

Inspiring AWE: Transforming Clinic Waiting Rooms into Informal Learning Environments with Active Waiting Education

Zeina Atrash Leong^{1,2}, Michael S. Horn², Lisa Thaniel³, Emily Meier⁴

Learning Experiences
and Design Lab,
Atraeleo¹

Computer Science and
Learning Sciences,
Northwestern University²

Center for Cancer and
Blood Disorders,
Childrens National
Medical Center³

Department of Pediatric
Hematology, Indiana
Hemophilia and
Thrombosis Center⁴

zeina@atraeleo.com, michael-horn@northwestern.edu, LThaniel@childrensnational.org,
emeier@ihtc.org

ABSTRACT

This research explores patient education in pediatric hematology and oncology clinics. Based on interviews, observations, and a review of existing patient materials, we argue that education in clinic waiting rooms is in need of reform. We applied design principles from research in science museums along with tangible interaction techniques to create the Sickle Cell Station, an interactive learning experience about sickle cell disease. To evaluate the effectiveness of this design we observed approximately 580 participants in a pediatric hematology clinic waiting area in four different design conditions. These observations included detailed video analysis of 81 patients and their parents to understand their interaction and learning with the Sickle Cell Station. Our results show an engaging learning experience with relevant conversation, inquiry, and collaboration. We describe how patient engagement varied in the four design conditions and conclude with implications for new designs in the area of Active Waiting Education (AWE).

ACM Classification Keywords

H.5.m. Information Interfaces and Presentation (e.g. HCI):
Miscellaneous

Author Keywords

Health, education, interactive media, children, design

INTRODUCTION

In this work we consider medical clinic waiting areas as potentially rich sites of informal learning. We draw on research from learning in science museums to design interactive “exhibits” to support patient learning around Sickle Cell Disease. Our goal is to engage families in collaborative learning experiences around relevant health topics. While perhaps not immediately obvious, we see many parallels between science museums

and clinic waiting rooms in terms of their potential to support hands-on learning. Modern perspectives on informal learning emphasize that it is learner-motivated, collaborative, ongoing, open-ended, and deeply shaped by contextual and social factors [3].

We know that families visit museums for purposes of education and entertainment [9], while they visit clinics out of medical necessity. However, in both settings, families have freedom to engage (or not) in experiences that seem appealing or interesting. Spending time on education is purely voluntary, and children in both settings actively seek activities they will enjoy. Much like museums, in waiting rooms families come and go with varying group sizes, interests, and available time to spend. Because pediatric clinics require guardians to accompany minors under 18, children always come in family groups. These patient groups have potential for fruitful collaborative learning experiences, which is a concept repeatedly highlighted in effective museum learning [9, 3, 8].

Most of the current educational materials provided to patients and their families in waiting rooms take the form of pamphlets and posters. While these materials do offer an opportunity for informal learning, they are only useful to the extent that people read and understand them. Unfortunately, prior research and our own observations suggest that children rarely read print material in waiting rooms. Moreover, the primary function of pamphlets and posters is to convey information (through text and pictures), not to engage learners in active exploration. This is in contrast to hands-on science museum exhibits that are often designed to engage learners in hands-on explorations of scientific phenomena.

In this study, our intention is to reimagine learning in clinic waiting rooms by applying what we know about exhibit design in science museums. Our goal is to support more active and collaborative family learning that is less about reading information and more about engaging in active experiences tied to deeper conceptual understanding. To try to accomplish this, we began with a series of observations in clinic waiting rooms to more fully understand the design context. We then applied design principles from research in science museums along with tangible interaction techniques to create the Sickle Cell Station, an interactive learning experience about sickle

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ACM ISBN 978-1-4503-5620-6/18/04...\$15.00
<https://doi.org/10.1145/3173574.3173672>

cell disease. To evaluate the effectiveness of this design we observed approximately 580 participants in a pediatric hematology clinic waiting area in four different design conditions. We analyzed video of 81 patients and their parents interacting with the station. Our results show an engaging learning experience with relevant conversation, inquiry, and collaboration.

There is much to be learned about people's behavior, learning, and engagement with innovative designs in waiting rooms. For example, is it feasible to put these large scale interactive learning systems into waiting rooms? Will people use them as we imagined? How will these materials impact patient behavior in the waiting room, or health regimens? Currently, we only aim to answer the first basic questions: can we do this? Will people use it and how? And do they understand the material? In future work, we hope to expand to learn more about greater impacts, such as personal health changes.

BACKGROUND

Studies have investigated the effects of poster and video messages, pamphlets, and computer applications on topics such as women's health, diabetes, and antibiotics [10, 18, 27]. Researchers have also proposed using technology to enhance patient communication with doctors or informative biographical videos [2]. Research in waiting rooms is otherwise limited.

Museums Design Principles

In contrast, research on visitor learning in science museums has grown considerably in the past few decades, especially in terms of designing experiences that emphasize visitor-driven inquiry learning (e.g. [3, 5, 6, 7, 8, 9, 25, 26]). Researchers and designers have also studied interaction around exhibits using new technologies such as multi-touch tabletops [1, 11, 13], games [29], whole body experiences e.g. [22], and tangible systems [12]. Our design for waiting rooms was informed by two museum research efforts: the Active Prolonged Engagement (APE) studies at the San Francisco Exploratorium, and the Family Learning Project (FLP) from the Philadelphia/Camden Informal Science Education Collaborative (PISEC) Group [6, 7, 15].

The concept of Active Prolonged Engagement was developed through a series of studies contrasting traditional "planned discovery" exhibits with open-ended interactive exhibits [15]. Planned discovery exhibits lead visitors to notice specific details or counterintuitive phenomena as a way to pique curiosity and interest. In contrast, APE exhibits strive to foster more open-ended, visitor-driven explorations. These types of exhibits ideally appeal to a broader range of users who collaborate, explore, play, and observe to longer engagement times and deeper involvement [15]. The Family Learning Project studied collaborative visitor learning around exhibits. The team identified and measured family learning, the connection between learning and exhibit design attributes, and how to change exhibits to promote learning [6, 7].

Both of these programs highlight similar design features for exhibits to promote engaged learning. Accessibility is a key design feature; that is, exhibits should be usable by people of varying backgrounds, ages, and abilities. The use of the exhibit should be led by the visitors' own interest, rather than text

around the exhibit. Given the open-ended nature of the task, a variety of outcomes should be supported through exploration. Both research projects also generated lists of conversational and behavioral attributes that indicate meaningful learning.

Montessori

Much of our inspiration comes from the Montessori pedagogy, which invites children to gain independence and encourages exploration. Children begin with lessons of sensorial familiarity with physical materials in the environment [20]. The design of these manipulative materials highlights three prominent features that motivate our design: 1) they are used over a long period of time (months and years); 2) they feature subtle uniformities such as color and shape that reinforce the concepts being taught; and 3) they are designed to be adaptable for multiple concepts of increasing complexity [20]. Typically, following a simple lesson that introduces the material, the child's familiarity is leveraged to teach more sophisticated concepts hidden within the details of the material's design.

Technology & Health

Technology has come to play an important role in health care by supporting patients, doctors, and their relationships through online communities, management systems, and even treatment options. Overall technology can positively influence learning, self-care, and skill development as well as strengthen the established medical learning environment [17]. Increasingly common are devices to inform patients of the details of their visit or discharge information (e.g. [28], [4]), or to promote health knowledge and persuade patient behavior [23]. However, most of these devices tend to focus on clinic visit details such as staff, medications, or test results and not the mechanics of the body or diseases and disorders.

Sickle Cell Disease

We look specifically at children with Sickle Cell Disease (or SCD). SCD is an inherited blood disorder in which the red blood cells polymerize when deoxygenated and become hard, sticky, and shaped like sickles. As these pointed cells move through the blood stream they clog the flow of blood causing pain, strokes, internal damage, and anemia [24]. Studies among medication treatments have found that if patients are unaware of the function of drugs they are less likely to comply to their medication schedules [14]. Epidemiologists argue that there is a need for a sickle cell public health agenda noting that a lack of education and weak social support structures may affect health and well being of sickle cell patients [30] and that better education may have a positive impact on compliance [19]. Patient education and empowerment strategies are among the top priorities for improving health and life quality for sickle cell patients [21].

PARTICIPATING CLINIC

We conducted our study and design work at a hematology and oncology clinic is part of a large urban children's hospital in the mid-Atlantic region of the United States. The clinic serves a large and diverse population. During two to five-hour long visits at the hospital, patients are seen by nurses, physicians, nurse practitioners, social workers, and/or psychiatrists. Patients come for all routine care for checkups, treatment, and

even blood transfusions. In the waiting room, children are given entertainment options, plenty of space, and comfortable furniture. Classic toys, child sized furniture, modern electronic entertainment (e.g. video games, and TV), paper educational materials, and an art room give children many options to pass the time while waiting for their appointments.

Preliminary Environmental Analysis in the Clinic

To learn more about patient experiences in this clinic, we conducted background observations, interviews, and assessments of pre-existing learning materials [16]. We found an average wait time of 32 minutes for families in the waiting room. The youngest children that we observed (less than 6 years old) tended to play with anything available and moved from one task to another quickly. Wait sessions with older children were less varied: they tended to sign in, take a seat, and stick to one activity (typically TV or a mobile device) until they were called in for their appointment. Children did not tend to print material, including both material provided by the clinic as well as those brought from home [16].

We also analyzed a wide variety of educational materials offered to SCD patients and their families. We evaluated 44 samples in 7 formats: websites, pamphlets, books, booklets, fliers, DVDs, and CDs. We categorized these materials into 6 topics: care program, genetics, medication, sickle cell overview, or a treatment option. We also analyzed the reading level of text-based material (38 samples) directed at patients. Of these, only one booklet measured below a fifth grade (typically 11 years old) reading level; the overall average was at the ninth grade reading level, well above the average patient age (10.5 years). With the exception of one booklet, none of the educational documents provided to patients were at a level for children below the age of 10.

DESIGN PROCESS AND IMPLEMENTATION

Based on our preliminary observations and analysis, we designed an exhibit for patients and their families called the Sickle Cell Station. We followed an iterative design process with multiple rounds of ideation, prototyping, testing, evaluation, and redesign. The resulting station includes 4 main features: a mobile application, a tangible blood vessel, a supporting poster, and a pamphlet.

We tested designs that focused on the difference in hemoglobin structure within normal red blood cells and sickle cells, and the difference in blood flow behavior with sickle cells. While the four components can be used independently, they are designed so that each part reinforces the others. We designed each piece of the system to provide opportunities for collaboration. The vessel, tablet, both sets of tangible cells, and poster can all be shared by multiple users at once.

Since we are trying to educate patients as they wait, we aim to provide an experience that they can, and want to, take advantage of during their wait session. For this reason, much of the station is not mobile; creating an experience that they can only have and, hopefully, look forward to at their visit. However, given the sporadic nature of some wait sessions (for example, breaks to use the restroom, or being called to the clinic for vitals), a tablet application provides a system

that patients could hypothetically take with them on their own mobile devices.

We attempted to make the exhibit inviting to children by focusing less on textual information and more on hands-on interactions that demonstrate important concepts. Our goal was for patients to develop their own questions that would encourage further investigation across the different materials offered by the station. Biological explanations are used throughout the station design. Hemoglobin behavior and its impact on cell structure are highlighted in all branches of the station textually, physically, and visually.

Tangible Cells

Both the tablet application and interactive blood vessel activities include tangible blood cells. The normal cells are made from a stretchy jersey material and filled with mung beans that represent hemoglobin molecules. The sickle cells are made with a thick vinyl material and filled only with strands of beads on stiff wire, representing the locked together mutated hemoglobin. The specific fabric resulted in a higher blockage frequency highlighting the complications that arise from sickle cells, and allowed more time for the sensors to recognize the cells. One 5mm magnet was placed in each sickle cell to trigger hall effect sensors in the vessel as they slide down. We made the white blood cells from terry cloth because they naturally appear hairy under a microscope, and platelets from dark purple semi-flexible material. Both additional types of cells use mung beans as the filling. Images showing a tangible blood smear are shown in Figure 1.



Figure 1: All cell types to form tangible blood.

Tablet Application

Two large tangible cell representations are reinforced by the augmented reality view that visually shows both types of hemoglobin in its respective structures. On top of two physical blood cell models is a tag for the augmented reality software to recognize the three dimensional orientation for image projection (this is detailed in a previous publication and seen in Figure 2). We also created videos showing blood flow through vessels with and without sickle cells for the tablet app.

Interactive Blood Vessel & Cells

The primary attraction of the station is the interactive blood vessel. We wanted to bring the vision of microscopic blood cells to a more familiar and child friendly size and allow children to explore the flow of blood with an interactive blood



Figure 2: Image of Sickle Cell Virtual Reality



Figure 3: Screenshots of tablet application Home page

vessel. Users can create and observe blood flow by mixing tangible blood cells and dropping them down the vessel. The complete vessel measures approximately four and a half feet long and spans between eight to 24 inches at the widest point. To give an organic shape similar to that of a natural blood vessel in the human body, the vessel is constructed from fiberglass molded around the trunk and branches of a medium sized tree.



Figure 4: 3 children using the interactive blood vessel.

This vessel can function in two modes: online or offline. Offline, the vessel acts as a standalone science manipulative. Users can create and observe blood flow by mixing tangible blood cells. The blood flow using these cells changes depending on the addition or removal of sickle cells, just as it does in

the human body. Each cell is designed to replicate the shape, proportion, and texture of those found in human blood, as described in the Tangible Cells section. The flow is based entirely on physics using the slope of the vessel and traction of the various cell materials to influence speed and blockage.

Online, an Arduino USB board (<http://arduino.cc>) serves as the computing device for the system, identifying the location and type of cells that pass through the vessel. We used Everlight PT204-6C 3mm Phototransistor T-1 sensors and a corresponding OSMO Opto Semiconductors GaAs Infrared Emitter SFH 4512 light to count the number of blood cells passing through the vessel. The addition of infrared bulb ensured a more consistent stream of light given the variations between and within environments for lighting. To count the number of sickle cells in the blood, we used Melexis A1324 3-pin Ultramini Through-Hole Hall Effect sensors that detect passing magnets found in the sickle cells.

The output of the vessel indicates the oxygen levels retrieved from the input cells. In real life, if blood is cut off from a muscle the color will change to purple or blue due to the lack of oxygen. We attempt to mimic this phenomenon by lighting the vessel color based on oxygen levels, highlighting the difference between normal and sickle cells. The LED RGB strip pulses between a red and blue value based on the count of normal and sickle cells that have passed through. Normal red blood cells increase oxygen, and sickle cells increase oxygen by a smaller amount. The vessel then runs out of oxygen, slowly turning bluer until more cells are put through.

Information Poster and Pamphlet

The station also includes an information poster that illustrates a large blood vessel, and issues related to sickle cell disease; this is discussed in a previous publication (cite anonymous). Following from our iterative testing, we decided to also generate a pamphlet specific to the Sickle Cell Station. The pamphlet was designed to be large enough for children to hold easily and uses only images and text found in other parts of the station.

NATURALISTIC OBSERVATIONS

Following the final development of the station we conducted an observational study of the design in the waiting room. Part of our goal was to understand how engagement and interaction varied across the different material types: pamphlet, poster, tablet, and vessel. Recruiting participants into a study can bias them and change the way they interact [5]. To avoid this, we unobtrusively observed patients in the waiting room as they naturally interacted with our designs. Because of strict privacy issues in the clinic, video and audio recordings were not allowed, and participants were welcome to come and go as they pleased. This protocol was approved by the relevant Institutional Review Boards, and a sign explaining that a study was taking place was hung on the entry door of the waiting room, as well as beside the material. We observed each of our materials independently for interest, engagement, the formation and transition of user groups, duration of use and user interactions.

Each of our 4 materials was placed in the waiting room one at a time on separate days until over 100 people had entered

the waiting room. Since some days at the clinic are busier than others, we opted to base the length of the study on the amount opportunity it had to be used rather than an amount of time it sat in the waiting room. All material was placed at child height. A researcher sat in a nearby chair with full view of the material location and noted behaviors, start times, leaving times, age estimates, group size, and user interaction notes for all material users. Parent ages were not included in any analysis: only adult counts, and children's ages. We used the entry and exit times to calculate dwell times and group formation at the station. The researcher was also available if participants had any questions. In addition, we maintained a count of every patient group that entered the waiting room during the observation session with age estimates. Demographic information was not formally collected for two main reasons. First, we did not want to interfere with the natural flow of users during the observations; and second, we were not authorized by the IRB to discuss personal information with patients. The IRB was sensitive and strict, limiting us to discussion of only the material and sickle cell content. With the exception of the birthdays on the consent forms, we were not allowed to ask about personal information or medical history of participants.

Following the observations, we analyzed notes for total people in the waiting room, notice rates, capture rates, and dwell times for each of the conditions using five observation codes:

- Level 0 - Not Acknowledge - The person does not notice the material
- Level 1 - Glance - The person notices material for less than 2 seconds
- Level 2 - Remote - The person looks at or watches others use the material from a distance
- Level 3 - Attentive - The person reads or watches the material from the study location for more than 2 seconds
- Level 4 - Engage - The person is physically involved with the material

The *notice rates* include Levels 1 and 2, people that look at the material for less than 2 seconds divided by the total number of people in the waiting room; the *capture rates* include Levels 3 and 4, users at the material for more than 2 seconds divided by the total number of people in the waiting room. *Retention rates* are the percentage of users who notice the material and then become captured; i.e. the number of captured users divided by the number of notice users. For each condition we also look at the formation and makeup of groups and collaboration among the participants. We define a group session as two or more people using the material at the same time. Entry groups are the groups of people that entered the waiting area together.

Findings from Naturalistic Observations

During five non-consecutive days of in-the-wild observations, a total of over 580 people were observed in the waiting room while any of the materials were available. Only 80 people noticed any of the materials including the poster, the pamphlet, the tablet, and the vessel. More than half of these notices were for the vessel condition. The breakdown for these conditions and the participant totals can be seen in Table 5. We found 9% of visitors noticed the poster, 6% to the tablet, 4.5% noticed the pamphlet, and 42% noticed or used the vessel.

In the only case of a child capture with the pamphlet a 6-year-old boy took the pamphlet to his mom who told him to put it back. In total 18 people noticed or used the poster material. These individuals made up 14 user groups ranging between 1 and 2 users. We saw 8 children notice the material, 6 of whom read the poster with a median of 20 seconds. With capture rates of 1 percent and 4 percent for the pamphlet and poster studies respectively, we found the engagement with these materials to be consistent with previous observations and research. These rates are even lower if considering only child users - an arguably important group at a pediatric clinic.

The tablet condition showed a slight improvement over the traditional materials. In total 9 people visited the tablet forming 5 separate groups with an average group size of 1.8 people, each of which only had original members - that is, they came in together. The dwell time for children ranged from 1 to 5 minutes with an average of 4 minutes, standard deviation of 1.73 minutes and a median of 5 minutes. These averages are not meaningful to report given the small sample size, but we are including them for consistency and completeness of the table 5 with other conditions. While the tablet material demonstrated a noticeable increase in dwell time, the sample size remains too small to draw any conclusions.

The vessel condition resulted in 47 users (5 men, 14 women, 15 boys, and 13 girls); 10 of the 47 used the vessel more than once in the same day. The children ranged from 1 to 18 years old: 9 participants under 6 years old; 5 between the ages of 6 and 9 years old; 8 between 9 and 12 years old; 4 between 12 and 15 years old; and 2 children 15 years or older.

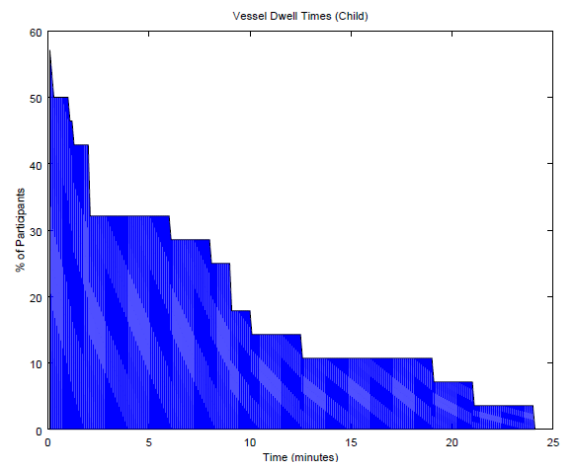


Figure 6: Percent of child users and their dwell time. Median is 7 minutes.

There is a striking difference between the vessel and the three other conditions in notice rates as well as dwell times. Children that are physically engaged with the material spend an average of 12 minutes using the vessel. Adult averages don't reach close to that quantity of time, but still show a substantial increase over other materials. The percentage of users and their dwell times are illustrated in the histogram in Figure 6.

Condition	Total Observed Participants	Child Avg. Age (yrs)	Adult Notice Rate	Child Notice Rate	Total Notice Rate	Adult Capture Rate	Child Capture Rate	Total Capture Rate	Adult Avg. Dwell Time (min)	Child Avg. Dwell Time (min)
Poster	193	9.75	9.5%	9.1%	9.3%	8.6%	6.8%	7.8%	0.60	0.43
Pamphlet	133	6.00	6.8%	1.7%	4.5%	1.4%	0.0%	0.8%	0.00	0.00
Tablet + Poster	146	6.67	3.6%	9.5%	6.2%	3.6%	7.9%	5.5%	5.28	4.00
Vessel + Poster	112	8.43	40.4%	43.1%	42.0%	25.5%	24.6%	25.0%	1.43	7.93

Figure 5: Overall participant analysis of In The Wild data collection.

Another interesting difference is the retention of users, or people that notice the material and then stay to read or interact. The number of people that notice the material and then stay to use it is higher for both the poster and the tablet conditions. A higher percentage of people walk away from the vessel early on; of the 47 people who notice the vessel 19 do not stay to use it, while of the 18 people who notice the poster only 3 leave without reading some portion of it.

Even the vessel has a lower retention rate, the children that stay at the vessel, whether or not physically engaged with it, use it for nearly 8 minutes on average. In comparison, over 80% of users drawn to the poster stay to read it, but they only stay for an average of 45 seconds.

Figure 7 illustrates a sample of group formation around the vessel and the transition between members. Each line represents a single user's session at the vessel across time. Line colors show entry group associations - i.e. members of the same entry group are the same color. Note the different number of colors present at the station at any point of time. People from different entry groups come to work together.

In total at the vessel, there were 8 group sessions with an average group size of 3.75 and standard deviation of 1.38, and both a median and mode of 4 members per group. Five of the group sessions had members from multiple patient groups - suggesting a great opportunity for collaboration, which was demonstrated by the conversations between users.

There is an evident difference between the vessel and other material forms. The vessel had a notable impact on grabbing users from the waiting area; although many people walked away after noticing the station. Those who stayed were more likely to be young children (a neglected group in patient education), more likely to be engaged physically, and more likely to use the material for long periods.

USER INTERACTION ANALYSIS

Methods

Using our naturalistic observations as a starting point, we used video recordings to study user experiences in detail. We were interested in the onversations families were having with the station, who was involved, and how they used the materials. We were specifically looking for behaviors that have been shown to promote learning in the FLP and APE exhibit studies. This included asking and answering questions, commenting on or explaining the exhibit, reading text silently or aloud, continued interaction after reading exhibit text, experimentation and exploration outside of the given text, and using the exhibit

to pursue answers. Final user testing was conducted in three main sessions: pamphlet, tablet, and vessel. For the purpose of this paper, we will only be analyzing and discussing the user experiences during the vessel studies.

During testing, one flier advertising the study was posted outside the main entry door and another in the testing area. A researcher sat in an easy to see area to recruit participants. Our material was designed for the general waiting area population, and the study was not limited to sickle cell patients.

Because space is limited in the waiting area, we could not rope off the research space. Groups were taken to the testing area and consented to video and audio recordings of their interactions with the station. We introduced the material and left them to use it for as long or as little time as they liked. We waited several feet away and recorded notable interactions and conversations during testing. Following participants' use, we asked questions about their experience pertaining to usability and understanding of the materials. Video and audio recordings were collected. In only one case, a group agreed to participate without recordings; we took notes of their conversations and interactions with each other and the materials. The video recorder was hung from the ceiling for a birdseye view of the participants interactions. In two cases, due to issues with the primary video camera, a backup handheld video camera was used to record from the lower end of the vessel. An audio recorder was placed on top of the electronics compartment on the backside of the wood stand.

We calculated ages from the birthdates on the consent forms to the date of the study. We used videos to calculate dwell time, using the start and end times of interactions with the material. Likewise, group counts and parent involvement are also given from video analysis. Gender was not collected in the consent forms, but estimated in observation notes.

We categorized the videos based on the type of collaboration between adults and children: children alone, parents as guides, parents as collaborators, parents as instructors. We transcribed each video with dialogue and actions of the users, including the direction of their gaze, where they were standing, and how they used the vessel cavity, its cells, and the poster. We analyzed the video transcriptions using the existing museum framework models for learning processes. We coded the dialogue using performance indicators for learning taken from the FLP and APE studies including Questions, Answers, Comments on the exhibit, and Reading silently or aloud. For this study, we are not including statistical analysis of these sessions.

Sickle Cell Station Usage Timeline

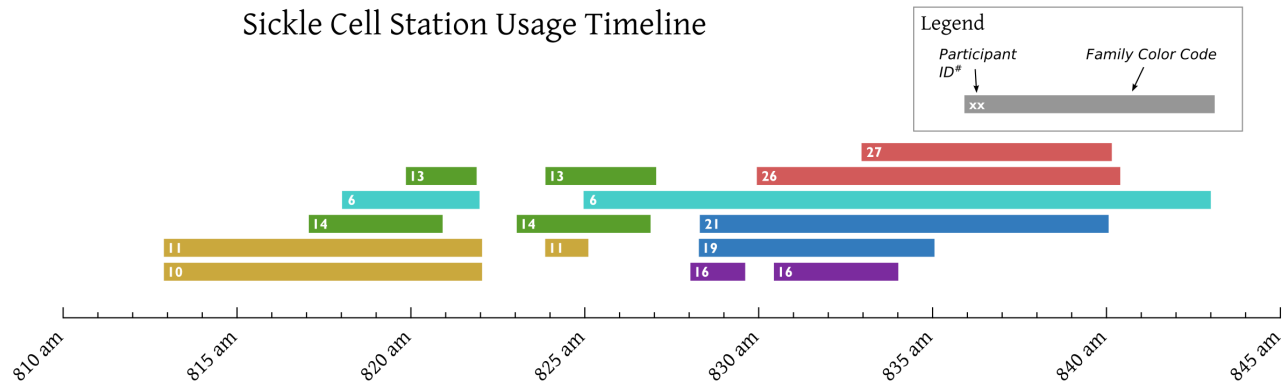


Figure 7: Diagram of group formation around the station.

We will use a series of example sessions to illustrate the diversity of users, user groups, and experiences seen with the vessel during the consented studies. We will also use these sessions to demonstrate the features recognized by museum research as keys to learning through exhibits. Using dwell times and levels of engagement and learning, we hope to show that waiting rooms are not only conducive to museum style education but that they in fact may even provide additional advantages from the lengthy wait times, confined space and options, and immediate supply of fellow users that have something in common. The names of the participants are pseudonyms, and each sample contains direct quotes from the highlighted user.

Participant Analysis

The user studies took place over 9 nonconsecutive days. In total, 81 users including 48 child users (24 female, 23 male, 1 unknown) were recruited for the vessel interaction study. The average age of participants is 7.75 years old ranging from 18 months to 20 years, standard deviation of 3.76. The participants tended towards the early elementary years: 8 participants are less than 5 years old; 25 participants are between the age of 5 and 8; and 10 are 9 years or older. These users made up 22 groups ranging from 1 to 6 simultaneous users. 14 of the 22 groups included at least one child and one adult.

All of the participants for the vessel study approached the researcher. The contrast between recruitment of the pamphlet study is striking; for comparison, we actively recruited 10 of the 12 pamphlet participants with substantial effort.

The overall average dwell time was 11.39 minutes for all child users with a standard deviation of 8.74 minutes. The longest session lasted over 34 minutes while the shortest ran just over 1 minute. 23 participants ended their session because they were called in; 17 left because they were done; the remaining left for other extrinsic reasons - parents called them away, or a hovering child forced them out.

VESSEL VIDEO INTERACTION ANALYSIS

Below we describe and discuss 3 examples that illustrate different group relationships and exemplify the behaviors seen in museum research: this includes 2 parent-child dyads, and 1 sibling pair.

Adults & Children

Crowley repeatedly discusses the importance and benefits of parents as collaborators in the museum experience arguing that “the guidance of parents is an important bridge between the intentions of the exhibit designer and the experience and knowledge of the child.” [8]. Evidence from the vessel study show similar importance in the waiting room. With the vessel, parent involvement comes in three main forms: narrating, guiding, or collaborating. Seven of the parents served as guides, encouraging children with an occasional question or comment about the station or their work, in between they may physically walk away. Narrators, on the other hand, stand beside the child throughout the session, comment on the exhibit or make suggestions, but never engage with the station or leave the child - we saw this in three cases. In four sessions, collaborators stand with the child at the station and work together to test ideas or answer questions; these parents are physically involved with the station.

Clarice - Parent as Guide

The attentive yet infrequent comments from parents-as-guides propose new experiments or clarify a behavior from the cells that would help the child move forward. Our first example demonstrates a common interaction where the parent helps guide the child with intermittent commentary on their actions or details of the system. Clarice, a 9 year old girl, is in the waiting room with her mother. She begins using the system as her mother stands with the researcher. After a short time her mother joins her at the vessel and introduces the system to her.

After a few rounds of cell dropping, she stands looking at her mom, as if she’s waiting for her. She feels the inside of the vessel as she waits. Her mom joins her.

Mom: “So these are different blood cells, so this is red blood cells. So these must be white blood cells. And these must be umm,” looks at the poster “platelets..”

Clarice: “What are platelets?”

Mom: “Its just part of your blood. so your blood is made up of your red blood cells, your platelets, and ...” Mom picks up a handful of sickle cells and turns towards her daughter.

Before the mom can continue her explanation, the receptionist calls her to check in. Clarice continues to use the station.

The mom introduces the vessel with a simple explanation of its parts identifying each type of cell. She even references the poster to identify the platelets for herself. Clarice shows particular interest in platelets and asks about them. Her mom begins an explanation of blood composition using the tangible cells but gets called away before she can finish, and Clarice continues to explore the blood flow alone.

Mom: Returns to the station and picks up sickle cells. "these other ones that are kind of shaped like this, these moon shaped ones, these are sickle cells." Clarice feels the cells. "See how they go through. they have a little bit more trouble.." They put two sickle cells down the vessel and watch them slide down. Her Mom steps back.

Again the mom used the station to explain the concept that sickle cells get stuck. Clarice follows with her own explorations, picking up cells and dropping them in the vessel to see what they do in comparison.

Mom: "... sometimes when the moon shaped ones, the sickle ones.."

Clarice: "The sickle cells?"

Mom: "Yes. Sometimes they get stuck. Right here there's one blocking." She points at the vessel on the poster. "They can block and cause some pain. But these red ones.." picks up a red blood cell from bucket and drops it in vessel "go right through."

Clarice: "The white ones too," as she picks up and drops in a white blood cell. "And these," as she picks up and drops in a platelet.

Clarice and her mom repeatedly use the poster as a reference for their conversation, in this case pointing at the blockage on the large vessel image. They also take this opportunity to compare the flow of each type of cell independently, testing one at a time, and naming the cells as they go.

Mom: "Does it look like there are more red blood cells or white blood cells? Or even?"

Clarice: "Red!"

The mom is asking questions, and Clarice is answering them thoughtfully. The mom follows with physiological information from the poster. She discusses the quantity of cells - a feature noted in the design of cell distribution both tangible form and on the poster. The mom draws attention to this fact and then points out that red blood cells carry oxygen around the body. This concept is an important basis for understand both that sickle cells cannot do that as well, and also that the blockages prevent red blood cells from getting by to deliver that oxygen.

Clarice: "I'm going to put one of these cells [sickle cell]... even though they get stuck... then we'll just take two of these..." She picks up two red blood cells and drops them down the vessel trying to dislodge the sickle cells.

Clarice has already explored the flow behavior of each cell and has progressed to exploring what happens next. She knows that the sickle cells get stuck and is trying to dislodge them with other cells. While Clarice continues to use the vessel, her mom tells the researcher "We think this is a great tool. We'll talk to her about it later, but it was really easy." Ideally this shows that patient groups are taking this experience home with them in a positive way. As discussed with staff interviews [16] the conversations parents are having at home about the education received in the clinic is an important translation to the culture and experiences of each child and family. Furthermore, this is validation that the system is easy and accessible. Clarice began to use the vessel before her mother joined her. Additionally, while her mother discussed the cells with her, she never explained the function of the system.

Martin - Parent as Collaborators

We saw collaboration in many forms during vessel use, but Martin's mom was a most extreme case where she was more involved with the station than her son. Martin, a 9 year old boy, stands beside his mom as she collects cells, places them in the vessel, and reads the poster quietly and aloud. In this case, the mother is in control of the learning process; she leads the learning agenda, sets tasks, and provides feedback [8]. In much of this session the son isn't even present.

Martin's mom is one of two groups that focused on trying to figure out what they were suppose to be doing, as though they were trying to figure out a "planned discovery" [15] task that wasn't posted. The mom identifies all parts of the exhibit, and reads along with the poster, as if it were an instructional guide.

Martin: Stands beside her holding two red blood cells. "What are we suppose to do?"

Mom: "We gotta figure it out"

They both stand for a moment, each holding cells and squeezing them, reading the poster quietly.

Mom: "Ok... so these are platelets," reading the poster out loud, "these heal wounds by clotting... We're gonna figure this out!"

Martin: Leaves, returns and looks at the vessel, then at his mom, and back at the vessel. "It's going to go through by itself when you drop it?" He takes a red blood cell from behind his mom's hand on the vessel as she describes the cells outloud.

Martin's mom demonstrates her focus on "figuring out" the exhibit insisting there is something that they are "suppose to do". Note that they are not questioning how to use the exhibit. They are trying to solve the mystery of the discovery task. Martin's mom collects cells in the vessel as she reads, holding them at the top. Martin itches to put cells down the vessel - now trying to predict the behavior. Martin comes and goes from the station checking his mom's status, waiting for the drop. Finally after minutes she decides to see what happens.

Mom: She picks up a sickle cell "These are the sickle cell traits. These are the bad guys." She goes on to give detailed explanations about the parts of the system, often following the text from the poster.

Martin: "Just drop it!"

Mom: "Waaait!" as she continues reading. "So if you carry the trait your blood cells turn into these ... Alicia has the trait but she doesn't have sickle cell... Are you ready? ...Hold up! hold up!" as she begins to read the poster again.

Martin: "Just drop it!"

Mom: "I'm trying to understand. I'm trying. I'm not a doctor." She lets go of the cells throwing her hands in the air. At this point the buildup of cells is very large; the force pushes any lodged cells through to the bucket, and even pushes cells over the edge. The mother says, "Ok... som-... no... Do it over. Cause some of them fell on the floor." The mom has a different strategy using the system than the children from the other sessions, and even the strategy that her son is pushing - anxious for his mom to "just drop [the cells]!". She collects her cells, and continues to read the poster, changing her arrangement based on the information she's reading. She mentions a friend of theirs, relating the information to a real person. Although the description of her understanding isn't accurate to the behavior of the trait, she shows an understanding that you must have the trait to have sickle cells.



Figure 8: 6 minutes - First release of cells and observing cell motion.

The mom doesn't drop a cell down the vessel until 6 minutes into the 9 minute session. The mom builds up to the grand release of cells. When the time finally comes she throws her hands in the air, as if she's expecting a grand discovery. Martin's mom shows some disappointment in the behavior of the cells. We suspect because the mystery she was hoping to reveal is still nonexistent. After a second similar attempt of collecting cells for a grand release, she points at the blockage on the poster. "See what's supposed to happen is..." Martin walks away as she continues to read the poster.

A majority of sessions are intuitive, children walk up and immediately place cells in the vessel then continue to explorations, often not looking to the poster for any advice, only identification. Martin's mom, however, seems to overthink the process or expect something more specific from the system. Martin holds multiple cells as he watches his mother, feeling the red blood cells and sickle cells; however, he never interacts with the vessel. He leaves the station repeatedly and returns to check her progress. He asks her to drop the cells, anticipating the response, but waits patiently as she leads the experience.

Just the Children

Simone - Silent Session

Much research shows benefits of learning for siblings in shared experiences. However, in several cases, there is little or no dialogue at all. Take the following example of a 7 year old female, Simone, and her younger brother, approximately 2 years old. Simone and her brother do not exchange any words, but share the experience together, including Simone teaching her brother how to use the vessel. In her 19.5 minute session, Simone's entire dialogue is included in the transcript below. Simone's session highlights use by young participants with non-verbal advantages seen with the vessel use. She doesn't ask many questions or provide answers, but through her exploration you can see her engagement and inquiries. Her actions are slow and thoughtful as she carefully selects cells and watches each slide to the bottom before proceeding to the next.

The mother and daughter begin the session with Simone standing in front of the vessel.

Mom: "... this is a vein and this where your blood passes through. Can you see right here you have one real close to your skin?" Pointing at visible vein in Simone's arm, "you have a lot right there and they're all over your body."

Simone: "This is like inside your bone?" She feels the inside of the vessel cavity.

Mom: "Yeah, exactly. This is where all the blood goes through..." Simone and her mom have covered a lot in just the first few seconds of their session. Her mother is mapping the representation to Simone's body, creating a familiar connection to Simone's own body and experiences.

Mom: "What do you think these are?" as she points inside the bucket, and then sits in a nearby chair.

Simone: Walks over to the bucket and looks inside, picks up cells and feels them before placing them in the vessel.

Her mom leads her to the cells, but provides no description or instruction. She asks a simple question that puts Simone in a position to begin her exploration.

After a few minutes, Simone's younger brother comes over and feels cells in the bucket. Simone notices him when she walks over. She pats him on the back, walks over to the vessel, points at the top and drops a platelet down the vessel. The boy follows her and places a sickle cell down the vessel.

The simplicity of the station allows for children to join others or begin independently with little to no instruction. The mother never explains to Simone how to use the system, only what a vein is and that this material represents a vein. Simone is guided to the bucket of cells then independently tests each type - never asking about how to use it. She feels each thoroughly before she drops it down the vessel. When her younger brother enters the session, again, no words are exchanged, specifically, no words to describe the use of the system. Simone merely points at the top of the vessel and he begins use.

Repeatedly we see the boy take a cell from the bucket, feel it with two hands as he walks to the top of the vessel, pausing before he slides it down. On many occurrences children place cells down the vessel one at a time. This gives them an opportunity to explore each cell with their hands prior to observing its behavior in the vessel. These interactions demonstrate the low entry skills we hoped to achieve with the device.

DISCUSSION

Chronic diseases that begin at birth pose an interesting problem for patients since there is no initial lesson. Our interviews suggest that current materials need reworking [16], especially if they are intended to be used by children. Most information is either shared orally by a physician or given in writing using language geared to an adult audience; both are strategies that require parental involvement and may not be engaging for children. We explore enhancing this learning experience in the clinic space using museum design concepts. Below, we gauge success by comparing user experiences at the waiting room station to indicators of learning used in APE and FLP.

Accessibility

Overall the system was used as expected and without difficulty by participants. Users were able to walk up, take cells from the buckets, drop them down the vessel, and replenish the upper bucket without direction, physical help, or issues with the system functionality. Participants from 2 to 19 years old to adults could easily access, manipulate and map across all parts of the system including the cells, vessel, and poster without instruction or error in functionality. There were examples of

reading aloud and silently in every example mentioned. With its large size, multiple sides and multiple access points, the system allowed groups from parent-child dyads to 6 children at the same time to work without trouble or interference [7]. We demonstrated a variety of strategies from parents and children in using the system highlighting its accessibility by users of different group consistencies, and different backgrounds and experiences. People, specifically young children, were drawn to the station, especially in comparison to the traditional education materials in this environment. More than half of the participants fell in the 5-8 year old age range—an age group previously found to be neglected in sickle cell education.

Deep Exploration

We saw users demonstrate explorations asking “what if we...” and proposing ideas or experiments to dislodge cells or create variations in their drops. Typically this was in the form of variations in quantity and type while dropping cells trying to dislodge blocks. APE exhibits signify prolonged engagement comparing a 3.3 minute dwell time to 1.1 minutes at traditional planned discovery exhibits; users at the Sickle Cell Station spent around 8 minutes. This may be a result of the confined waiting room space, especially in comparison to expansive museums. Regardless of why people are spending longer times, we know that they are spending more active and engaged time learning with the station than with traditional paper materials. Moreover, many instances illustrate understandings of complicated concepts of the human body including blood cell identification, blood flow, and much more. In one instance, an 8 year old boy acknowledges the metaphor of pumping blood as he swapped buckets and announces “Look! I’m the heart!”.

Sensory experience

The sensory experience from the tangible cells is one of the prominent features designed to support learning in younger users [20]. We hoped that this would be a natural way for children to notice the difference in sickle cells and normal red blood cells easily, and from there they continue to build an understanding of more complex concepts. For example, the youngest participant at only 18 months old may not be able to understand or explain the complexities of the hemoglobin molecule mutations; however, she does notice the difference in texture between the kinds of cells. At following visits, she may be able to label each cell with the help of a parent, and relate the difference in texture to a difference in the way the cells slide down the vessel.

Supporting collaborations

Participants managed to repeatedly form groups with other patients during observations and consented testing. The overlap of ages and backgrounds in these examples bring a quality of diversity to the learning experience with different goals, focal points, and skills that are shared and learned from. The longest running video session is illustrative of this. One girl begins her session alone. She is joined intermittently by 3 other children before being called in and replaced with 2 new participants. Over the 54 minute non-stop session, 7 users join the vessel, each from a different entry group.

CONCLUSION

Waiting room education has had static form and progression for decades. Museums, on the other hand, have spent years formulating designs and experiences that engage users, and are inviting and effective. We used the APE and FLP learning standards in addition to Montessori design concepts to create a station that plays to the waiting room community. The design aims to inspire patients’ intrinsic motivations to use their wait time to learn about relevant life-dependent issues.

The vessel pulled in more users than any other form of material. With the exception of retention, all rates for the vessel show improvement over other material types - especially in regards to young children with average dwell times well over museum standards. We see inquiry and exploration, reading quietly and aloud, reading to answer questions, and reading because the poster is there, and commentary and explanations of the exhibit parts and their behaviors. Users mapped the poster information to their work with the vessel and vice versa, tying in what they were reading to encourage their explorations. The conversations among participant groups were rich with biological content, covering blood composition, definitions of blood cells, clots, the heart beat, and blood transfusions to name a few. We heard many examples of personal associations, primarily relating the blood vessel to veins in the child’s own body, but also to friends with sickle cell and even chemotherapy. Users demonstrated an understanding that sickle cells are stiff and that this causes blockages in the blood vessels. Beyond the potential collaborations and learning experiences with the station, children enjoyed using it, showing verbal confirmations of fun, and dwell times well over the APE goals.

Naturalistic studies show substantial increases in interest from patients groups using interactive technologies for learning. Interaction analysis show learning through inquiry, exploration, and collaboration with adults, children, family, and strangers that mimic those found in museum literature. This evidence supports the idea of Active Waiting Education as a means to improve patient involvement in their own health education.

LIMITATIONS & FUTURE WORK

Interviews to learn more about sickle cell patients’ opinions, experiences, and needs would influence the station’s design and extensions. However, given the restrictions of patient privacy and schedules of both staff and patients in the clinic, finding sickle cell patients for interviews was difficult. Race, gender and age have a significant influence on people’s behaviors and perspectives, but was neither collected nor analyzed alongside the user interactions due to tight IRB restrictions. Estimations were made for record keeping, but this comes with judgement from the researcher. In future work, more rigorous IRB allowances may be achieved to detail the behaviors of different groups based on demographics.

We have only begun to test the results of learning, analyzing the engagement and use of the activity for further development of the field. In future work we would like to test detailed outcomes, designs in other types of medical or non-medical waiting areas, learning assessments, detailed analysis on the conversations and interactions, and more formal statistical analysis on the intragroup collaborations.

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