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User Experience Design for Presence-Aware Spaces and Technologies

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USER EXPERIENCE DESIGN FOR PRESENCE-AWARE SPACES AND TECHNOLOGIES

by

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Abstract

User experience design is a diverse field of study that is constantly changing as unique technologies and modes of interaction are developed. Metaphors are a critical aspect of UX design, serving to acclimate users to new technologies by comparing them to existing objects and ideas. As newer technologies become increasingly distant from real-world objects, developers are quick to look to existing technology for metaphors. This results in a lack of experience-unique metaphors that would create a more immersive experience. This thesis focused on identifying potential real-world metaphors through the use of emerging technologies in an interactive art installation. Based on observations and participant responses, it was clear that the installation was successful at establishing an engaging user experience. However, findings exposed that this experience was facilitated not by metaphor, but by stimulation more along the lines of mimicry. Though different than the initial objective, this discovery was profound due to the implications it holds for developing presence-aware technologies and spaces in the future.

Dedication

To my cool but dorky sister, Veronica.

Also to my parents. Thanks for all of your support.

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Definitions List

User Experience Design (UX Design) – any aspects of a user's experience with a given system, including the interface, graphics, industrial design, physical interaction, and the manual

Human Computer Interaction (HCI) - a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them

Metaphor – things regarded as representative or symbolic of something else. Commonly used in experience design to acclimate users to a technology

Emerging technology - contemporary advances and innovation in various fields of technology

Presence–aware Technology (PAT) – rely solely on the physical actions of the user's body as input and do not require external devices like remotes or controllers

Presence-aware Spaces – areas that facilitate the use of presence-aware technologies

Background

From day one, learning and interacting with the world drives the human experience. A common way humans comprehend and learn new things is through the use of metaphors. Metaphors, "things regarded as representative or symbolic of something else", help humans acclimate themselves with unfamiliar situations. Human's application of metaphors occurs involuntarily in life, as each reference to one is the result of some outside stimulus. This instinctiveness is stressed by Lakoff and Johnson in "*Metaphors We Live By",* who state, "We define our reality in terms of metaphors and then proceed to act on the basis of the metaphors. We draw inferences, set goals, make commitments, and execute plans, all on the basis of how we in part structure our experience, consciously and unconsciously, by means of metaphor". The recognized effectiveness of metaphors has resulted in their application across disciplines (science, math, reading and comprehension, etc.) and from natural occurrences to artificial, man-made creations.

It comes as no surprise, then, that the use of metaphors became prevalent in the field of technology, a field marked by rapid and constant change. Developers of early, marketable technology understood that the powerful tools they were creating would appear completely alien to the majority of their target audiences. These developers realized that if their audience could not use, let alone understand, their product, then it would not be used. What emerged from this realization was a use of metaphors that helped propel technologies into the public space, metaphors like the desktop model. Early computer interfaces resembled lines of text and were driven by typed commands (Figure 1). In contrast, desktop interfaces were made up of objects that had similar functions to their real-world counterparts (Folders held individual files of similar themes,

the Trash Bin was used to delete files) (Figure 2). Even though users still had to adapt to new modes of interaction such as the mouse and keyboard, they were able to learn in an environment that was already somewhat familiar to them.

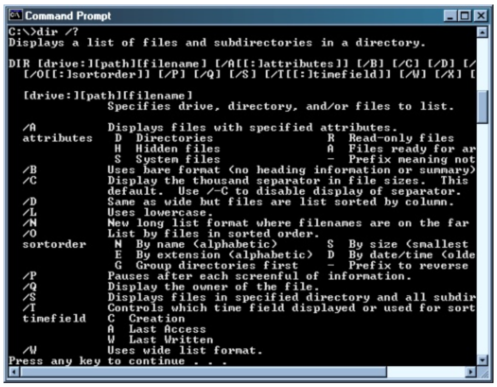

Figure 1. Command Line Interface

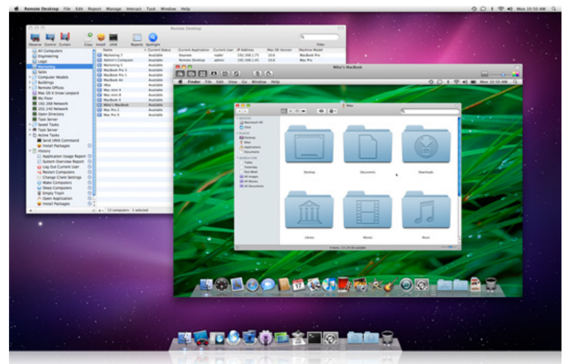
Figure 2. Desktop Model

It wasn't long before developers and designers alike began to challenge the use of a mouse and keyboard as the primary ways of interacting with a digital interface. As computers shrank in size, it became apparent that, eventually, there would be no room for these external devices. In their place emerged interactive displays driven by physical gestures, "a movement of part of the body to express an idea or meaning". [1] Just like the desktop transition, the gestural interaction movement was popularized through the use of metaphors in regards to both the graphical and interactive elements. Buttons that once were designed as check boxes became visuals resembling light switches that could be turned on or shut off. At the same time, graphical controls that would move users through a page were replaced by swiping gestures that acted as though the user was flipping through a book or magazine. The push for metaphor driven interactions and

[1] *Definition provided by Merriam-Webster and Dictionary.com*

[2] Template programs refer to programs that are included within a library. These template programs provide simple examples that can be studied and expanded to facilitate an understanding of the

displays became so imperative to design that industry leaders like Apple created guidelines to encourage new developers to use them.

Today, there is a trend of technology becoming increasingly integrated into our everyday lives. Some emerging technologies require no tangible interaction to be used, providing a unique "hands-free" experience compared to existing mobile and tablet-based devices. One such technology leading this trend, the Microsoft Kinect, is attempting to revolutionize the way the field of gaming is approached and developed. Using infrared light to capture and track a user in its field of vision, the Kinect provides players with a hands-free way of playing their favorite games. As is the case when developing new devices, Microsoft has relied on metaphors to propel their design. These include context-driven metaphors that are specific to the game being played (e.g. throwing a ball or jumping over an obstacle). Others, however, are directly derived from existing, surface-based technologies. A prime example of this is the navigation controls of the Kinect Dashboard. Although the Kinect operates very different from a tablet, it still relies on the swipe gesture made popular by devices like the iPad.

Figure 3. Example of a “Select” gesture using the Microsoft Kinect

The Kinect demonstrates that gestural interaction in technology has, in a sense, become a metaphor for itself. This is not necessarily a bad thing; in fact it is consistent with the way metaphors are formed considering the widespread popularity of gesture-based devices. However, presence-aware technologies like the Kinect exist in a very different context than surface-based technologies like the iPad. This means that there are potential naturally occurring metaphors that could drive more powerful user experiences when interacting with these technologies. A goal of this thesis, then, is to identify a natural occurrence that can be explored and manipulated to observe the ways humans may interact with a presence-aware space. Through this exploration, it will be possible to begin extracting unique user interactions with their natural environment to help propel the design of these technologies and spaces.

User Experience Design

"User experience design is NOT a step in the process. It IS the process."

Whitney Hess, Mashable.com

January 9th, 2009

Type, "What is User Experience Design" into a web search and stand back as you watch the screen fill with sites, each providing their own unique definition of the term. Humorously enough, it seems that every other site contradicts the one before, making a "blanket definition" quite difficult to find. The term's coiner, Don Norman (ex-Vice President of the Advanced Technology Group at Apple), may have defined it best through his explanation of his arrival at the term: "I invented the term because I thought human interface and usability were too narrow. I wanted to cover all aspects of the *person's experience with the system* including industrial design, graphics, the interface, the physical interaction, and the manual" (uxdesign.com). While this is a fairly comprehensive definition, Norman goes on to say that "Since then the term has spread widely, so much so that it is starting to lose its meaning…". Due to this ambiguity of UX design, many designers and developers in the field feel that the best way to define UX design is by identifying what it is *not*.

Among these "myths" of UX design is the popular notion that it exists *only* within the context of technology. This notion is not just false but it also alienates individuals' from the conversation who are intimidated or unfamiliar with technology. To put it bluntly, Mario Bourque from Trapeze Group says, "(UX design is) about how we live. It's about everything we do; it surrounds us" (uxdesign.com). To Bourque, and many

other designers and developers, almost *anything* created with the ultimate intent of being used by someone is open to the scrutiny of UX design principles. Even those who consider themselves unfamiliar with UX design have experienced countless moments in their lives where they have misinterpreted the function of an object, such as the classic example of attempting to pull the handle on the “push” side of a door (Figure 4). While a simple moment like this may have resulted in a feeling of awkwardness or embarrassment by a user, it is more the lack of UX design rather than user ignorance that created the confusion.

Figure 4. Example of a poorly designed door here at the University of Maine

The lack of technology does not imply a lack of UX design. Nevertheless, most of the time when the term “user experience design” comes up in today’s culture (perhaps to the disdain of Bourque), it is within the context of technology. One predicament faced by emerging technology UX designers is the inherent difficulty in designing updated, innovative user experiences that challenge existing technology models. Because the

majority of users have a tendency to stay within "comfort zones", emerging technology designers are locked in a constant battle between creativity and usability. An interesting example of this battle can be seen in mobile device keyboards, specifically in devices like the Samsung Galaxy family. This brand of device makes use of Swype technology, an innovative software that provides a "faster and easier way to input text on a screen" by allowing users to slide their finger from letter-to-letter in order to create words (Figure 5) and lifting their finger to create spaces (Swype specifications). The software uses an algorithm that analyzes both the letters selected and the order in which they were selected to determine which word the user meant to type. The software is accurate and, in theory, much more efficient and convenient than a standard keyboard model for mobile devices due to space constraints and gestural functionality.

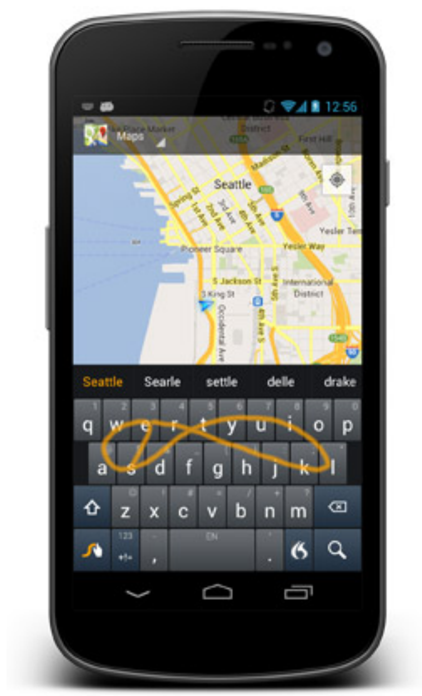

Figure 5. A Swype pattern of the word "Seattle"

However, adaption of this technology has not been widespread. While there are many factors that contribute to this, it is clear that the general mindset of users towards how a "keyboard" functions is a major hurdle in Swype technology's acceptance. Thus, according to Hess, UX design is not just about "making stuff easy and intuitive ... In order to get people to change their behavior, we need to create stuff they want to use, too."

In order to design a UX that was consistent with the thesis objective, a model had to be chosen that could facilitate a user experience that would allow them to interact with a virtual space just as they would in a real space. Perhaps expectantly, there seem to be just as many UX design models as there is definitions for UX design itself. These model contexts range from strictly conceptual to fully marketable strategies and products. In the end, a model that concentrated on the conceptual rather than marketable aspects of UX design was chosen because these models tended to fit more in line with research-based applications. The Implementation, Mental, and Representation (IMR) model is one of these conceptually focused structures. The IMR model of UX design breaks the process down into three overarching groups, each fueled by a user-specific question (Table 1).

Table 1. Organization of the IMR Model

Group	**Question**	**Description**
Implementation	"How does this work?"	Describes how a developer builds a system.
Mental	"How do users *think* this works?"	Describes how users perceive external environments and realities.

Representational	"How is this presented to the user?"	Describes the layer of interaction between the system and the user.

Creating an experience that would blur the line between the real and virtual worlds depended heavily on an understanding of how users perceive themselves and the environment around them. Thus, while these three groups are all important, the Mental Model was concentrated on the most due to the metaphor-driven nature of the research.

Human-Computer Interaction

Closely related to UX design, Human-Computer Interaction (HCI) was also explored to understand how it could facilitate a metaphor-driven experience. While both UX design and HCI are user-centered processes, HCI focuses much more on the connection between humans and technology than the entire UX as a whole. Also, unlike UX design, HCI seems to have a much more concrete definition across all fields normally regarded as "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" (HCI Bibliography).

Emerging from the idea and introduction of personal computer usage in the late 1970's, the discipline of HCI came at the perfect time. Engineers and technicians eager to develop these machines, and newly established areas of study such as artificial intelligence, cognitive psychology, and philosophy of the mind were seeking ways to test and apply their work (Carroll). In these early years, the focus of these designers,

developers, and intellectuals was on one simple word: *usability*. An early slogan of HCI, "easy to learn, easy to use", is a testament to the fact that usability was just that. If an individual could access a system, than it was usable. Now, usability often "subsumes qualities like fun, well being, collective efficacy, aesthetic tension, enhanced creativity, flow, support for human development, and others." (Carrol). A primary reason for this development is because of the recognized importance of HCI between when it was coined and today.

There are a plethora of topics that accompany the study of HCI, ranging from cognitive processes to technical considerations. Each of these topics contributed to a process model that was attempted during the implementation of this approach. This model, presented by Paul Pop from Embedded Systems Laboratory, specifies that HCI design should:

- Be **user centered**
- **Integrate** knowledge and expertise from the different disciplines that influence HCI design
- Be **highly iterative** so that testing can be done

(*Embedded Systems Laboratory*)

Implementing within a user-centered model fell in line with both the UX design model used as well as the overall objective of this thesis. Although personal knowledge of many HCI disciplines was limited, it was supplemented as much as possible by external research from primary sources such as psychologists, artists, and technical developers

and designers. Finally, iteration was stressed continuously throughout the construction of the installation though consistent user testing and feedback independent of the final deployments. This model, along with the UX design model, established both the conceptual and implementation frameworks necessary to design this metaphor-driven installation.

Presence Aware Spaces and Technologies

During the conceptualization and implementation of this thesis, the term "presence-aware" was constructed to contextualize applied strategies and devices. The term in itself is somewhat flawed because, technically, every user experience requires a user's "presence". However, an experience driven by presence-aware technologies are distinct from other experiences in two ways. First is the level of engagement a user must initiate to experience the space/technology. While other technologies require an intent (e.g. the press of a button, turn of a dial, etc.) to engage the user, presence-aware technologies (PATs) activate as soon as a user enters the space, sometimes without the user realizing it. The second distinction of PATs is the lack of tools or devices necessary for interacting with the technology. Presence-aware technologies rely solely on the physical actions of the user's body as input and do not require external devices like remotes or controllers. This, in theory, results in a much more engaging user experience and is the primary reason why these types of technologies were used in implementation.

One of the most popular uses of current PATs is integration into buildings for various purposes. For example, many buildings today are outfitted with automatic lights triggered by change (and lack thereof) within the space. Numerous security systems operate in a similar way, constantly scanning an area for changes and analyzing whether

the change is hostile or not. PATs within these contexts usually have specific purposes and thus the amount of various interactions the user has with them is limited. Recently, contexts that support a more creative user experience have emerged in the fields of art and gaming. Through the use of PATs, artists have had the ability to create pieces that allow for active participation of a user with the art, transforming the user from a spectator to part of the art itself. Gaming, a field that has always been reliant on a deep level of user interaction, has begun to reassess what it means to "control" a virtual environment and play with the idea of the human body as an input device.

Although the application of PATs exists across numerous contexts, the actual UX design within each context is shallow. In most cases, a users presence in a space merely acts as a trigger, an instant that decides whether a state is on or off. Even the experiences facilitated by contexts like video games that make use of presence-aware technology are limited, often directing users to mimic the actions of a digital representation rather than discover interactions and functionality. The potential of presence-aware technologies and spaces remain untapped, evident in these existing implementations that leave the user disconnected from the experience. That is why it is important to establish UX design models for PATs now, while many of these technologies are still emerging.

Identifying a Metaphor

To identify the thread that exists between presence-aware technologies, it was necessary to determine what separated these technologies from others such as desktop and tablets. This question does not have a concrete answer, as there is more than one key feature that differentiates presence-aware technologies from its counterparts. One facet of presence-aware technologies was the fact that rather than using intermediate tools,

these only require a user's presence. This is analogous to many simple situations and tasks in real life, such as opening a window. In essence, presence-aware technologies simply translate movements and gestures a user performs in the real world and represents them in a virtual context. Under this assumption, it is possible to see an incredibly close connection between the virtual worlds created by presence-aware technologies and the real world itself. Thus, this approach attempted to design an experience that highlights this connection by focusing on the metaphor of human's manipulation of physical space.

This metaphor, though, is much too broad. There are billions of metaphors that can be extracted from the real world, to many to try and condense into one experience. As previously stated, presence-aware technologies exist in many different contexts, making it difficult to choose metaphors that can be specifically applied to each one. However, because a Kinect was used as the presence-aware technology for this approach, it was possible to further contextualize the metaphor. The Kinect excels at analyzing the position of users and objects in its field of view using a system of infrared cameras described later on. Because the Kinect provided this accurate representation of depth and movement, the once broad metaphor of physical manipulation could be condensed into a metaphor of user movement within the real world. With this new, overarching metaphor, it was possible to begin conceptualizing the proper creation and deployment of this approach.

It is important to note that the broadness of this metaphor may have played a role in the eventual lack of metaphor in this thesis. However, a number of other factors could have contributed to this lack of metaphor as well. Specifically, the role of linguistic theory and the very idea of metaphor has a much deeper role and meaning than the ones

presented here. This initial research operated under the assumption that metaphor in technology exists only from the real to virtual worlds, when in reality the two inform one another. This relationship is dynamic, evolving in a much more profound way than is addressed through the basic desktop metaphor. The idea of interactions, gestures, and usability do not exist simply within technology but also through cultural conventions. These conventions shape the human experience, which in turn shapes the experience that technology can provide. Although this thesis did not explore these concepts of metaphor, acknowledgment was noted to be addressed in future research and iterations of the installation.

Approach

The primary objective of this thesis was to assess the success of designing user experiences through a metaphor of physical manipulation. Many current technologies act simply as tools the user manipulates to interact with a virtual environment, establishing an obvious divide between the real and virtual worlds that results in a limited sense of immersion. By designing for a metaphor analogous with the real world, users will feel as though the physical and virtual worlds are one, creating a more powerful, immersive experience. To accomplish this, a User Experience (UX) design model was chosen with a special focus on the idea of mental modeling, an area of UX modeling that attempts to answer the question "How do users *perceive* an experience". An art installation was created which made use of the Microsoft Kinect to track user actions as they explored an environment built of silhouettes. Video and images were collected as users navigated the installation and questionnaires were disseminated post-installation. Data collected was

later compiled and assessed to determine the success of the installation in providing an experience that both engaged users and blurred the line between the real and virtual worlds.

Why an Art Installation?

The Irish Museum of Modern Art, or IMMA, presents artwork of both established and emerging artists in many forms, including installation art. In 2010, the IMMA hosted a series of talks, one of which was simply named "What is Installation Art". This talk drew attention to the works of many installation artists and evaluated their pieces to establish a definition of installation art. According to the IMMA, installation art is characterized by "the totality of objects and space that comprise the artwork… a mode of production and display of artwork rather than a movement or style". Here, it is clear that the physical layout of installation art is extremely important to the experience of the piece. The objects and space are so vital, in fact that the talk goes on to say, "In some instances, the site or location of the work is an intrinsic and non-negotiable element of the work". This is one characterization that differentiates installation art from other forms of artistic expression.

Of course, installation art is not defined by the creation of a space alone, but also by how participants are expected to experience it. According to the IMMA, participants of installation art are actively involved in the space rather than passive observers. The majority of installations "involve(s) the viewer entering into the space of the artwork and interacting with the artwork. Additionally, these viewers "encounter the artwork from multiple points of view, rather than from a single perspective". Both of these quotes differentiate installation art from, again, other art forms in which a participant simply

views the art from a single perspective. Participants are encouraged, if not expected, to become active contributors to the art installation. It is through this combination of viewer participation and strict space that defines installation art.

Based on these characteristics, it was concluded that observing users through their participation in an art installation would be an effective way to assess the success of designing user experiences through a metaphor of physical manipulation. Additionally, promoting the implementation as an art piece rather than another observation tool (e.g. an experiment) would help to create a more informal and comfortable experience for a user. This fit within the strategy of producing as natural of an experience as possible, which would in turn result in more natural interactions between the user and the space.

Interactive Shadow Environment

The human relationship with shadows is an implicit one, driven by the fact that shadows exist in our lives from birth. A shadow is defined as “a dark area or shape produced by a body coming between rays of light and a surface”. Shadows can be broken into two groups, *cast* shadows and *attached* shadows. A cast shadow is when one surface occludes another surface from the light source, whereas an attached shadow is formed when a surface obstructs the light falling on itself (Hu & Brown). Humans may not have to actively think about their shadows, but that is not to imply that shadows do not serve a purpose. Multiple studies have shown that humans use shadows frequently to more properly assess the depth and shape of the world around them (Knill). Additionally, the motion of shadows can help determine the position of an object relative to the space that it is in. Thus, while active processing of shadows may not necessarily take place, they are still crucial to our assessment of the world.

It was believed that using shadows as the primary cue and interaction context would be effective for two major reasons. First, as made clear in the definition of shadows themselves, is the implicit connection people have with their shadows. Unlike a character in a game that serves only as a virtual representation of the user, a shadow had the potential to be perceived as the participants themselves, regardless if that shadow existed in a real or virtual world. The second reason was the hypothesis that forcing a user to interact with an environment only through the use of their shadow would be a much more engaging and immersive experience. Using their shadow rather than an external device like a controller would further connect the user to the space itself. By observing their shadow within the same plane of existence as the other shadow objects in the space, it was believed that users would feel as though they were in the world itself, effectively blurring the line between the real and virtual worlds.

Implementation

To capture data necessary to assess the success of the proposed objective, an art installation was created that presented a user with an interactive virtual scene built of virtual shadows. The shadows within the scene were visual representations of real world objects, designed to facilitate a metaphor of real-world physical manipulation, a metaphor that is applicable across many PATs. The Microsoft Kinect was used as the presence-aware technology and was integrated into the installation using open-source software. All technology used in the installation was hidden from users in an attempt to erase any preconceived notions of how to interact with the space. As users experienced the space,

data was collected via photos and video. Additionally, upon leaving the space, users were given an anonymous questionnaire to captures their thoughts and experiences about the space.

Presence-Aware Technology Used

The Kinect's ability to track and analyze user movement stems from a pair of lenses located on the face of the device. The first of these lenses, an *Infrared Emitter*, bathes the space in front of the Kinect in infrared light (invisible to the human eye). The second lens shields a camera that captures the reflected infrared light, establishing a visual representation of the layout of the space. Varied depths of users and objects in the space are represented by the brightness of the infrared reflection (a closer object creates a brighter reflection, and vice versa). This process of emitting and receiving reflected light results in an infrared image of the Kinect-captured space (Figure 6). The Kinect software then analyzes the pattern of light created by the varied depths in the space, primarily to determine the users position. This effort to track a user is aided by additional Kinect software that is pre-programmed to identify a generic human body shape.

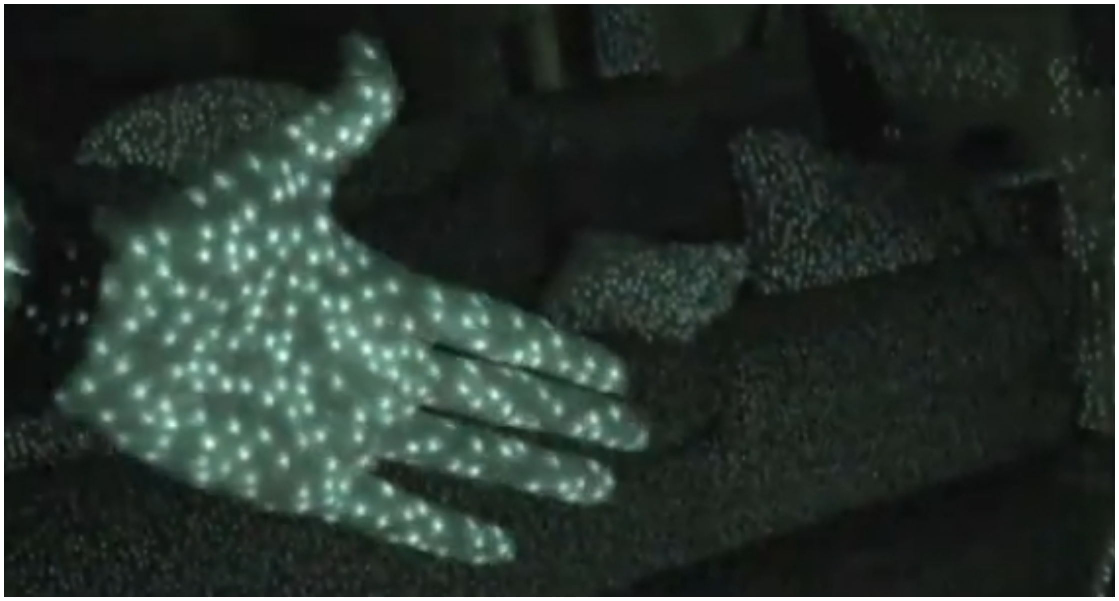
Figure 6. Infrared image of the Kinect in action

The Kinect was used for this implementation due to a variety of reasons, the first being the "ready-to-go" capabilities built into the system. The Kinect is unique in the sense that, unlike many other cutting edge technologies, its documentation and programmed structures is, for the most part, open-source. What this means is that anyone interested in developing a project using the Kinect needs only to purchase one and download the necessary software to begin. Additionally, the gaming context that the Kinect was designed for fit well into the concept of this final implementation. It was necessary to provide the user with a fixed space in which to interact with the installation, yet at the same time insure that they had a free range of motion while in it, another requirement that the Kinect could facilitate. Finally, because the Kinect driver is both open-source and popular among emerging technology developers, there are many downloadable programs that simplify the integration of a Kinect into a project. Thus, instead of having to interpret the raw data coming from the Kinect itself, novice developers are able to use a more understandable input.

Programs Created

Two different programs were ultimately created and deployed, each designed within the driving metaphor of physical manipulation in the real world. The programming environment chosen for each implementation was Processing, an open-source environment developed by Ben Fry and Casey Reas that builds off the coding language of Java. A passage taken from the Processing website describes it as:

> "…an open source programming language and environment for people who want to create images, animations, and interactions. Initially developed to serve as a software sketchbook and to teach fundamentals of computer programming within a visual context, Processing also has evolved into a tool for generating finished professional work. Today, there are tens of thousands of students, artists, designers, researchers, and hobbyists who use Processing for learning, prototyping, and production."
>
> \- http://processing.org/

This description is a brilliant embodiment of what Processing is and effectively highlights the key reasons why it was chosen for this implementation. Processing's focus on graphics and interactions is ideal for an implementation as visually oriented as this. This is reinforced by the community of artists and designers that flood the website with questions, tools, and tips eager to communicate with other uses. This type of sharing community results in a plethora of resources in the form of libraries, a digital package that can be added into a program to enhance its capabilities. Daniel Shiffman, one of the lead contributors and educators in the Processing community, created one such library, SimpleOpenNI. This library gives the programmer access to data coming from the Kinect such as depth and number of users within a space. This data can then be manipulated within the Processing environment to produce visuals and trigger actions. It

was because of SimpleOpenNI's powerful features that it became the technical foundation of this research.

Each program's primary purpose was to facilitate the creation of a user's virtual shadow. Two template programs[2] from the SimpleOpenNI library were crucial in this creation. Both template programs, called *SceneMap* and *User,* made use of the built-in functionality of the Kinect that detected and pinpointed a user when they entered into the field of view. However, each template program handled this information differently. The first, *SceneMap*, analyzed the incoming video from the Kinect and broke it down into a list of pixels (the smallest controllable element of a picture represented on a screen). Any pixels within the outline of a detected user were filled with a unique color, effectively producing a colored representation of the user on a solid background (Figure 7). By manipulating this program, a user-specific visual could be displayed on the screen and colored to match the appearance of a shadow on a wall (i.e. black for the shadow and off-white for the background).

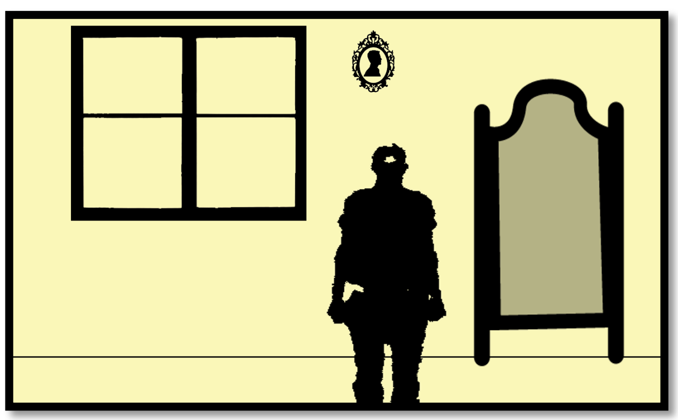

Figure 7. A demonstration of how *SceneMap* can be used to create a silhouette

[2] Template programs refer to programs that are included within a library. These template programs provide simple examples that can be studied and expanded to facilitate an understanding of the library's capabilities.

Although *SceneMap* was powerful on its own, it lacked the ability to represent depth which was vital for convincing user's that it was indeed their shadow depicted on the screen. *User* was another template program used to compensate for this fact. In this template program, a series of virtual limbs are mapped to a user when they enter the Kinect's field of view. These limbs each have unique identifiers (e.g. SKEL_RIGHT_ELBOW) as well as attributes that can be tracked over the course of the program. How far the user stood from the Kinect determined one such attribute, the limb's depth. As the user moved closer to the Kinect, the depth value went down, and vice versa (Figure 8 & 9). This number was plugged into a formula that calculated the shadow's transparency. The resulting output created a visual consistent with how shadows appear relative to the light sources that create them in the real world.

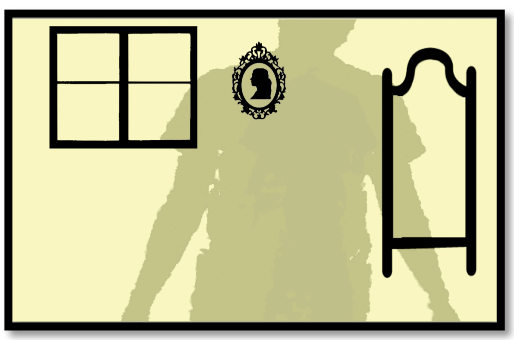

Figure 8. Standing close to the Kinect

Figure 9. Standing away from the Kinect.

Processing was also used to construct and display the visuals that made up the shadow environment. These visuals were built from scratch using simple object functions such as *rect, ellipse,* and *image* (facilitating the creation of rectangles, ellipses, and images, respectively). The type and amount of visuals differed between deployment versions. In the first version, transparent orbs with black outlines were drawn and animated to appear as though they were floating down towards the ground. An infinite number of these orbs were created as the program ran, but only between six and ten

would be drawn (visible to the user) at a time. These orbs were designed to simulate the appearance and behavior of a real world bubble as it passed between a light source and a surface. In the second version, the bubbles were removed and were replaced by fixed objects that resembled other real world objects. These objects included a mirror, a picture frame, and a window. Unlike bubbles that were constantly spawning and popping, objects in the second version did not move.

A color detection algorithm built specifically for this installation facilitated user interaction with the shadow environment. In essence, this algorithm routinely looked at specific areas of pixels and actions were triggered if those pixels changed to a certain color (in this case, black in accordance with how the user's shadow was drawn). The size of these pixel areas was dependent on what object they were associated with. For example, the algorithm when applied to a bubble object searched for the small circumference around the bubble for color changes. The algorithm was also used to designate larger portions of the screen. The latter technique was referred to as applying a "hotzone" to the program. These hotzones were invisible to the user, but were nevertheless triggered by their presence.

Physical Components

The installation was constructed within a 10' x 7' x 25' space. The dimensions of the space were chosen to properly hold all of the technology involved while still allowing a participant to move around uninhibited. A computer running the program was connected to a projector located at the far end of the installation space. The projection was thrown onto a screen 10' x 7' screen made out of a semi-thin material. This material

allowed the projection to appear on the opposite side of the screen (i.e. in front of the user) while also hiding the projector and computer from view. A space of thirteen feet in front of the screen was left empty so as to provide a participant enough space to move around. Past this space was a Kinect attached the underside of a small table, effectively hiding it from a participant. On the top of this table was a hollow orb lit up by a small LED. This orb was meant to appear as the light that was illuminating the space, thus cementing the idea that it truly was their shadow they were seeing on the screen. In reality, the material the orb was made out of diluted the LED enough as to inhibit the casting of a shadow.

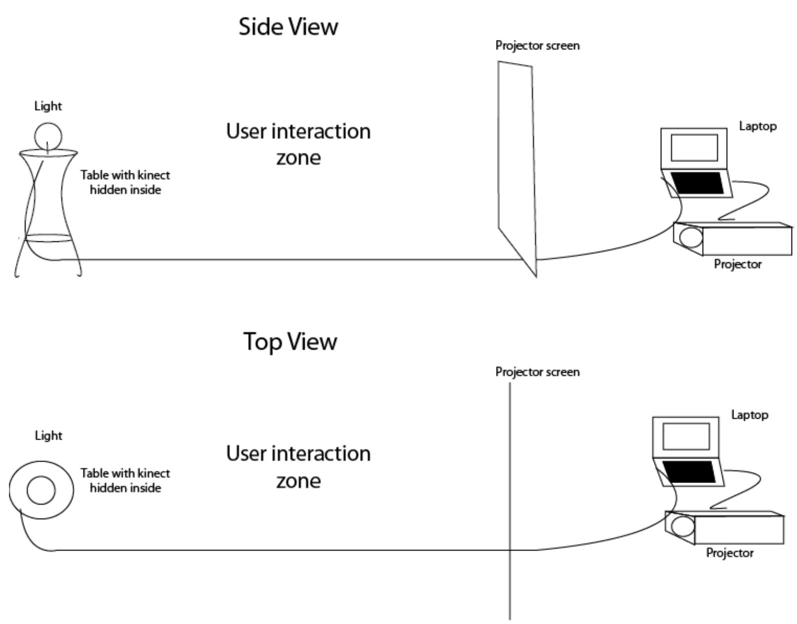

Figure 10. Mock-up of physical installation

It was imperative that all of the technology within the installation was hidden from the user to prevent any preconceived notions from biasing participant interaction. If participants knew that a Kinect was running the system, it was believed that those who were familiar with Kinect gestures would use them in an attempt to trigger changes within the environment. This would turn the environment from one driven by physical

manipulation metaphors to Kinect gesture metaphors, which would in turn result in flawed data. However, it was also expected that some users would realize there was some technology driving the visuals that they were experiencing as they explored the environment. However, as long as they were unsure as to what the exact technology was, it was believed that they would still behave as if the shadow was their own.

Results

Upon entering the space, the majority of participant's quickly focused on the projection of their shadow on the screen. To confirm that the projected image was indeed based on their shadow, users made slow and precise movements such as walking side to side and raising and lowering different limbs. After concluding that the projected image was theirs, the participant's next moves followed four distinct avenues. Some participants continued to explore the projected shadow image itself by moving closer and father away from the screen (changing the transparency of their shadow) and speeding up their movements. A second subset of users, satisfied that the shadow was their own almost immediately, sought out other areas of interest projected on the screen such as the silhouettes of falling bubbles, windows, and mirrors. The third subset of users pulled their gaze from the visuals projected onto the screen and instead attempted to discover what was driving the installation. These users were observed blocking the "light" (the glowing orb) as well as trying to look behind the screen and under the table in order to find the technology involved in the creation of the on-screen visuals. Finally, there was also a small subset of participants who did not engage with the installation at all. These

participants made little to no effort to interact with the space and usually left soon after entering.

A questionnaire distributed after a participant left the installation consisted of five questions that required the user to reflect back on their experience within the installation. These questions were designed to provide insight into a participant's thought process, which would not be apparent from simply observing them within the space. The same questionnaire was used for each version of the program in order to compare the two different approaches. After the deployment of each version, the questionnaire responses were sorted based on question and common responses were extracted (See Appendix 1).

Table 2. Breakdown of Common Responses to Questionnaire

Question Asked	Version One Common Responses	Version Two Common Responses
What were some of your first thoughts upon entering the space?	Confusion, did not know what was supposed to be done	What can I do with the visuals on the screen?
What were some of the first things you did upon entering the space?	Attempted to pop bubbles, tried to discover what the technology was	Played with my shadow, attempted to interact with visuals on the screen
When did you realize the silhouette on the screen was not your actual shadow?	Immediately, When the silhouette was programmed to act unexpectedly	Immediately, When the silhouette was programmed to act unexpectedly

What actions did you perform to modify the silhouette (if any)?	Repositioned self within the space, tried to block the light	Moved quickly, posed in front of the mirror
Was there anything you expected to be able to do that you weren't?	Expected the bubbles to be more sensitive	Interact with more things

To assess the results of this approach, it was important to measure them against criteria for validating if a user-experience for a presence-aware space is successful. These criteria were based on basic UX design principles that were illustrated previously. The first of these criteria is the level of engagement a user experiences within a space. If some level of personal engagement cannot be validated somehow, than it must be concluded that the approach was not successful. The second criterion is whether or not the user discovers the technology driving the approach. If this occurs, it will be unclear if the following actions performed by the user are based on the experience itself or the prior knowledge the user has about how the technology works.

Discussion

This approach and implementation was certainly not without flaws. One was the lack of a control experiment that would observe how a participant would act with a similar space with full knowledge of the technologies involved. Without this control, it is difficult to definitively say that what that the experiences would be very noticeably different. Another major flaw were the technical limitations of the Kinect and Processing

themselves. These limitations led to small hiccups and errors that would jar the participant out of the engaging experience that was being created. The limitations of the Kinect, specifically, resulted in a flawed representation of the user's shadow that fooled some but was a setback for others. Finally, it was clear after the first installation that the implementation of the "hotzoning" trigger method had been completely misleading. In the first installation, these hotzones were positioned towards the edges of the screen space in the hopes that they would be accidentally discovered and subsequently played with. However, deployment showed that this use of hotzones went against the method of discovery that was trying to be instilled in a participant. Instead of helping participants engage the space, this deployment of hotzones confused and disoriented them, resulting in visual changes that the participants believe happened randomly. It is because of this observation that the program was so dramatically transformed (visually) from one installation to the next. However, even with these flaws, this approach provided some interesting insight into how users experience a presence-aware space. Though there were many unique themes that could be extracted from the data collected, two were chosen that most prominently highlighted the required criteria.

Silhouette Recognition

In both versions, though many knew some technology must be involved, users were unaware that the Kinect was specifically being used to drive the installation. Without this knowledge, the only determinant of the user's actions was what they perceived on the screen. It is important to note that each silhouette object was designed to resemble a generic, real-world object and that every user correctly identified what the

object was supposed to be. Through this identification, users were able to infer methods of interaction such as the fact that bubbles could be popped (version one) and that posing in the mirror triggered an event to occur (version two). However, recognizing what a silhouette was supposed to represent did not mean that every user interacted with it the same way. For example, in the second version of the installation, some users attempted to slide the window silhouette up while others tried to push it outwards. Although the intent was the same, the manner of interaction was different. Thus, the user's ability to recognize cues demonstrated the effectiveness of designing an experience based around the metaphor of a real-world space to initially engage. However, it also exhibited the variability that can arise even if an object is perceived as simple.

Identification with the Shadow

After the first version's deployment, during the compilation of questionnaire responses, it was noticed that many of the participant's were answering questions as if they had been in the same world as the projected silhouettes. Rather than saying things like "I tried to pop the bubbles on the screen using my shadow", many participants said, "I tried to pop the bubbles to my left". Although this was noted, it was not completely studied until during the second version deployment. This version was deployed in a slightly shorter area than the first, which resulted in a slightly wider user silhouette. This was immediately picked up by almost every user (though they were a different group than the user's from the first deployment) and conveyed both through observation and questionnaire responses with statements like "I felt fat". What this seemed to

demonstrate was a level of engagement between the user and the visuals that blurred the line between the real and virtual worlds.

Other interesting information came from observing and questioning participant's who made little to no effort to interact with the space. While many factors could have contributed to their response, two in particular were obvious based on comparing each deployment version. First, it is likely that the majority of users who chose not to interact with the space felt awkward and isolated due to the fact that they were aware they were being watched by others. This becomes apparent by comparing the number of non-interacting users in the first deployment, which took place in a fairly open space, to the number in the second deployment, which was set up in a small room. Not surprisingly, the first deployment had a higher number of users who did not interact with the installation. The second likely reason for this attitude was a lack of immediate understanding of what the participant was supposed to do. By again comparing each deployment version, it is clear to see one facilitated more immediate participant understanding than the other. Falling shadow bubbles were the only obvious visual cues that were presented in the first version. Thus, once a participant had interacted with those, it was not clear that there was anything else to do. In contrast, the second version consisted of multiple shadow objects, which encouraged participant's to interact with others after triggering one object. Thus, again, the number of non-interacting participants was greater in the first deployment than the second.

However, perhaps the most profound outcome of these deployments concerned the effectiveness of the implemented metaphor, or lack thereof. Data collected from both observations and questionnaires confirmed a space had been created using presence-

aware technologies that engaged participants in a meaningful and understandable way. In spite of this, it seemed that although the goal had been to design an experience using metaphors, no specific metaphors had ever been established. The conclusion was drawn based on the initial example of the desktop metaphor. In this metaphor, the user's knowledge of the function of a physical desktop helps them acclimate to the new space and functionality (i.e the computer) as well as the method of interaction (i.e. the mouse). In the experience created for this thesis, the relationship between user and technology was much less apparent, as users demonstrated that they were unfamiliar with what technology was driving the installation. Users did not pose in front of the object that resembled a mirror because a metaphor led them to do it, they did so because that is *exactly* how they would interact with a mirror in the real world. These interactions were evident with every object within the shadow environment, even those with no programmed trigger (e.g. although nothing happened when the window was touched, every user still tried to open it in some way). What seemed to have been created was a space and technology pair that could be interacted with without the use of metaphors.

If participants did not need a metaphor to understand how to access the functionality of the installation, than where does that leave presence-aware technologies from a design perspective? In other words, might there a more fitting term for this kind of user acclimation within the context of PATs? Based on what was observed and questionnaire responses, one such term that comes to mind is mimicry. Mimicry is defined as the act of imitating or copying in action or speech. Those participants who were engaged in the installation, void of any prior instruction, responded to the familiar shadow objects by mimicking the actions they would perform had the object existed in

the physical world. This demonstrates that it was something more along the lines of mimicry, not the initial metaphor of manipulation in the physical world, that acclimated participants to the installation.

Thus, it seemed as though this approach failed the main objective of identifying presence-aware specific metaphors. However, through this failure, the approach taken has hit on a much more profound and inspiring concept. Based on the observations and questionnaire results, it was clear that users were able to effectively interact with the shadow environment created. Not only that, but also these results demonstrated that users knew exactly what actions led to certain programmatic reactions. This suggests that unlike many technologies of the past, presence-aware technologies may not be as reliant on the use of metaphors to acclimate new users. Instead, a new component along the lines of mimicry may be what designers look towards as they design the user experiences of the future.

Conclusion

This thesis focused on identifying potential real-world metaphors through the use of emerging technologies in an interactive art installation. Although the installation was designed with the metaphor of manipulation in the physical world in mind, it was evident that the metaphor had not been successfully implemented. However, based on the data collected, it was clear that the presence-aware technologies driving the installation could promote meaningful interactions by users without the use of metaphors. In its place, a stimulation resembling mimicry was capable of acclimating users to the space. If this is finding is consistent across PATs, both those that exist now and those that have yet to be

developed, this would be a true breakthrough in the field. Overcoming a dependency on metaphors may immediately make these technologies open to entirely new audiences who have had trouble understanding new technologies in the past as well as unlock creative ideas that were previously inhibited. However, it is important to note that even. In fact, the idea of mimicry will still be plagued by many of the common hurdles of metaphors in the past, namely a limitation on the technology to support abstract gestures and the inability of some people to understand these interactions. These hurdles must be fully researched and studied before presence-aware technologies and spaces can be fully adopted as more than creative outlets.

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Appendix I: Survey Details

To remain hidden as the experimenter during deployment, each version was set up to run automatically while I observed and collected data from a distance.

Version One Participants/Questionnaires Received: 16/16

Version Two Participants/Questionnaires Received: 17/17

Question Asked	Version One Common Responses	Version Two Common Responses
What were some of your first thoughts upon entering the space?	Confusion, did not know what was supposed to be done	What can I do with the visuals on the screen?
What were some of the first things you did upon entering the space?	Attempted to pop bubbles, tried to discover what the technology was	Played with my shadow, attempted to interact with visuals on the screen
When did you realize the silhouette on the screen was not your actual shadow?	Immediately, When the silhouette was programmed to act unexpectedly	Immediately, When the silhouette was programmed to act unexpectedly
What actions did you perform to modify the silhouette (if any)?	Repositioned self within the space, tried to block the light	Moved quickly, posed in front of the mirror
Was there anything you	Expected the bubbles to be	Interact with more things

expected to be able to do that you weren't?	more sensitive	

Responses were considered common if the majority of them were similar relative to each question. For example, when asked, "What were some of your first thoughts…", nine out of sixteen participants responded with some form of "confused" in Version One while seven out of seventeen responded with "What can I do with the visuals" in Version Two. Although these ratios are different, each had a majority within the question itself.

Descriptive Statistics

Identification with Shadow

Roughly 75% of participants who engaged with either version of the installation experienced some form of self-identification with the human silhouette projected on the screen. This was evident based on questionnaire responses that took a first person perspective rather than a third person perspective. For example, some participants responded with statements like "I posed in the mirror" rather than "I positioned my silhouette in front of the mirror". This suggested that a convincing, clean representation of a human shadow was unnecessary in creating an engaging experience as first thought.

Silhouette Recognition

Although the object silhouettes were designed with specific real world objects in mind (e.g. a window), participants were never instructed on what each one represented. Even still, 100% of the participants correctly identified the falling orbs as bubbles in the

first version of the installation, and 88% of participants correctly identified every object displayed in the second version. This is a surprisingly high percentage of participants considering the fact that these similar interpretations were based on objects that were created from generic dark rectangles and circles.

Altered Perception of the Real World

In the second version of the installation, 29% of participants exhibited signs of an altered perception of the real world, evident through both observation and questionnaire responses. These participants seemed to move more slowly through the installation and left comments such as "The installation made me feel fat". This "fatness" was due to a simple space issue in which the Kinect had to be pointed at a slightly skewed angle, resulting in a wider, stouter visual of a participants shadow. Because this necessary modification had seemed irrelevant before the deployment of the second version, it came as a shock when roughly a quarter of the participants were noticeably affected by it.

Author Bio

Samuel Foster was born in Dover, New Hampshire on August 6th, 1991. Moving early in his childhood, Sam was raised in Saco, Maine, growing up there to graduate from Thornton Academy in 2009. After graduation, Sam enrolled in the New Media program at the University of Maine in Orono, picking up a Business minor as well during his academic career. Living by the adage "jack of all trades, master in none", Sam spent much of his time exploring the different areas of New Media. However, he eventually found a focus in user experience design and interface design towards the middle of his junior year.

Upon graduation, Sam plans to spend half a month in Scotland to celebrate the completion of his undergraduate degree. In the fall of 2013, Sam will continue his education in the MBA program offered at the University of Maine. Here, he will focus on the role of emerging technology in business and how it may facilitate new markets and new consumer experiences. In the future, Sam hopes to find a career either in a technologies design lab or teaching experience design to high school students.