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# Designing the World as your Palette

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## **Abstract**

“The World as your Palette” is our ongoing effort to design and develop tools to allow artists to create visual art projects with elements (specifically, the color, texture, and moving patterns) extracted directly from their personal objects and their immediate environment. Our tool called “I/O Brush” looks like a regular physical paintbrush, but contains a video camera, lights, and touch sensors. Outside of the drawing canvas, the brush can pick up colors, textures, and movements of a brushed surface. On the canvas, artists can draw with the special “ink” they just picked up from their immediate environment. We describe the evolution and development of our system, from kindergarten classrooms to an art museum, as well as the reactions of our users to the growing expressive capabilities of our brush, as an iterative design process.

## **Keywords**

Drawing, Children, Storytelling, Interaction Design, Tangible User Interfaces, Usability Research, User Experience, User Interface Design, User Research, User-Centered Design / Human-Centered Design, Visual Design

## **Categories and subject descriptors**

H.5.1 [Information Interfaces and Presentation]:  
Multimedia Information Systems—artificial, augmented,  
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## Industry/category

Education, art, painting, drawing

## Project statement

“The World as your Palette” is our ongoing effort to design and develop tools to allow artists to turn their world into a color palette to paint with. Central to this idea is the concept of building visual art projects with elements (specifically, the color, texture, and moving patterns) extracted directly from artists’ personal objects and their immediate environment using an augmented paintbrush called I/O Brush [2]. I/O Brush looks like a regular physical paintbrush but has a small video camera with lights and touch sensors embedded inside. Outside of the drawing canvas, the brush can pick up colors, textures, and movements of a brushed surface. On the canvas, artists can draw with the special “ink” they just picked up from their immediate environment.

In this paper, we describe our journey over the last two years of developing the I/O Brush project originally designed for children, into a suite of tools with complementing palette and an active canvas with portrait history, which could be used by artists and broader audiences to create and share art filled with personally meaningful objects and stories.

## Background

I/O Brush was originally conceived and developed as a new creative learning tool for children. We have installed our first prototype of the I/O Brush system in two kindergarten classrooms and conducted extensive evaluations with kindergarteners. Children quickly grasped the concept of taking elements from their real world and making paintings with them. They have

explored a variety of interesting colors, textures, and patterns found in their classroom, and in the process shared their explanations of their work and stories behind where the colors came from with their peers. (Please see [2] for more detailed discussion of our first prototype of I/O Brush and the results from our kindergarten study.)

Given the success of and the interest generated by the proof-of-concept, we were invited to install an I/O Brush system at the Ars Electronica Center (AEC) in Linz, Austria. This gave us the opportunity to develop I/O Brush into a more robust system to be used for an



**Figure 1.** A child drawing with I/O Brush using a variety of everyday objects.

extended period of time, but also to develop a system that gives artists more control so that I/O Brush can tickle the imagination and creativity of not only children but also adult artists and the more general public.

Finally, our experience developing the system for the Ars Electronica Center exhibition and observing broader user reactions has inspired us to build new features and improvements that led to our current extended system design.

### **Project participants**

All phases of this project were carried out by Kimiko Ryokai and Stefan Marti, research scientists and PhD students at the MIT Media Laboratory in collaboration with:

Research advisor: Hiroshi Ishii

Undergraduate student programmer: Rob Figueiredo

Collaborating institution: Ars Electronica Center

### **Project dates and duration**

Phase 1: Initial prototyping and observational study in kindergarten classrooms, July 2003 – April 2004.

Phase 2: Developing and installing a version for the Ars Electronica Center exhibition, June – September 2004.

Phase 3: Further design and development – September 2004 – current

### **Challenge**

I/O Brush was originally designed as a tool for children to explore colors, patterns, and movements found in their environment by sampling them from their environment and making visual art with them. As a drawing tool, our first prototype had only basic control. For example, no matter how hard children pressed the paintbrush against the canvas, the ink always came out

in a uniformed flow, with constant stroke width.

Therefore, the main challenge in phase 2 was to go from I/O Brush having relatively limited expressions as a drawing tool, to a tool that could be used by adult artists and visitors of an art museum.

The Ars Electronica Center in Linz, Austria is one of the first and oldest electronic arts museums, which attracts over 60,000 international visitors every a year. Our I/O Brush installation was scheduled to go on for at least a year. Therefore, our first research prototype, which needed constant maintenance, had to be made into a robust exhibition piece, which could be physically handled by general visitors over the course of a year. It also needed to be simple for the visitors to use, with minimal instruction or none at all.

For phase 2, the AEC exhibition, we had an extremely tight schedule for making our prototype into a museum ready piece, including shipping the equipment, and installing the system at their Linz museum site, all in just 10 weeks. Therefore, we had the challenge to prioritize our design and implementation needs.

### **Solution summary**

We designed and built our first proof-of-concept I/O Brush system in the summer of 2003. Our goal at that time was to support children's creative learning process through visual arts project; therefore, installing the system in kindergarten classrooms and observing children's interaction with the system was important. Working with over 40 kindergarteners (ages 4-5) gave us the opportunity to identify both the technical challenges (e.g., more robust sensing inside the brush for sampling various uneven surfaces) and design ideas (e.g., children will be able to run around freely if the



**Figure 2.** The children trying out different colors and patterns they can find in their environment.

brush was wireless) for the next prototype design. It is also in this phase we learned that children reach all over places with I/O Brush to sample colors and patterns in their environment (Figure 2).

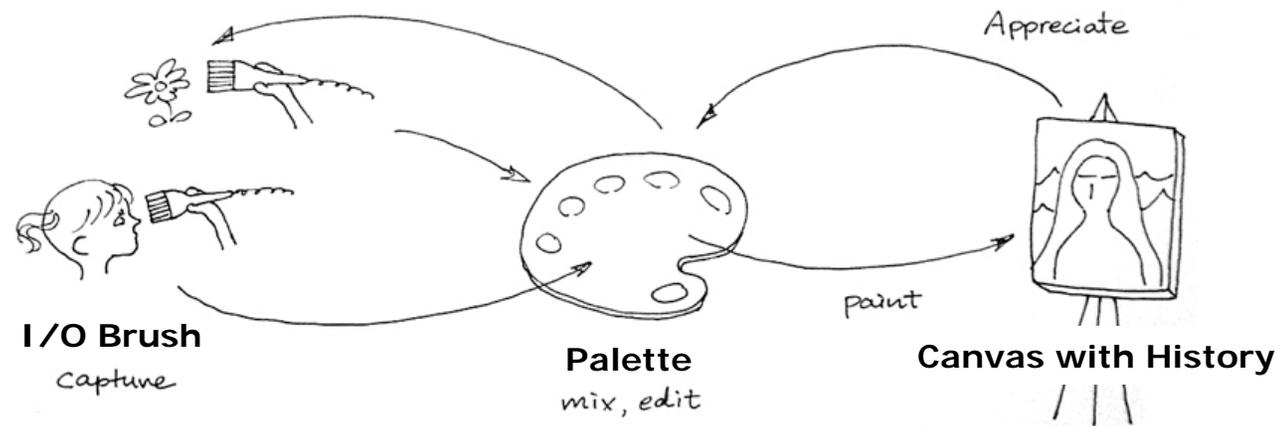
We made countless observations and lists of improvements from our kindergarten study. However, given the time constraints of 10 weeks from the invitation to exhibit and the start of exhibition, we did not have enough time to implement all the features for the next AEC exhibition. As the museum exhibit was to go on for at least a year, our priority in phase 2 was to make a robust, long-term exhibit piece prepared for heavy physical uses, yet at the same time allowing more artistic expressions by museum visitors. After examining several different kinds of sensors and design considerations, an aesthetically pleasing, expressive, and robust I/O Brush was developed.

During the opening week at the Ars Electronica Center end of August 2004, several thousands people (both children and adults) used I/O Brush as an interactive museum piece. The new I/O Brush was a big hit, but we made several important observations that lead to our current design and implementation.

First, compared to our previously observed kindergarten artists, adult artists and visitors at the AEC were much more particular about sampling colors,

textures, and movements with I/O Brush. Specifically, they wanted to see exactly what the ink they picked up with I/O Brush looked like before applying that ink on the canvas to draw. In reaction to this, we later developed the concept of a physical palette to accompany I/O Brush. The idea is to have the palette serve a platform to collect and process ink before applying it to the canvas, just as artists do when painting with real water color or oil paint.

Another important observation we made was people's awareness and raised interests regarding the material that made up works of art. By creating paintings with colors, textures, and movements extracted from everyday material or unusual places, and by watching people make creative use of I/O Brush, people showed increased interests in finding out where the material/colors/ink that make up works of art could come from. In response to this, we developed a feature where the canvas can keep a record of where each color used in the portrait was sampled. The brush strokes artists make on the canvas are linked to pop-up movies on the canvas that document where the artists had picked up certain materials. With this feature, the portrait can take both artist and audience back through the journey and reveal the stories behind the special palette of colors.



**Figure 3.** The extended “World as your Palette” system.

To summarize, through iterative design and multiple implementations of our project so far, what started out as a system with a single augmented paintbrush has developed into a suite of tools that has the potential to empower child and adult artists by making art charged with personally meaningful objects. The suite of tools allows artists to build their own paint box by taking elements from their world, building a portrait with their personal paint box as the technology automatically records the process, and allowing them to share with the audience both the portrait and stories that represent the process behind the portrait. (The diagram above illustrates the complete system.)

### **Solution details**

In this section, we will describe the details of our design decisions and how they were implemented into the system made for the AEC exhibition. We will then

describe our current designs motivated from our observations at the AEC exhibition.

### *Simplicity*

We have made an explicit decision to make the brush simple with no buttons on the brush at all. In our first prototype for kindergarteners, the brush had three buttons on its handle for changing modes (texture mode, color mode, movement mode). These buttons needed to be pressed only when changing modes. Contact switches were embedded inside the bristles, so when they were “picking up” ink from the surface, they simply needed to press the bristle slightly against the target surface. Children generally got the functions of these buttons but there was some confusion as whether to hold one of the buttons in order to sample at the beginning of play session. To avoid any confusion, for the AEC exhibition version, we decided to remove these mode buttons from the brush and put them on the



**Figure 5.** Design evolution of the brush handle.

frame of the canvas next to a “wipe canvas clean” button. This way, the brush remained simple, a tool to dip/“pick up” ink and draw with the ink, just like a regular paintbrush.

As a museum exhibit piece, the brush had to be robust yet beautiful. We decided to make a hardwood brush handle (turned from a single piece of solid maple wood) with all the electronic components tucked inside (Figure 4 and 6).



**Figure 4.** The AEC version of I/O Brush with a maple handle.



**Figure 6.** The brush handle on a lathe (left) and the video camera and components inside the brush (right).

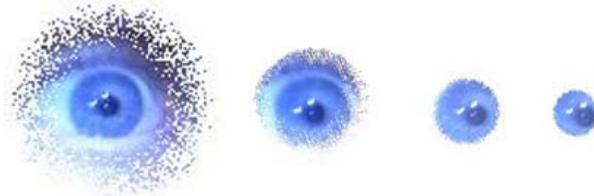
#### *Scale, form, and orientation*

Though the physical design of the brush was simpler, there were many improvements in both the software and hardware in the brush developed in phase 2. We experimented with different sensing technologies (e.g. contact switches, force sensors, piezo sensors). Force sensors embedded at the bottom of the brush bristles, gave the best result in reading the pressure applied on the brush bristles, without being influenced by the vibrations of the brush as a whole. With the force sensor input, unlike our previous technology with contact switches, we were able to vary the volume of ink flow. The more pressure artists apply, the thicker/fatter the ink flows on the canvas. This allowed artists to be much more expressive with their brush strokes and movements.

We also explored a variety of sampling scales afforded by the size of the physical brush. The size of the physical brush bristles could not be too small, as people generally want to sample not just a small dot on a surface but some identifiable patterns and motifs. The brush could also not be too large or too heavy as people (including children) needed to hold and draw

with it freely. Our solution was to keep the diameter of the bristle area “eye” size. It may not be big enough to sample a large motif such as a postcard size picture, but it is big enough to sample small units such as eye, letters, etc.

On the canvas, artists can control the size of the sampled image to be released by how much pressure they apply on the brush. Figure 7 shows different sizes of an “eye” ink produced by different amount of pressure applied onto the brush bristles.



**Figure 7.** “Eye” ink used with varying pressure.

Our final hardwood paintbrush at the AEC was not too big even for small children. Our choice of having a paintbrush as a metaphor for “picking up” instead of using a syringe or pipette worked out well as it invited people to sample from each other’s body and faces.

Another interaction we observed at the AEC exhibition was the orientation of the ink. The ink captured by I/O Brush is essentially an image with an orientation. For example, if a person sampled an eye in sideways, the eye would appear on the canvas sideways as well. At the AEC, we observed people trying to turn their ink by rotating the brush as they draw. Yet the ink did not



**Figure 8.** “Eye” ink being turned while drawing a curve.

turn with the brush, as there was no mechanism to support that interaction. Our solution was to later add a MEMS-based inclinometer inside the brush. The resulting ink effect created by our most recent version of brush can be seen in Figure 9. Adding the inclinometer inside the brush yielded more expressive



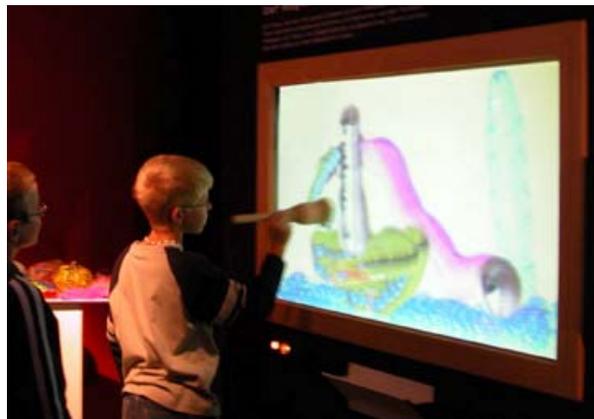
**Figure 9.** Applying pressure and rotating the brush creates rich stroke variations from a single “ink.”



**Figure 12.** An artist at the AEC painting with I/O Brush and smudging his painting.

capabilities through the physical interaction with the brush in addition to the pressure.

For the AEC exhibition, we also increased the scale of the canvas. For our first prototype, we used a 21-inch Wacom™ tablet display [3]. It is relatively large for an LCD screen, yet the size of I/O Brush demanded a bigger screen. For example, kindergarteners ran out of space when they were drawing their names on the screen. For the AEC exhibition, we incorporated a much larger 50-inch infrared vision based touch panel over a back projection screen. This scale worked well with the physical scale of I/O Brush. People, even little kids, moved and spread out using the whole canvas.



**Figure 10.** A child artist drawing with I/O Brush at the AEC.

#### *Touching the portrait*

When we look at painters painting with real paint, they touch the portrait a lot with their hands and fingers, taking a little paint off here or there, and smudging the



**Figure 11.** Smudging paint on the canvas.

corner of a stroke. In fact, when we worked with the kindergartener children in phase 1, the children did a lot of touching to their portrait on the LCD screen voluntarily even when there was no interactivity through the screen. In response to this, for the AEC exhibition, we improved our software to allow this “smudging” interaction by sensing when artists touch the portrait directly and smudge. (Figure 12 shows artist at the AEC smudging his paint with fingers.) This allowed finer control over their painting, which could not have been achieved with just the brush alone.

#### *Offer a place to work with the ink: Palette*

One of the most interesting and important observations we made was how people preferred seeing what they are picking up with I/O Brush prior to painting with the ink on the canvas.

Our own development version of the software had a little window in the corner of the canvas, which served as a monitor for displaying the image being captured by the video camera inside the brush. When we were developing and debugging the software, we had this

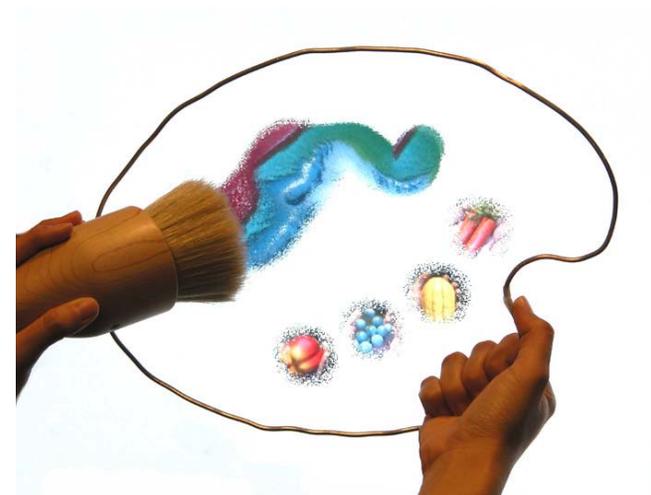


**Figure 13.** A real time “monitor” window shows what they are sampling.

window open so that we could see the camera inside the brush adjusting/focusing to the surface in real time. While we were at the AEC setting up our system prior to the opening day, we had our “debugging window” open. We had accidentally left the window open for a demonstration with the Art Director at the AEC before the opening of the exhibition. The director liked having the debug window on the canvas so that people could see exactly what they were picking up from the camera. Over the next few days, it was clear this was a good decision. Several thousands of people used the

brush during the opening week at the AEC, and people constantly looked at the monitor window (Figure 13).

However, there was a bit of awkwardness to having a “preview” window on the painting canvas as the window intruded the canvas space. An artist also had to look away from the physical objects they were sampling and look at the screen. Our solution was to provide another space dedicated for such an intermediate process, and keep away from the canvas but closer to the artist. This led to our development of a complementing palette for I/O Brush (Figure 14).



**Figure 14.** Our software implementation of a palette shown with wire mockup frame.

After returning from the AEC exhibition in the beginning of September 2004, we began developing the software of the palette. As of December 2004, the basic function of the palette software is complete and runs on the corner of the large canvas. Once more extensive

studies of the functions of the palette are complete, the palette will run on a separate tablet PC that artists can carry around.

On the palette, artists can now sample and drop off multiple inks on a palette space. In our current prototype, up to 5 different distinctive inks can be stored on the palette so that the artist can go back and forth between these inks. To pick up an old ink, the artist simply brushes over the reservoir and the software assigns the ink as the current ink so that the artist can paint with it. The rest of the space on the palette is dedicated for mixing multiple inks. An artist can "mix" multiple inks by drawing in the space with multiple inks. By layering the multiple inks in the space, the artist can also create new ink. The mixed paint can then be picked up as new ink.

*Portrait that tells stories behind the material: Canvas with memory*

For the AEC exhibition, in addition to installing the I/O Brush and its large canvas, we also prepared a finished art piece painted with I/O Brush. This art piece also was an interactive demonstrational piece where each color in the portrait had an associated documentary film of where the ink came from. When the visitor touched a certain place on the portrait, the film of where the material came from emerged and played over the portrait briefly. For example, the petals of the flowers in a portrait were extracted from a ragged teddy bear. People quickly understood the idea and enjoyed finding out where the ink came from. Moreover, the activity picked the visitor's curiosity to inquire into the materials that made up the art.



**Figure 15.** Children interacting with the portrait with history.

This led to our implementation of the canvas that keeps a history of where the inks came from. Our current implementation of this technology works in the following way. The video camera inside the brush constantly streams video to the computer, but only the last 5 seconds before the brush makes the "touch down" is saved in the program. The saved "history" is mapped to the brush strokes on the canvas, so when a person touches it, the history movie plays back on the canvas. The idea is that the history movie captures the source of the ink, and so both the artist and the audience are able to identify where the ink originated from (e.g. one may see the face of a person trying to capture an eye or a button from the person's jacket, etc.) This way, the canvas serves as a place to hold both the artist's portrait and the histories of materials used in creating the portrait.



**Figure 16.** Touching a particular part of a portrait reveals where that ink came from. In this example, the canvas reveals the color came from a leather shoe.

## Results

At long last, both children and adults have tried the most recent version of our extended I/O Brush system currently installed at our own laboratory. While we are still in the process of developing our new suite of tools, we were most interested in finding out their uses of “palette” and the “history,” the two features that were developed after the AEC exhibition.

Children grasped the idea of the palette and used it to both inspect what they picked up and to return to ink that they had picked up previously. They also got the idea of the brush recording the history of where it has been. For example, they made a stuffed animal dance before it was sampled and were happy to see the stuffed animal appear on the canvas dancing when they touched the ink. However, playing with the history

function of the tool was so much fun that it sometimes seemed to distract them from ongoing painting activity.

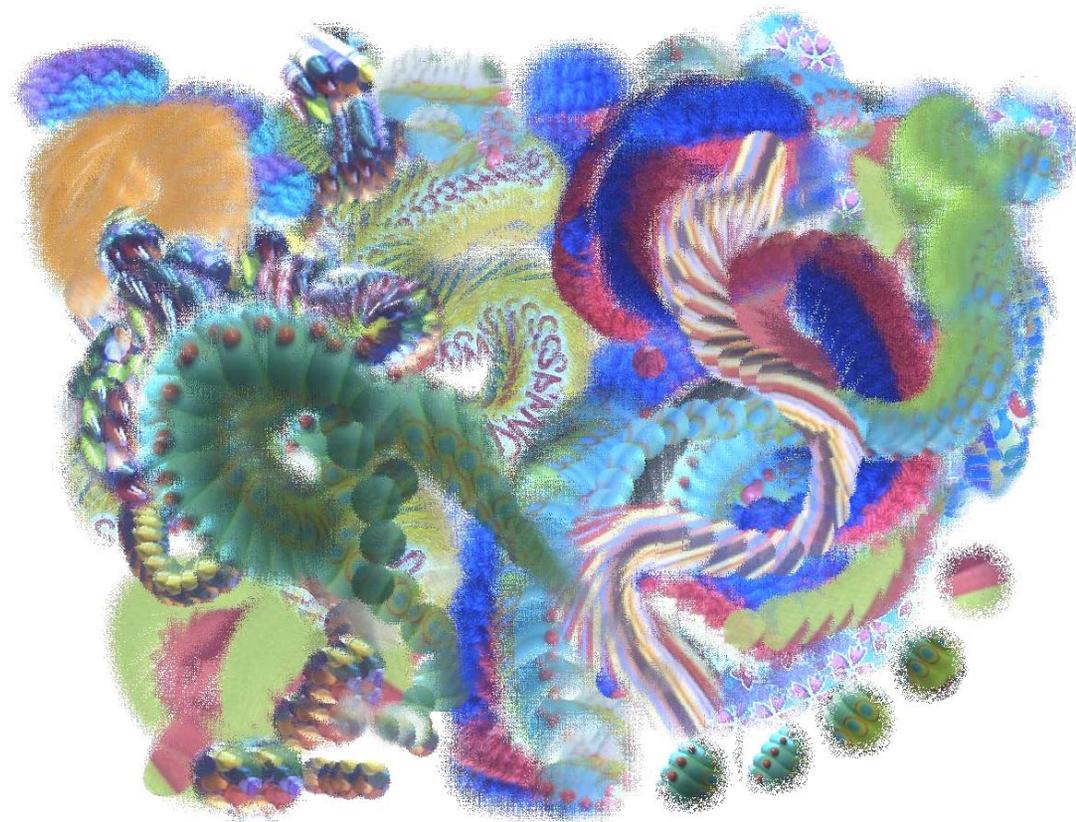
Adults also appreciated seeing the ink they were picking up and being able to go back and forth between the old ink and new ink. Adults used the history function more symbolically than children. For example, one adult embedded a picture of his mouth moving behind a little bug he drew as a surprising touch to the portrait. Another adult drew a window through which the audience could see moving letters/message when they touched the window. We plan to conduct more extensive studies with adult artists over a longer period of time, but we are excited to see the potential the system has in providing artists with multiple layers of canvas where they can embed and construct complex messages behind the portrait.

Although the palette was not yet running independently on a separate computer, it seemed to have just enough functionality to evaluate the interactions and potential design challenges. For example, artists quickly exhausted the five reservoirs on the palette, wanting to keep more individual inks available on the palette. Therefore, the palette needs to be able to accommodate more reservoirs while at the same time keeping a reasonable size to be used as palette.

Some artists also expressed interest in controlling the ink further by adding a water repository on the palette so that they can control the transparency of the ink, just like they would with real watercolors. These accounts also serve as evidence that they were comfortable with the idea of having a palette with I/O Brush.

Occasionally, artists touching the canvas in order to smudge the paint were misinterpreted by the system as touching the screen to activate the history to emerge. Currently, we distinguish these two actions just via the touch duration; further tuning of this threshold is needed.

Finally, Figure 17 is an example of an art piece made with our most recent system. It is noteworthy that the portrait has been made from material found in the artist's office. As the audience touches parts of the portrait and watches the documentary/history, it reveals that such a colorful portrait was put together by a collection of objects surrounding the artist's office.



**Figure 17.** "colorful dream"

## Conclusions

The project is still ongoing and will continue to develop. We believe we have learned a great deal and have fashioned a number of key features that makes the system a better tool.

In time, the system could be taken outside and made mobile to interface with nature directly. Finlay [1] tells an interesting story behind the invention of portable paint boxes. With the invention of the collapsible tin tube, portable paint boxes were born. "Without oil paints in tubes, there would have been no Cezanne, no Monet, no Sisley or Pissarro: nothing of what the journalists were later to call Impressionism. Impressionism, after all, was a movement that depended on recording nature in nature. Without being able to use colors outside it would have been hard for an artist like Monet to record the impressions that the movements of the light had made on him, and so create his atmospheric effects."

In a way, the technology we presented here also opens up a new arena where children and artists have access to elements that were difficult to obtain (or rather did not even think about obtaining) before. As the technology allows children and artists to rely a great deal on the context they are in, they may inescapably pay attention to the objects and elements that

surround them. The portrait also may serve as a remembrance of the context the artist has been in. For example, a portrait a child creates in a classroom may have a palette of colors quite different from a portrait the child creates in her own room at home. Like wise, a portrait an artist creates in an urban setting may contain different colors/tones from the one the same artist creates in a country setting. In time, just as the impressionist movement was brought about by the invention of the ink tube, our effort to provide a suite of technological tools to turn the environment into a color palette may contribute to bringing about a new generation of artists and expressions afforded by their physical world.

## Acknowledgements

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