to the tabletop.

The last and most important consideration for the final design was safety. While testing the alpha prototype there were a couple of instances in which the edge of the tabletop ran into a student's knee. Two measures were implemented in order to eliminate this issue. The first was a set of four bump stomps around the ball joint in order to restrain the baseboard and tabletop from touching, removing a potential pinching hazard. The second was to place child-proofing foam around the edges and corners of the artboard to make it less dangerous in case it contacted one of the students (see Figure 2).

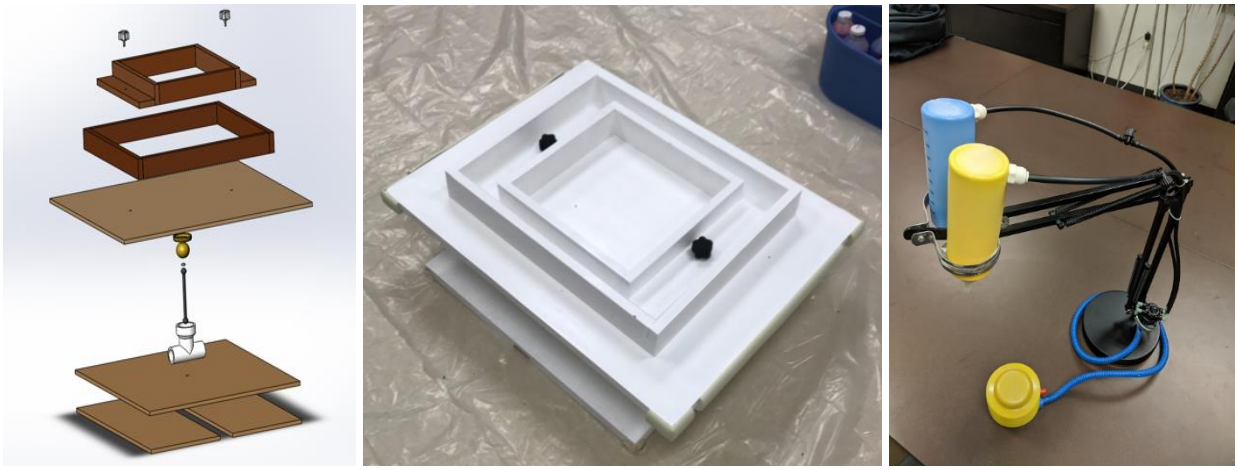

Figure 2: Exploded view of beta prototype artboard (left), artboard at delivery site (middle), and paint dispensing mechanism (right).

The final beta prototype used a commercially available foot bellows with an integrated check valve, and then converted to a pneumatic system that utilized irrigation system components that are readily available at local hardware stores. A pressure regulator and valve system enable teachers to help students to control their input to apply appropriate amounts of paint to the canvas, while the push to connect components enables the students to change colors quickly. The articulating arm was developed from a modified heavy base lamp that could suspend the paint bottles above the canvas while allowing them to move freely into position. This design removes the grip strength barrier to applying paint and allows the students to take more ownership in how paint is applied before being spread, thus engaging them throughout the entire art creation process (see Figure 1).

Results and Feedback

The beta prototype artboard successfully allowed the students to rotate and even aim the marbles on the canvas throughout the art creation process. The youngest

students were able to lift and tilt with ease, as the artboard required little force to use. The final design is robust and capable of withstanding the strength of a child. The teacher also really enjoyed the additional table edge that was incorporated to allow images and letters to be placed on the edges of the board.

When the beta prototype of the paint distribution system was first brought into the classroom, one of the students immediately remembered the alpha prototype and wanted to use the product immediately. The paint distribution system still has a few steps that require assistance from a teacher or administrator to ensure that all of the paint is not applied in one location but overall the student is in control of even the paint application process, which previously had to be entirely handled by the teacher for students with low grip strength. The flexibility of the system also allowed students and teachers to manually guide the bottles outside of the fixture, making it modifiable depending on the student's engagement needs.

Clinicians observed that aiming the marbles through the paint helped the students to practice their motor and coordination goals in a fun and engaging way in addition to fulfilling the art objective. Students were able to learn how to use both products very quickly. The setup time for teachers and administrators is very short, with the only additional steps required being that paint be put in smaller dispensing bottles. The cleanup process is as simple as popping the canvas out of the frame and wiping the paint off the marbles that were used. Overall the solution was very successful.

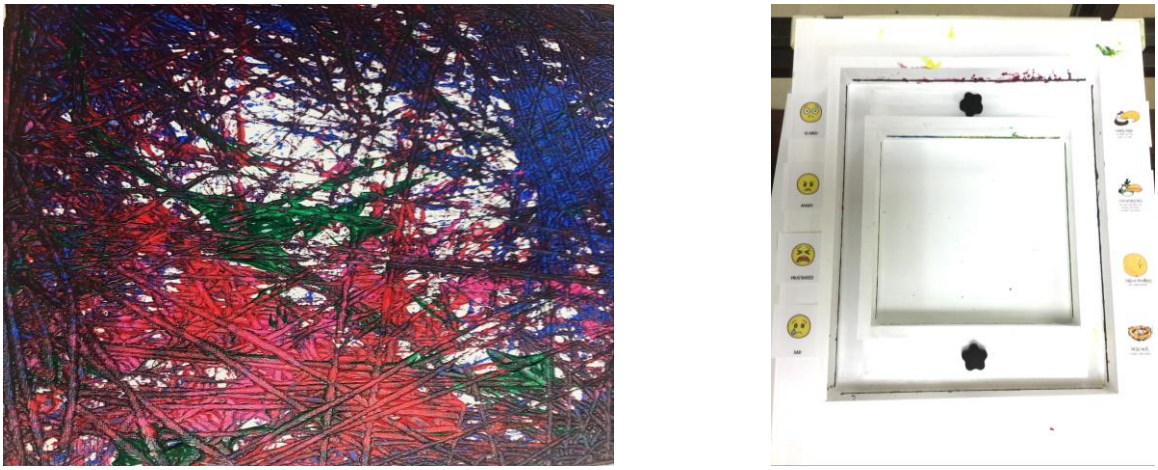

Figure 3: Example of art created by students (right). Beta prototype artboard being used as emotional communication station in art room at Valley View Elementary School after delivery.

Cost

A key design constraint for this solution was ease of replication, so that the device could be deployed to multiple schools. For this to be successful, affordability, ease of component sourcing, as well as ease of manufacturing had to be considered. As many components as possible were sourced from either local hardware stores, such as Home Depot and Lowe's, or from Amazon. The few hardware pieces that could not be sourced as easily, were purchased in bulk from McMaster-Carr and the spare parts delivered as part of the product to facilitate the building of additional systems. The total system cost was $124.77 and $74.31 for the artboard and paint dispensing system, respectively. Current technologies range in cost from $70 for the ArtSphere Easel to

$300 for the rotating artist's easel, so the device falls well within the market range given its added functionality and market reach. The design is also easily customizable and can be made more affordably for a single size to save on hardware costs.

Significance

The aim of this project was to assist students with motor or cognitive impairments to produce their own art in an easy-to-use, flexible, and engaging platform. The delivered beta prototype enabled the elementary school art teacher to begin immediately engaging her students with various physical, cognitive, and emotional needs. The secondary deliverable of build instructions will enable other teachers to replicate and use this device at schools throughout the district. It is hoped that the benefits of its use will impact many students in special education programs and potentially also in after-school enrichment activities. The delivered product will have a permanent home in an art classroom, which allows students of all grades to engage with their own creative art process.

The design of the artboard benefits students in ways that extend beyond the artistic process alone. The tabletop dimensions were designed to be larger than the frames for the canvases, leaving room for an instructor to customize the board and attach images, numbers, and letters to connect the creative process to learning goals. For example, emojis are frequently used at the school to open a conversation with students who have emotional difficulties throughout the day. It allows them to more easily express and vent their emotions (see Figure 3). Numbers and letters can also connect the art to learning goals. An example of this is challenging the students to shift the marbles on the artboard from the letter "A", on one side of the board, to the number "6" on the other. This actively engages student's communication skills and leads to enhanced learning.

The project prototypes also made an impact on a class of fifth graders who were learning about a product design process. They were fascinated with the prototypes that were originally just brought to show ideas. This product could also be used to discuss prototyping and product design to students in the future.

Finally, the art created through this adapted art program will be showcased at an upcoming gallery night to promote awareness of the need and advantages of incorporating adapted art into the school curriculum. It is hoped that art teachers everywhere will be encouraged to develop their own adaptive art programs and that this is just the beginning of a community of resources that will be available in the future, so that students everywhere can benefit from creating their own art.

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