Designing visitor experience for open-ended creative engagement in art museums: A conceptual multi-touch prototype design

by

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RESEARCH QUESTIONS

1. What theories and approaches have been used to develop digital interactivity in museums in order to reach their educational goals?

2. Compared to science museums and natural history museums, how do digital interactives of art museums fall short of the learning potential?

3. How can designers change the passive visitor experience in art museums into an active engagement through the design of open-ended interactions?

ABSTRACT

The popularity and influence of digital interaction in museum design has greatly increased along with developments of society and technology. Science museums and natural history museums treat digital interactions, such as multi-touch displays, as important tools in exhibition design that improve the interactivity of visitor experience through open-ended activities. Art museums, however, which mostly focus on displaying art collections and lack hands-on activities in exhibits, have yet to embrace this type of interactivity. The visitor experience in art museums is still relatively passive: their digital interactions are limited to catalogs of art history, which offer few opportunities for personal input. Furthermore, modern art is especially difficult for visitors to interpret and engage. This study is an attempt to address this gap in usage of interactive displays in art museums by introducing open-ended interactions as a way to engage visitors about modern art. It culminates in the design of a *multi-touch* application, *What Inspires You?*, to demonstrate possible approaches that can be used to enrich the visitor experience in art museums through educative perspectives. Museum education literature shows that constructivism is an effective theory for guiding interaction design to personalize visitors' learning experiences at museums. The conceptual prototype developed in this study is informed by constructivism and a way for art museums to help visitors bridge modern art and personal experience by engaging them with the inspirations that affect art creation and then allowing them to experiment with artistic expression themselves. The prototype combines concepts of museum interactivity, pedagogies of museum education, and multi-touch interface design to enhance dynamic experience so visitors can create their own unique learning experience. This prototype is a new potential approach that can help art museums to engage their visitors more effectively through open-ended interactivity.

OPERATIONAL DEFINITIONS

Interactivity

The degree to which two or more communication parties can act on each other, on the communication medium, and on the messages and the degree to which such influences are synchronized. It includes user-user interaction, or user-machine interaction and user-message interaction. (Liu & Shrum, 2002)

Discovery (in context of museum education)

This method encourages visitors to explore information and knowledge through open-ended activities rather than on getting the right answers. (Witcomb, 2006)

Constructivism (in context of museum education)

Constructivism is a theory to explain how human construct knowledge when information comes into contact with existing knowledge that had been developed by experiences. (Glaserfeld, 1989)

Museum interactives informed by a constructivist learning theory are based on a more nuanced understanding of the nature of communication in which the production of knowledge is embedded in the process of communication, and there is awareness that this is two-way. There is the opportunity for visitors to create their own personal story out of offered information. It allows visitors to make their own meanings and then document those for others. (Witcomb, 2006)

Information utility (in context of museum education)

Information utility is a channel to add value to museums by opening two-way flows of information between museums and visitors. If we define information broadly, it may be

an experience involving some combination of intellectual, aesthetic, sensory, spiritual or emotional character. Key functions of museums: to collect, preserve, study, exhibit, and interpret. The museum can be defined as information utility to public and encourage the transition from displaying artifacts as the main function to information communication for adapting to the new world. (MacDonald & Alsford, 1991)

Multi-touch

Multi-touch technology allows a touch screen to sense input from two -- or more -- points of contact at the same time. This allows you to use multiple finger gestures to do things like pinch the screen to zoom in, or spread the screen to zoom out.

Visitor experience

There are two dimensions to the visitor experience: inside and outside.

Inside: the experience happens in the visitors' perceptions. It's seen from their point of view, created by a combination of their feelings, sensations and prior experiences.

Outside: an experience is made up of many separate pieces outside the visitor. The outside dimension begins the instant a person decides to visit, continues throughout visiting time, and ends when the person leaves. (Weaver, 2007)

CHAPTER 1: INTRODUCTION

According to the International Council of Museums (ICOM),

> "A museum is a non-profit making, permanent institution in the service of society and of its development, and open to public, which acquires, conserves, researches, communicates and exhibits, for purpose of study, education and enjoyment, material evidence of people and their environment." (ICOM, 2005)

Museum design is content-driven, informative, educational, and entertaining. Exhibitions in museums can either be in place for decades or travel around in a relatively short time. In general, the interpretive techniques must be accessible to all types of audiences. A combination of static/passive and dynamic/interactive components provides diverse audiences with multiple layers of information to get into the story. History museums mainly use artifacts, text, and archival images to answer the question "what happened before?" in a linear chronological path. Science museums try to translate dry and confusing scientific concepts into a story that the public can easily digest. The story can be told using multimedia and interactives in various ways. Children's museums use a large amount of interactions in colorful exhibits, which engage children to learn through creativity and experimentation. These exhibits challenge children physically, socially, and emotionally (Lorenc et al., 2008).

However, unlike the previous museum types, art museums have not found it easy to provide interactive visitor experiences. Exhibition design in art museums is in some sense limited, because their focus is not on teaching broad concepts, but rather on displaying collections of objects (such as paintings, sculptures, multimedia works, and installations) that visitors can only interact with through passive observation. In an attempt to increase visitor interactivity, most art museums provide handheld guides with audio tour in order to enhance art

interpretation and empathy (Tallon & Walker, 2008). Recently, some of them have started utilizing apps on smart phones to replace traditional handheld guides. These apps integrate multiple functions, such as tour guide, exhibits information, membership activities, and maps. However, they are static in nature because they are simply collections of information. Another limitation to these applications is that they are presented through small screens that only allow one person to interact at a time.

In general, the public feels dissatisfied with cultural institutions for five reasons: 1. Cultural institutions are irrelevant to the visitor's life. 2. The institution never changes. 3. The authoritative voice of the institution doesn't include the visitor's view or give the visitor context for understanding what's presented. 4. The institution is not a creative place where visitors can express themselves and contribute to history, science, and art. 5. The institution is not a comfortable social place for the visitor to talk about ideas with friends and strangers (Simon, 2010).

Exhibits in art museums play the role of a dominating lecturer. When walking into an art exhibit, visitors only expect to communicate with artwork and the theme of the exhibit visually and mentally. Vision is useful for quick digestion, but weak in facilitating deep art interpretation. Additionally, these exhibits are typically aimed at adults because it is difficult to keep children and teenagers' attention onto passive content. However, museum interactivity and art education research have shown that hands-on activities and social interactions greatly improve effectiveness of exhibits (Beale, 2011; Wachowiak & Clements, 2001). Art museums are fundamentally concerned with visitors' ability to apply what they learned at the museum in the context of daily life, and could therefore benefit by applying this research and integrating more interactive and social displays. In the past, art museums have challenges when attempting to

engage visitors with physical hands-on activities due to space limitations. Instead, art workshops, which are operated in independent areas of museum buildings, take over the function and responsibility of interactivity and approachability to visitors, especially children and teenagers. However, these workshops are usually disconnected with exhibits, and require specially scheduled, often lengthy activities.

Recent improvements in multi-touch technology and related interaction design help make such technology a potential way for art museums to integrate interactive exhibit design in a space-efficient way that engages visitors near relevant art displays. The general public is familiar with touch screens and multi-touch applications, making them an attractive option for engaging visitors in museum displays. Research has suggested that multi-touch technology is particularly attractive to children and teenagers (Marshall et al., 2011), an audience art museums traditionally have trouble reaching. Therefore, a multi-touch tabletop application is a good choice to explore the possibility of interactivity in art museum displays. Such applications are flexible to install and attractive to visitors. Furthermore, interactive applications on large multi-touch tabletops are working effectively in science museums and natural history museums. Therefore, it is likely that art museums could also effectively use this kind of display.

The main goal of this study is to develop a meaningful conceptual prototype with interactive content that allows art museum visitors to learn through open-ended experiences. The prototype is intended for use with a large multi-touch screen on a kiosk. It would be installed in an area of an art museum that provides seating for visitors, which will help attract families with children and school groups. Visitors may interact with this prototype individually or share their experience in a group through collaboration.

To achieve this goal, the prototype was researched and designed through a combination of museum interactivity, museum education, and interface design theories that center on multi-touch technology. Each area has its own fully developed philosophy and system. The following chapter closely examines the relevant literature in these areas. To get a complete picture of existing digital interactives in the museum world, field observation of museum digital interactives around the United States has been conducted. Information collected in these field observations is documented and analyzed in the methodology chapter of this thesis. The methodology section culminates in a conceptual prototype of a multi-touch tabletop application, *What Inspires You?*, which allows open-ended immersive experiences that engage the visitor through personalized learning that connects modern art to their daily lives. Two tables of criteria – one for museum interactivity and one for interactive design – were constructed based on the literature and used as guidelines and evaluation criteria for this application.

CHAPTER 2: LITERATURE REVIEW

Museum Design

Museum design involves a variety of areas, including exhibition design, 3D design, museum interactivity, graphic design, digital interaction design, and information design. Each branch of design has its own emphasis. In this section, museum interactivity, exhibition design, and digital interaction have been explored for this study.

Museum Interactivity

A museum is a place that materializes and visualizes knowledge (Fyfe, 2006). A museum's function is to collect, preserve, and present information and knowledge for the public to appreciate and learn from. To compete with the entertainment industry, modern museums are attempting to move away from the perception that they are boring educational institutes by becoming active learning centers where people, especially young children, can discover new knowledge about the world and challenge themselves (Falk & Dierking, 2000). Therefore, *interactivity* becomes one of the most important design tools to attract visitors to come back to museums. Hands-on exhibits, playful programs, and educational adventures refresh visitors' minds with new experiences while they are visiting "traditional" museums. A combination of ordinary displays of objects and images with creative interactions offers an effective method for designers and museum experts to make the visiting experience more attractive and meaningful.

The idea of interactive exhibits has a long history. It can be traced back to 1889, when the Urania in Berlin contained visitor-activated models and was popularized in the 1960s when the New York Hall of Science, the Lawrence Hall of Science, and the Exploratorium all started adopting interactivity into their exhibits. There is a strong association between interactivity and science museums and science centers. Science museums and centers use diverse hands-on

exhibits to enhance learning experience of visitors. Those hands-on exhibits are usually presented through some technological media: for example, an exhibit with a device involving physical activity that the visitor can operate is added to the main display (Witcomb, 2006). These interactive programs successfully attract people to spend more time manually manipulating components of exhibits (Hinrichs, 2008). Interactive exhibits are especially attractive to children and families, who form the mainstay of museum audiences (Kidd et al., 2011).

The entertainment and media industries adopted interactive features into their developing process relatively quickly. However, interaction in the museum context is different because it not only provides a playful experience but also allows the visitor to become more engaged with the material. The museum world can be treated as part of a contemporary language of the mass media (Witcomb, 2006). Especially in the twenty-first century, interactive media (such as the Internet, smart phones, and video games), have become a main part of people's lives. One-way instruction is gradually replaced by interactive communication that offers an immersive learning experience.

When designing interactive exhibits, designers and museum experts usually utilize *discovery* and *constructivism* as pedagogies to construct interactivity in the context of the museum. In modern museums, these two pedagogies work together to promote the construction of meaning. Compared to the didactic expository model (when the visitor can only receive information passively) and stimulus-response model (when the visitor can only stimulate one correct answer to get response), the discovery approach empowers the visitor to explore open-ended results. The focus is on exploration rather than on getting the right. Andrea Witcomb calls these interactions "dialogic interactivity". She explains that

> dialogically interactive exhibitions tend to make an effort to connect with visitor by representing aspects of visitors' own cultural backgrounds and using open-ended narratives. (2003)

For example, some exhibitions have incorporated visitor comments into the exhibition space and a few art museums have even encouraged visitors to add their own labels to displayed works (Nashashibi, 2002).

Another approach towards museum interactivity is "play", which integrates games, interactions and learning to create immersive visiting experiences (Beale, 2011). Games enable discovery and also allow the museum to become a social space so that it can facilitate co-experience. In games, the *player* is more important than the *objects* in the context of the museum[1]. "Often games enable the audience to be in charge, gaining a closer relationship to the museum objects or stories" (Beale, 2011).

The key to successful visitor learning is to "help bridge the original contexts of museum objects with visitors everyday lived context" (Froes et al., 2011; Falk & Dierking, 2000). That is why designers should think about a single sentence message of "what you want the visitor to take away from the game" before idea creation starts (Cutting, 2011).

Spaces that achieve poetic and affective responses through a highly aesthetic form of exhibition are also working with notions of "immersion" and "experience." Compared to science museums and centers that incorporate a large amount of interactive exhibits, art museums and galleries are still struggling with this issue. Various art museums have also begun to explore the possibility of interactive exhibits especially for children. For example, at museums such as Art Museum of Western Virginia and Arizona Museum for Youth, exhibitions displayed

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[1] *Objects* in the museum will be the collection.

> A variety of styles of presentation, conceptual approaches and educational philosophies but all incorporated a variety of sensory experiences and interactive elements to attract the interest of children, encourage creative thinking and enhance learning about visual arts. Some exhibits examined the processes of art production, the tools and techniques of artists; others explored the formal elements such as pattern, line, color, or the subjects which fascinated the artists. (Simpson, 2002)

These examples demonstrate that art museums and galleries are beginning to include more interactivity into exhibits to make art more accessible to the visitor. However, they still have a long way to go compared to science museums and natural history museums. They have a great deal of room to use interactivity to improve the visiting experience. It is important for that art museums make this change, because interactivity in museums is not just a trend. Rather, interactive exhibits will be a key tool in engaging visitors and creative immersive educational experiences for them.

Exhibition Design

Exhibition design creates environments that communicate with people by melding communication design and the built environment. Exhibition design is an integrative process that involves a large number of factors (such as environmental graphic design, print graphics, electronics and digital media, mechanical interactives, lighting, audio, interior design, architecture), requiring exhibition designers to work in multidisciplinary teams (Lorenc et al., 2008). Exhibition design can be applied in public spaces, such as museums, public centers, trade shows, and showrooms.

Exhibition environments are usually located at places of intense social interaction. A host of people gathering around and interacting with the exhibition environment makes exhibition

design unique and dynamic. However, the dynamic of groups also helps establish rules for designers. When working on projects, designers need to decide who their viewers will be. These rules also impact exhibition design. “It is important to work with a client to determine the types of visitors they already attract, as well as those they want to bring in” (Lorenc et al., 2008).

Usually, people behave very differently based on their identities and backgrounds. For example, if a family wants to enjoy an exhibit together, then content and communicative techniques should be presented in multiple layers so that each age group is able to participate simultaneously.

The understanding of exhibition design is changing over time. Exhibitions are now judged on the quality of their stories and presentation instead of the collections they display. Storytelling has become recognized a very powerful way to communicate ideas. Designers have moved exhibition design toward immersive environments and large-scale spectacle, both of which help tell stories by creating affective and sensory experiences. Although human tour guides in museums probably will never be replaced, tools from new technology (such as touch-screen kiosks, personal digital devices, apps, and the Internet) are enriching *visitor experience*. Therefore, experience design and participatory design work effectively in exhibition design, especially when interactive elements make passive exhibitions dynamic and help to enhance visiting experiences.

The goal of exhibition design is to inform and promote this topic of each exhibit to audiences. Furthermore, it enhances visitor experience by providing an immersive and communicative environment with a compelling story and dynamic interpretive techniques. This provides a powerful tool to museums for creating appeallilng educational exhibits: “The desire to be surrounded by a story in a public space, to be told stories dynamically, and to have an

interactive experience blended with real environments will forever drive design decisions" (Lorenc et al., 2008).

Digital Interaction in Museum Design

The museum as *information utility* to public encourages the transition from displaying artifacts as the main function to being center of information while adapting to the new world. In the current culturally diverse and dynamic society, museums serve a vital role as witnesses to civilization. (MacDonald & Alsford, 1991). To enable museums to fulfill their role as information providers for society, museum design has stepped into the digital age. A variety of technological means have been used to enrich learning experiences and information sharing, such as websites, handheld guides, apps on smart phones and tablets, QR codes, tabletops with *multi-touch* interfaces, and even gesture-based technology.

However, although it is easy to introduce interactivity at relatively superficial levels, it is challenging to provide meaningful participation (MacDonald & Alsford, 1991). Interactive digital programs have gone through many experiments and practical applications. Especially in the context of science museums, museum designers are using exhibition design to integrate a large amount of digital technology into their displays. Consequently, visiting a science museum has become a journey through immersive technology shows. Nowadays, museum websites are building virtual spaces to engage viewers by including digital objects and information on the Internet (Huhtamo, 2002). A variety of handheld technologies have been explored and utilized in different settings, including traditional audio tours in art museums and apps on smart phones and digital tablets in various museums. Apps are gradually becoming a main tool of museum tours, and are replacing traditional audio tours. Additionally, they integrate diverse functions, such as artifact information, exhibition schedule and location, floor plans including GPS, and even social

interaction. Furthermore, Konstantinos Arvanitis believes that mobile media not only bring museums into everyday life by offering their users the opportunity to access the museum content remotely in their own space and time, but they also attract visitors back to museum for the everyday knowledge (2005). Therefore, museums "without walls" are able to serve better as the information utility.

> This growing recognition of the importance of social interaction in museums and galleries can be seen as part of a broader trend, a trend that is increasingly placing 'interactivity' at the heart of the agenda, not only in science museums and science centers but also increasingly in the arts – and not just the contemporary arts. (Heath & Lehn, 2003)

Collaboration is another way to help visitors learn and engage with knowledge and objects. However, most interactive exhibits only focus on single users rather than enhancing collaboration and social interaction among visitors. Of course, the purpose of the interactivity is to enable visitors to look at objects with a deeper understanding. Early kiosk-based computer exhibits featuring mostly film and audio content are gradually being replaced by multi-touch tabletops; consequently, a new generation of multi-touch interfaces is being introduced in museum design. Interactions with multi-touch technology and computer interactives keep visitors at exhibits longer, which allows the concepts and content of exhibits to have more opportunity to trigger meaningful interpretation from visitors. Multi-touch interfaces are usually designed to be playful, imaginative, and immediate, which attracts visitors to touch and dig deeper. Furthermore, museum designers and experts tend to integrate these interfaces into the narrative flow of exhibits to make interactions even more natural (Kidd et al., 2011). The visual appeal of interfaces in a museum context is highly important because it influences visitors'

motivation and helps the visitor to derive information through interaction and context. In general, interaction techniques for museums should be as intuitive as possible, based on the "walk-up-and-use" principle, to help visitors understand the interaction and information easily. According to different time spans that visitors might spend on these interactives, both short-term and long-term exploration should be rewarded. Collaborative exploration of information encourages social interaction among visitors, and requires careful design of division of labor in case multiple visitors interact with interfaces simultaneously (Hinrichs et al., 2008). Because modern museum design tends to empower visitors, usability comes into designers' focus as well. Ben Gammon has compiled a list of findings on interaction design from five years of watching visitors getting computer exhibits wrong. He found, for instance, that some visitors probably have "techno-fatigue rather than technophobia," or that they are "expecting something exciting, colorful, challenging, with graphics, sound, movement" from interactives rather than a simple information display (1999).

Gesture-based technology is a promising means for engaging the public because it is user-friendly and familiar to the general public, because it has been widely adopted in consumer electronics. It has recently been adopted into science museums and centers. Usually this technology integrates video and animation, such as games on Wii and Xbox Kinect. Because researchers are still working on its accuracy of reacting area in public space (Roccetti et al., 2011), this technology needs more time to demonstrate its potential for museum use in the future.

Museum as Educational Infrastructure

Learning from Museums

Museums, by their very nature, are educational institutions. This fact had been recognized since at least the early nineteenth century (Hooper-Greenhill, 1991) Although

museum education doesn't have a very long history, it has profoundly affected European museums during two "reform" periods: the first from the mid-nineteenth century to World War I, and the second in the inter-war period, 1919-39. The first reform was characterized by a strong emphasis on illustrating national and imperial strength. The second period emphasized nationalistic political themes as well as on exhibiting new conceptions of art and science (Hein, 2006). In a seminal report by the American Association of Museums, *Excellence and Equity*, the educational role of museums was identified as the core to museums' service to the public. The report "speaks to a new definition of museums as institution of public service and education, a term that includes exploration, study, observation, critical thinking, contemplation and dialog" (American Association of Museums, 1992).

Because museum education currently plays a significant role in museum settings, educational theories have been researched and developed to improve it. Research from the past century has resulted in almost universal agreement that learning is an active process that requires engagement. This process is significantly modulated by the learner's previous experience, culture, and the learning environment (Bransford et al. 1999; Falk & Dierking, 2000). This recognition of the active learning process has resulted in a shift in perspective toward focusing on visitors. The social sense of museums and constant changes of current social constitutions have necessarily increased importance of multiple viewpoints of museum interpretation.

On this point, Falk and Dierking, who are chief researchers at the Institute for Learning Innovation and have focused on museum education for more than two decades, developed one concept to emphasize the necessity of understanding visitors. This book, *Learning from Museums*, explores three different contexts that affect learning experience of all visitors: the personal context, the sociocultural context, and the physical context. Learning is a very personal

experience. Usually, learning flows from appropriate motivational and emotional cues. Learning is also facilitated by personal interest and expressed within appropriate contexts. “New” knowledge is constructed from a foundation of prior experience and knowledge.

Falk and Dierking suggest that learning in museums is a fundamentally social experience, which is affected by social cognition, culture, communities of learners (families, couples, friends, etc.), story-telling, and modeling. Furthermore, learning is immersed within a physical context, but still requires ability of transfer from one context to another in order for visitors to digest and use knowledge that they learn from exhibits. Usually, visitors come to museums with expectations based on their personal motivations, interests, or history relative to museum-going. Exhibition design affects family learning and interaction of families visiting museums. The museum activities encourage children from school groups to interact socially with one another and engage in related learning experiences back at school. Besides learning new knowledge in museums, adults also get benefits to maintain social relationships, forge new sociocultural bonds and reinforce old ones. The physical place for learning is also very important. It is the point where exhibit design plays a significant role. Design facilitates conceptual organization, which allows visitors to create meaningful chunks of knowledge. Successful museum exhibitions can move visitors to a higher level of understanding. Today, there are more factors that allow visitors to follow up and extend their museum learning experiences as means of reinforcing experiences outside the museum, such as the Internet (Falk & Dierking, 2000).

Falk and Dierking also developed the “Contextual Model of Learning,” which bases the concept that learning is a dialogue between the individual and his or her environment through time. This model identifies eight key factors that influence learning:

Personal Context

1. Motivation and expectations

2. Prior knowledge, interests, and beliefs

3. Choice and control

Sociocultural Context

4. Within-group sociocultural mediation

5. Facilitated mediation by others

Physical Context

6. Advance organizers and orientation

7. Design

8. Reinforcing events and experiences outside the museum

To evaluate museums as educational institutions, evaluation studies must be conducted through interviews, surveys and observations. Questions in surveys and interviews should focus on certain details of knowledge in exhibits. The difference between visitors' pre-impression and post-reactions towards a sample topic is also an effective measurement in evaluation. Falk and Dierking list and describe several examples to demonstrate this point. One exhibit, *World of Life* at California Science Center, has been documented in detail regarding how visitors reacted to one specific point in this exhibit before and after visit, which proved its success. In *Art Around the Corner* program of the National Gallery of Art, school students visited exhibitions and talked about some specific paintings by following educators in gallery. Students' written responses were analyzed along four dimensions: (1) vocabulary used to describe the painting; (2) interpretive devices used to analyze the painting; (3) support for the interpretive devices used; and (4) overall response to the painting. The exhibit was judged to be successful because

students were able to use some professional vocabularies and interpretations in art appreciation and criticism (Falk and Dierking 2000).

In order to understand museum education, we must understand the informal and voluntary nature of most learning associated with museums. Therefore constructivism became popular in museum education.

> If the educational intention of museum exhibitions is to facilitate visitor meaning-making, then this has a profound impact on the nature of exhibitions and how they are conceptualized and constructed. Most obviously, if the goal is to facilitate visitors' opportunities to reach their own understandings, then the authoritative curatorial voice needs to be muted and modified. Museums have addressed this issue in a variety of ways, including by providing several different interpretations of an object or exhibit or by encouraging visitors to add their comments. Some exhibitions have incorporated visitor comments into the exhibition space and a few art museums have even encouraged visitors to add their own labels to displayed works (Nashashibi, 2002). Other strategies have included posing provocative questions to visitors, rather than answers; or seeking to upset linear or chronological representation. (Hein, 2006)

George Hein suggests that having a "meaningful experience" is more effective than attempting "defined content outcome" in museum settings. Museums and exhibits need to find a way to lead visitors toward inquiry for further education. (Hein, 2004) Then visitors may apply the inquiry and solution of problems into their daily life.

Art Education

Interactives in art museums offer not only background information to the public, but also serve educational purposes by inviting, as well as providing, interpretation to visitors when they react to art works.

"The essence of art is the spark of insight and the thrill of discovery – first experienced by the maker, then built into the work of art, and finally experienced by the viewer" (Perble & Perble, 1994).

Art is influenced by a series of experiences that affect things such as perception, awareness, ways of seeing, visual thinking, beauty, aesthetics, and creativity. Even if people think art is only the personal expression of artists, it is still a form of visual communication and language that can reach a broad audience.

In her article "Art – A Serious Work," Carol Seefeldt says that children need many interesting experiences in classroom and community, and encouragement to think, talk, and create art in response to their experiences (1995). Visitors in an art museum, including children and their parents, also need interesting experiences as their sensory memories are involved with emotions and creativity to produce art. Personal experience serves as a main factor of art motivation (Clements & Wachowiak, 2010).

To communicate a basic understanding of the visual aspects of art, some fundamental elements and principles of art should be conveyed to learners when educators design educational art activities. It is difficult to learn about art without references to the visual aspects of art as people strive to express their feelings and ideas. These elements are line, shape, value, color, space, texture, and pattern. Principles are balance and symmetry, variety, repetition, emphasis, and domination-subordination. Learners are supposed to get basic experience about these

elements and principles and learn to use these professional vocabularies as a result of art education (Perble & Perble, 1994; Clements & Wachowiak, 2010).

One of the teacher's greatest challenges is to help students become aware of the color, structure, pattern, beauty, and variety in nature and daily life. A general tendency to promote motivation for artistic creation is to combine *recalled experience* and direct perception in nature and daily life. Recalled experience means impressive and interesting memories that the learner has had before and now recalls. Direct perception involves objects or events that are presented in front of one's eyes. Both methods supplement each other effectively. Exhibiting one's work is also motivating. In school, teachers sometimes put students' work on walls along hallways to encourage further motivation from students.

Students should be urged to draw and make art about what they have learned. They should also be urged to talk about art. It is important for teachers to conduct discussions of aesthetics. The most effective teaching strategy in leading discussions is to encourage students to question, which promotes critical thinking. Aesthetics focuses on the ideas behind the artwork and the beauty of the artwork shown through design and means while art criticism focuses on one artwork itself. Therefore aesthetics usually tracks back to the reason and meaning to create art, which is meaningful and inspiring for amateurs. Some examples of aesthetic topics and questions include:

- "Can a picture that looks like the artist just threw paint around be called good art?"
- "If someone gets a different idea or meaning than you intended from your picture, does that mean your art is not as good? Is it better if the person knows exactly what you wanted to say?"

- "Are artists born or made? Does art that looks as though little children made it mean that it is not good art? Do people with many years of education usually make better art than people with less education?" (Clements & Wachowiak, 2010)

Because human interaction is becoming more global and international, and thereby greatly influenced by diverse cultures, technology, politics, and immigration, art is now becoming influenced by multiculturalism much more than before.

> Multiculturalism, more than an attitude but less than a theory. It can mean a cultural pluralism in which the various ethnic groups collaborate and dialog with one another without having to sacrifice their particular identities and this is extremely desirable. But it can also mean the bankrupt concept of the melting pot with its familiar connotations of integration, homogenization and pasteurization. (Joo et al. 2011)

Art education under multicultural pluralism, especially in the United States, is changing from the mastery of a language to one of interpretation. Whether in an art museum or an elementary school class, learners come from various cultural backgrounds, which bring attention and respect onto art works from different cultures. Cultural democracy encourages art educators to think about art in perspectives such as race, gender, class, nation, and religion. As one of society's major institutions dealing with the transmission of culture, the museum in America plays a major role in determining what is considered art (Clements & Wachowiak, 2010). In this cultural democracy, learners belong to a culture of their own, with values specifically determined by their personal identity and history. The only conditions necessary for the creation of environmental learning are access to an equal space of learning where learners have confidence to speak their own understanding and to show their own creations. (Joo et al. 2011)

Technology can also be involved in art education. There are many diverse applications (games/online videos) claiming that they are aids for learning art. However, in discussing the notion of "networked equality," Omar Wasow, a leading technology theorist, talked about the downside of these aids. He thought some digital products were like junk food, which was not necessarily increasing critical thinking. Designers need to focus much more on how to produce high-quality educational software in order to allow digital products function like a tutor, which helps cultivate wisdom (Joo et al. 2011).

Electronic media, such as computers, smartphones and tablets, encourage the constructivist view of art education. Students construct their personal knowledge bases through active learning. Some digital educational programs not only support children's drawing and painting, but also integrate slide shows, QuickTime movies, and sound recording. Pictures created by children can be emailed to parents. Children can also post their artworks onto blog in order to receive feedbacks of peers. Research also shows that computer art can be taught to small groups of children because they can learn computer skills as effectively in small groups as they can individually. Therefore collaborative projects can be encouraged in art classes. This is a natural call from the development of technology. Art educators certainly should take advantage of technology to contribute to their own work (Clements & Wachowiak, 2010).

Art Museum Education

Art museum education is a melting pot of museum education and art education, where both fields meet and function in a mutual manner. Art museum education attempts to find a balance between these two fields and keep developing them as times change.

Art museum education and practice has been a dynamic field since the 1960s. Many museum education theories and art education theories have been tested in practice. However, the

field continues to change due to developments in of society, technology, politics, philosophy, and economics.

A visit to the art museum in 1960s was like “taking a dose of cultural medicine – it’s good for you but tasted bad going down.” At the time, educators were trained as art historians who had academic knowledge of art and teaching practice. They acted as lecturers who were models of authority and transmit expert information about the collections to the passive visitor (Mayer, 2005).

In the 1970s, educators started looking into educational psychology, the psychology of vision, and art learning through interactive techniques, which included concepts such as creative drama, creative writing, questioning strategies, looking games, storytelling, hands-on activities. (Sternberg, 1989) Art museum educators looked for ways to displace passive listening with interactive tours. In the late 1970s, Lee coined a phrase *visual literacy*, which suggested that aesthetic education should be the “primary task” of an art museum (1978). Based on this theory, educators began to use phrases such as “aesthetic awareness”, “appreciation”, “skill of looking”, and “know how to see” (Mayer, 2005).

In the 1980s, visual literacy and master teaching became popular in art museum education practice. Master teaching, developed by Philip Yenawine for use in museum education, takes visual literacy as a basic component. It indicates values of great teachers and their teaching skills. It actually enables learners to “get” a concept by providing related information, focuses, context of the artworks and the learner’s life. It started encouraging personal connections of visitors with artworks (Mayer, 2005).

"Interpretations are born when people make connections between what they see and what they know about art and life. Multiple interpretations, even contradictory ones, work together to illuminate a work." (Hubard, 2007)

In the 1990s, museums empowered visitors based on the ideas of educators who thought the function of museum was to serve people instead of objects. It was a strong statement and radical reform. However, it fit into larger societal development. Theories supporting this new concept are also called "postmodern art museum pedagogy". Danielle Rice identified this pedagogy as an interpretive dialogue between viewer, work of art and respective contexts (1995). Visitors may get personally significant experiences with museum objects this way. The center of meaning making had been moved to construction of visitors' own museum meanings. (Mayer, 2005)

Juliet Moore Tapia believes that there are three distinct categories that constitute modernist traditions in museum education. They are (1) Humanist Pragmatism, which includes institutes such as the Boston Museum of Fine Arts and the Metropolitan Museum of Art, which are "civilized" and "capitalist"; (2) Idealistic Inclusiveness, which describes institutes such as Newark Museum, which could be seen as an "Institute of visual instruction"; (3) Aesthetic Formalism, which includes institutes such as Cleveland Museum of Art, which holds that museum should help "the establishment of standards of truth and beauty" (Tapia, 2008).

On the other hand, diverse educational theories have been utilized in terms of different features of exhibits in these types of museums[1] based on the educational backgrounds of educators and curators. Some of them belong to postmodernist theories. As most museum

[1] These theories have informed the practice of a large number of museum educators and the research of education: Howard Gardner's theory of Multiple Intelligences, Abigail Housen & Phil Yenawine's Visual Thinking Strategies, Csikszentmihalyi's Flow or Psychology of optimal Experience, Piaget's Theory of Cognitive Development, and Vygotsky's Sociocultural Theory of Learning.

curators and educators today would claim that they are constructivists, constructivism and the "Contextual Model of Learning" by Falk and Dierking are becoming popular in interpreting this world through the perspective of museums. (Ebitz, 2008) Visitors come from different personal, sociocultural and physical contexts, which also means that they are real and constructive in interpretation. Curators, educators, and visitors together construct museum worlds. Through the integration of curators' intention and information, educators' knowledge and strategy and visitor's contexts, meanings of artworks get fulfilled. The process of construction generates an impressive experience for visitors.

Human-Computer Interaction Design

Nowadays, people are surrounded with a variety of digital media that require interactions between human and computer. Interactive media has become one of the main methods of receiving information. Because museums function as *information utility*, it is the author's belief that an increased use of interactive media will empower visitors and enrich the visitor experience, and museums will keep attracting people to come back by offering information in an appealing way. Therefore, principles and practices for human computer interaction need to be explored in order to develop better design solutions for museum interactivity.

User Interface Design

In speaking about the human-computer interface and user interface design, Bill Buxton says, "this has always been about where the human and the computer meet" (2007). Interface design takes as its responsibility to make communication and interaction between human and computer easier to use and understand. Interactions become enjoyable and smooth when good user interface design does its job. There are several versions of golden rules of interface design

in professional world. The most famous is from Ben Shneiderman's "Eight Golden Rules of Interface Design", which are insightful, easy to grasp, and practical to use:

1. Strive for consistency
2. Cater to universal usability
3. Offer informative feedback
4. Design dialogs to yield closure
5. Prevent errors
6. Permit easy reversal of actions
7. Support internal locus of control
8. Reduce short term memory

(Shneiderman, 2003)

When users try to work with a computer screen, they are expecting an easy and smooth experience that cares about each move they make and each option the interface presents in the right place. Suzanne Watzman (2008) has commented on the importance of visual design:

> Good visual design is the tangible representation of product goals. It is concerned with the 'look', the method, and the style in which the information is presented. It should be the result of a thoughtful, well-considered process, not merely a decorative afterthought." A well-designed interface should be able to motivate users, increase ease of use and accessibility, increase the accuracy and retention of information, and focus on needs of its users. (Watzman, 2008)

According to work flow now common in the professional field, several steps help designers to create a usable interface. These steps have been described in a variety of ways, with differences originating from different perspectives of design and details of motivating projects,

but they are still fundamentally similar.[1] Generally, four steps are necessary to make a successful design. First, designers need to research their target audiences (users) and working context by asking questions such as: "who are our users? When will they use this product? How can the design most efficiently and effectively present information required for ease-of-use of this product?" Second, designers need to brainstorm ideas and design the product according to previous research about users and contexts. Thirdly, designers and programmers must work together to build prototypes for usability testing and then test these prototypes, because the design becomes more refined as ideas are tested and evaluated. Finally, the product needs to be implemented and monitored in order to re-evaluate and re-design it. This process is a continuous cycle, in which steps can happen simultaneously and be repeated based on needs (Figure 1).

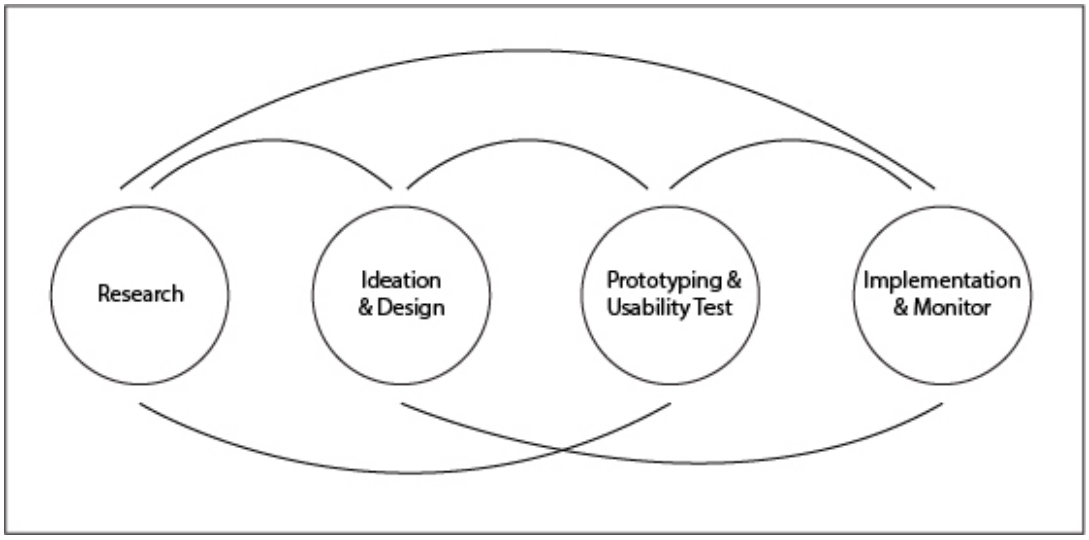


Figure 1. **Interface design working flow. Concluded and created by author.**

Universal principles of visual communication and organization of interface design include harmony, balance, and simplicity. In order to achieve these requirements, design elements (such as typography, layout, grid structure, graphics, icons and colors) work together dynamically to construct an effective and enjoyable user experience. Designers also need to take

[1] These versions can be found in book *The Human-Computer Interaction Handbook* 2nd edition, Lawrence Erlbaum Associates, New York, NY, 2008

physical, emotional, and cultural context into consideration when designing a new interface. Designers need to ask questions such as “with what medium will this interface be presented? In which circumstance will this interface be placed? In which culture will this interface be used?” Consistent, appropriate, and familiar visual language that takes less short memory and leverages existing knowledge makes navigation much easier. “The simplest, most redefined design is direct and includes only the essential elements” (Watzman, 2008).

Although simplicity is a critical feature of interface design, Donald Norman thinks that what we want is not a “simple design” but a “good design,” which tames “complexity” successfully, because our world is overwhelmed by chaos. He writes:

> The whole point of human-centered design is to tame complexity, to turn what would appear to be a complicated tool into one that fits the task, one that is understandable, usable, enjoyable (2011).

However, interaction design varies according to different user groups. For example, interface design for children is very different from design for the elderly. One way of conceptualizing different types of design for different ages of children is through Jean Piaget’s division of children’s development (Piaget, 1970). She described four stages: sensorimotor (birth-2 years), preoperational (ages 2-7), concrete operational (ages 7-11), and formal operational (age 11 and up). For children in the sensorimotor and preoperational stages, interaction is dominated by non-textual contents, such as illustrations, animations, and audio. Children in concrete operational stage can read words at appropriate reading levels. Development for children in the formal operational stage is more similar to that for an adult. Children would be more likely working with familiar metaphors and gestures, especially in a walk-up-and-use situation. Smooth interactions trigger their interests to dig deeper into the

contents. Children would like to work with more than one person at a single computer. Multiple input devices increase their productivity and satisfaction. Furthermore, technology for children can be divided into two genres: education and entertainment. Most of the time, designers try to mix these two genres to attract use of children and parents, which is called “edutainment”. As digital instruction tools come out, the learner-centered method is becoming popular in the human-computer interaction field and instructional design field. Leaner-centered design is based on several steps, including needs analysis, pedagogy, media and technology, prototype, formative evaluation, iterative design, and summative evaluation (Bruckman & Bandlow, 2008). This process is also very close to the design process of instructional design of E-learning (Morrison et al., 2007).

Multi-Touch Interface Design

As multi-touch systems become popular and useful in modern society, the mouse is joined by the finger as an input device for pointing and clicking tasks. However, using fingers to touch is more powerful than using a mouse in certain situations due to its direct gestural application on screen, such as pinch and rotate. Multi-touch technologies have a long history. Bill Buxton’s group at the University of Toronto was working on multi-touch in 1984, and their work was not the first in the field (Buxton, 2012). However, multi-touch systems didn’t attract much attention in daily life among public until Apple released the iPhone in 2007. The iPhone earns praise and admiration through its very smooth interaction and outstanding industrial design. After the iPhone, multi-touch devices have largely increased popularity in daily life. Multi-touch systems become a major way to interact with digital devices today.

For more than 20 years, several design concepts have been explored, researched and applied by interface designers, interactive engineers and academic researchers. Graphical User

Interface (GUI), which allows users to interact with electronic devices through graphical icons and visual indicators, is fundamental for other concepts. Natural User Interface (NUI), Tangible User Interface (TUI) and Gestural Interface (GI) have appeared with technological development and increasing needs of multi-touch system. All of these areas share many common features, but each focuses on different aspects of interactivity. NUI emphasizes “walk-up-and-use” features to simplify and smooth interactions (Wigdor & Wixon, 2011). TUI puts more efforts on tangible sense while a person interacts with digital information through the physical environment (Antle et al., 2009). GI focuses on use of gestures, which is widely used in motion-aware games such as Wii and Microsoft’s Kinect (Roccetti et al., 2011).

Many basic guidelines from famous researchers of human-computer interaction help modify interface design. Even Donald Norman and Jakob Nielsen suggest

> “several fundamental principles of interaction design that are completely independent of technology: (1) Visibility; (2) Feedback; (3) Consistency (also known as standards); (4) Non-destructive operations (hence the importance of undo); (5) Discoverability: all operations can be discovered by systematic exploration of menus; (6) Scalability: the operation should work on all screen sizes, small and large; (7) Reliability: operations should work. Period. And events should not happen randomly.” (2010)

There is not yet an agreed-upon, unified multi-touch user-interface language (Derboven et al., 2012) because multi-touch systems have been applied to diverse devices and contexts. Different sizes of screen, locations, orientations and gestures result in different treatments of interface design and ways of interaction (Buxton, 2012). For example, the use of an iPhone is much different from that of a large-scale tabletop kiosk. The interactive space of an iPhone is limited, which restricts the ability to display large visual subjects, while the tabletop device

allows showing subjects in great detail. Also, an iPhone normally only allows one user to interact with compared to the tabletop device that enables collaboration of multi-users. However, an iPhone is small enough to be taken with users anywhere, while a tabletop device has to be be installed in a fixed position. A research group has explored interfaces and applications for combining mobile multi-touch input with large-scale visualization displays (Keefe et al., 2012). However, researchers in this case only used mobile multi-touch input to control data on large-scale displays. There are no direct interactions through gestures happening on large-scale displays in this case.

NUI was created by the research team of Microsoft Surface during their work for Surface research and development. NUI is similar to GUI, but it has some different features. The first evolution for interface design was from the Command Line Interface (CLI)[1] to GUI. GUI freed users by using metaphors to enable interaction, such as Microsoft Windows. It relies on a known set of user interface elements, commonly referred to as WIMP: windows, icons, menus, and pointers, which significantly lowered the barrier for users to operate a computer system compared to a command line interface (Figure 2).

[1] Command Line Interface (CLI) is a means of interacting with a computer program where the user issues commands to the program in the form of successive lines of text (command lines).

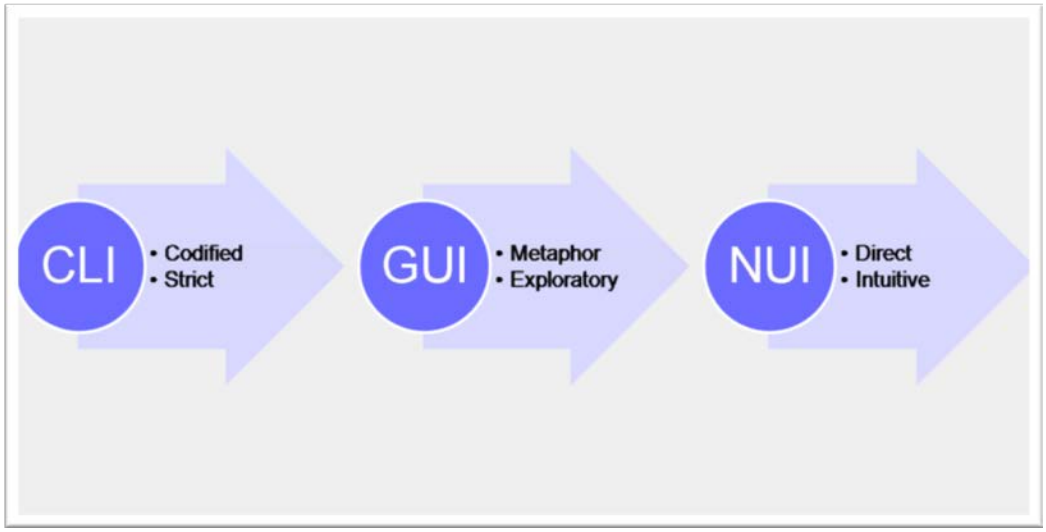


Figure 2. **Evolution of user interface. Created by August de los Reyes.**

NUI still relies on graphical user interface for interaction, but changes the concept from WIMP to Natural User Interface, which evokes feelings in users. The product must mirror users' capabilities, meet their needs, take full advantage of their capacities and fit their task and context demands. NUI cares how users feel while using a product (Figure 2) (Wigdor & Wixon, 2011).

NUI refers to a user interface that is effectively invisible with successive learned interactions, and is based on *nature* or *natural* elements. The *natural* refers to the way what users do and how users feel while they are using it. A NUI requires learning. It relies on a user being able to quickly transition from novice to expert. The learning is eased through design, which gives the user the feeling that they are instantly and continuously successful. This process is especially useful in walk-up-and-use contexts, such as museums, retail stores, and information centers. Thus, *natural* also refers to a goal that is to build a user experience that is natural to users, rather than mimicking the real world. While designing Natural User Interface, designers should avoid NUI becoming a GUI with touch by simply replacing the mouse with fingers.

NUI has great potential in public use due to its social aspect. Many modern NUIs are designed for multi-person input, allowing multiple users to gather around the display and interact

with it. In this way, they can elevate the activity from a solitary experience to a social experience. For a “social interface,” the more communication that happens between the people around the interface, the better. Designers can use cooperative techniques from video games, which are “shoulder to shoulder,” where people play side by side, or mediated in space or time or both, to make other NUI applications more engaging, fun, and social (Wigdor & Wixon, 2011).

A critical element of social computing is considering the issue of inter-user task coupling. There are three distinctive levels: highly coupled tasks, where users help each other accomplish the same task; lightly coupled tasks, where two users try to achieve a result that depends on them both, but they are engaged in different tasks to achieve it; and uncoupled tasks, where users share the same spaces, but they are engaged in separate tasks. Multiple users who are working around a multi-user device might be engaged in multiple levels of task coupling.

When designing for NUI, the design should follow a long list of design guidelines especially for interaction. For example, any item that responds to users’ touch must be at least 15mm in size in all directions, and there must be at least 5mm between minimally sized touch targets. Interface control elements should not be presented if they are not needed. Users focus on content and so should the interface. Designers may provide minimal number of interface elements that are required for the interaction (Wigdor & Wixon, 2011).

Multi-touch Tabletop Research and Design

Large-scale tabletop devices have shown its great potential in public use, especially on interactivity and collaboration, since Diamond Touch (Buxton, 2012; Dietz & Leigh, 2001) and SmartSkin (Buxton, 2012) were released. Large-scale tabletop technology and design have been greatly developed for more than 10 years. Abundant research and applications in this topic have made the technology mature and capable enough to use. Nowadays, we would be able to easily

find and use multi-touch tabletop devices in locations such as airports, information centers, retail stores, and museums. The user's previous and rich experience with touch screen makes interaction through tabletop devices much easier and smoother.

Large-scale tabletop devices are becoming popular because they not only allow larger amounts of information to be displayed and interacted but they also encourage social interaction and collaboration among users. Research about the effects of group size and table size (Ryall et al., 2004) has been conducted to reveal its rational relationship between the two factors. Apparently, a larger tabletop surface would allow for each person to have some personal/private space of his/her own. While designing interface for such a large surface, resource management, physical reach, and visibility should be considered and planned carefully, otherwise users cannot interact with the interface effectively because something is out of arm's length or eyesight. The size of the interactive tabletop does not affect the speed of task completion, but the group size does. Different group sizes lead to different work strategies and labor division in achieving the same collaborative goal. Distribution of resources strongly influences how people work together for different group sizes.

Because we sometimes see vertical interactive displays in commercial environment, then researchers have investigated which physical orientation of interactive display is the best in achieving collaborative goals, especially for purpose of learning. One related research effort has investigated how and why standing around a vertical interactive display affects collaborative activities differently from sitting around a horizontal interactive display (Rogers & Lindley, 2004). The key finding from this study was that situating a large interactive display as a horizontal surface in a workplace encouraged group members to work around it in a socially cohesive and conducive way because horizontal surface indicates a round-table meeting where

people work and share equally, while vertical surface creates a lecturing and dominating atmosphere.

A direct touch table-top information kiosk that allows multiple users to interact with it is a successful example to raise efficiency level of usability by encouraging users to share the same space and interact with each other while accomplishing tasks. This kiosk is installed at an information center of a university in Turkey. It is called a “Lazy Susan Table” by this research team because it shares similar features with the lazy Susan device that spins to accommodate different users. The interface of “Lazy Susan Table” is well designed as a combination of lightly coupled tasks and uncoupled tasks, which allows users to work individually in their own space. All shared objects are allocated so any user can easily reach them. The menu of first level of information is located in the center of screen. When necessary, the object was duplicated on different sides of the display (Figure 3). By creating two similar instances of the common information menu, it becomes easily accessible by users on all sides of the table. Other than single touch with one figure, two kinds of gestures need to be used in order to interact with this interface. One is a “drag and drop” operation, which works on first level of information. The other one is “touch and rotate” action, which works on second level of information. The usability test of the “Lazy Susan Table” suggests that even if four users interacted with this interface simultaneously, there were few conflicts. Cooperation is optional, but can enhance user performance in this case (Berkman et al., 2012).

Figure 3. "Lazy susan table" menu.

Because research has shown that the large-scale tabletop device works well for collaboration, further research has focused on the learning experience with this setup. “Futura,” which was tested at a 2010 Winter Olympics Celebration Site, was designed for users to improve their understanding of the importance and difficulty of achieving sustainable development through a simulated land use activity (Antle et al., 2011). The research team used four theoretical perspectives to conceptualize the design intentions and inform analysis: experiential learning[1], constructivist learning, collaborative learning, and game theory. The game was designed as a highly coupled task, which needed intense collaboration among users. The whole interface design is in a cartoonish graphical manner, which uses characters, illustration, and simple animation to simulate a microworld (Figure 4). Control bars are located on three sides of table. The fourth side shows game status (Figure 5). The testing environment was partly controlled by

[1] Learning by Doing from John Dewey.

researchers so that users may follow a certain order to participate into games. People tended to work together, especially in groups composed of parents and children. Resources were often shared and discussed by two or more users. Parents tended to support their children by helping them to interact with interface. People learn though experiencing the complexity and difficulty of balancing environmental and human needs in sustainable development. Group work also facilitates people to learn from each other. Their interactions construct the learning experience.

Figure 4. Futura interactive multi-touch tabletop.

Figure 5. Futura user interface.

Related research also suggested that simulated interactive interface greatly improved performance of tasks especially among children, which is described by Wigdor and Wixon as *seamless experience*. “One way to suspend disbelief and encourage fluid action is by mimicking real-world objects and using virtual-world capabilities to extend the objects beyond what is

possible in the real world" (2011). One team used digital cards as the basic interactive element for educative information because researchers consider that digital cards (Figure 6) could be directly manipulated by users (in this case, students), such as actions of pairing, grouping, linking and combining (George et al., 2011). Students learned very quickly about how to use this tabletop with multiple fingers or hands.

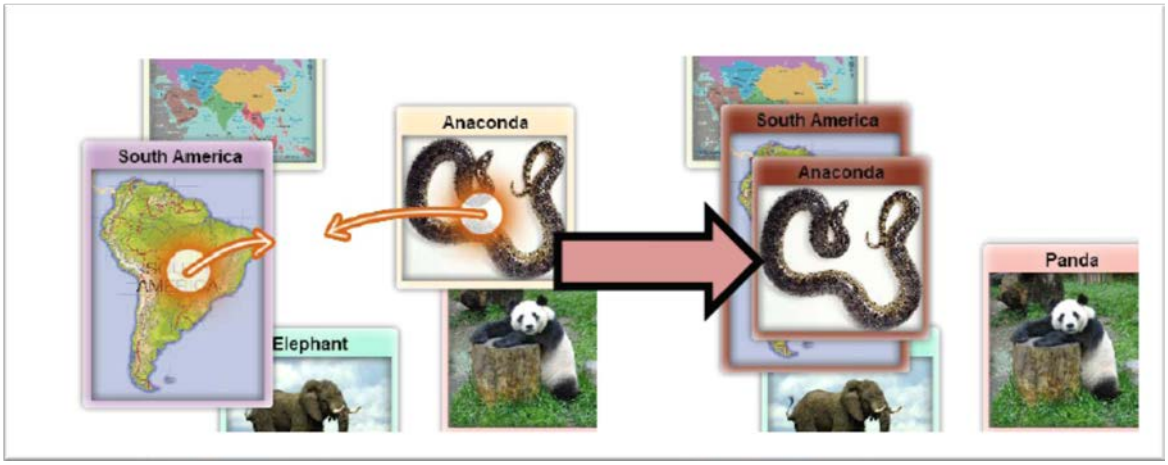


Figure 6. Seamless experience – card game on a multi-touch tabletop.

Another team used a digital puzzle game as the basic element to compare mouse-based and tangible-based interaction with children (Antle et al., 2009). In order to compare mouse-based and tangible input styles, the team invited school-aged children to solve puzzles using three input methods and associated interface styles: traditional cardboard puzzle, mouse-based GUI puzzle and TUI tabletop puzzle. After developing and testing the game, the team found significant differences between traditional and tangible styles of input. Children solved the tangible input style of puzzles faster and more successfully than the Mouse-GUI puzzle. Children spent more time actively interacting with the tangible input style of interface and people around. Tangible experience makes learning and problem-solving easier than indirect experience.

Most research of large-scale multi-touch devices have been tested and evaluated in lab settings. Two research teams, however, turned their eyesight from lab settings to real world for

exploring reactions and performance of users in the real public context. For their in-the-wild study of the "TouristPlanner" (Figure 7), Marshall and his teammates observed and analyzed how people reacted to a touring planner on a Microsoft Surface table at an information center in Cambridge, UK (Marshall et al., 2011). This research shows that people approaching the tabletop brought a history of interacting with other kinds of interface, which influence people's initial exploration. Different types of groups would interact with the tabletop in different ways, especially between single user, families and several strangers (Figure 8). Children in particular loved to explore the interface, which in turn attracted parents. Strangers or other groups were more likely bystanders and observers. The research shows that it was common for strangers to attempt to use the application at the same time, yet on most occasions, people who used the tabletop simultaneously were members of the same group friends or family. The research shows the benefit of NUI (Wigdor & Wixon, 2011) for supporting walk-up-and-use tabletops. It also shows the importance of appearance to the interface design in a walk-up-and-use context. "To enable potential users to make their mind up whether they might like to use the application, designers need to grab their attention immediately to communicate its purpose and mechanisms of interaction" (Marshall et al., 2011).

Figure 7. Interface of "TouristPlanner".

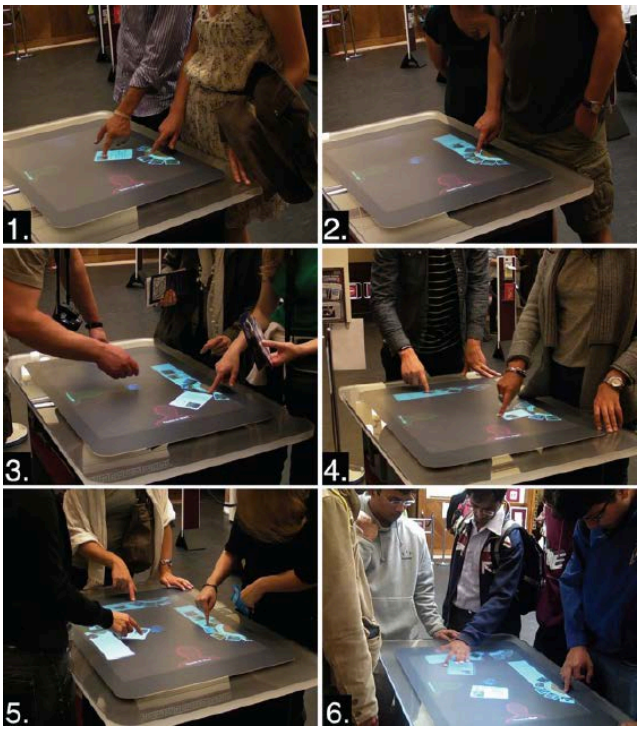


Figure 8. People stand around and interact with "TouristPlanner".

Tensions and conflicts between strangers were seen both in "TouristPlanner" and in the "CityWall" project, which was designed to primarily support parallel use (Figure 9) by a research team in Helsinki, Finland (Peltonen et al., 2008). The research shows that people sometimes interfere with the activity of another while using the same interactive space. In the "CityWall" project, people showing up in pairs is most common. Individuals and groups of three were seen more rarely. Groups larger than three very rarely stopped at the display.

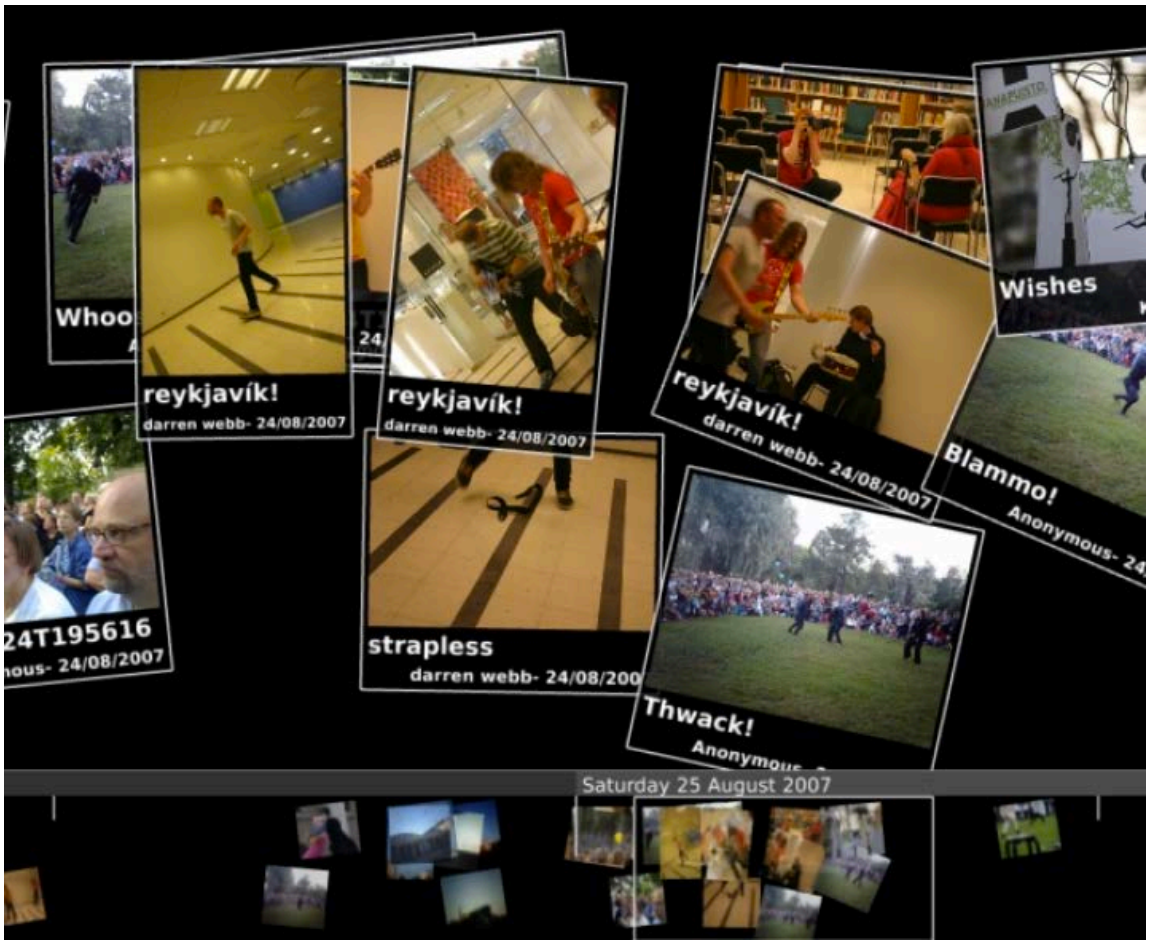


Figure 9. **Interface of "CityWall".**

However, problems can arise when designers don't consider the relationship among users, contents, interfaces, and contexts very carefully. The "Tree of Life" table (Figure 10) in the Berlin Museum of Natural History was popular among visitors when the museum re-opened in 2007 because of its advanced technology (Hornecker & Keynes, 2008). Visitors were interested in the display even if they could not understand its story. From the observations and data collected by the research team, Hornecker and his teammates found that the table was relatively easy to use but did not tend to hold visitors' attention.

Figure 10. Visitors interacting with "Tree of Life."

While the table is very aesthetically designed and seems easy to use at first glance, close analysis revealed noticeable glitches in interaction that required visitors to invest effort into learning how to "work the interface." This distracts from the content and leads to short holding time. Designers of the table used circles to reveal information and trigger animation. Because interface items that look similar are assumed to behave similarly, these circles sometimes misled visitors when mixed reactive and nonreactive circles appeared on the interface simultaneously. Another problem with this table was lack of educative levels. Visitors lost interests on it very quickly after simply scanning information because two levels of information are the only content that the table offers. There is no depth in content and interaction for visitors to dig into. Visitor studies have shown that families in museums share information and discuss what they are looking at. Parents engage in educational conversations with children on certain topics (Falk & Dierking, 2002). To enable visitors to move into deep engagement while getting something out of an interaction, multiple layers of activity are necessary. One program in the context of the museum should allow for playful engagement with topics and different levels of access, which

keeps children engaged while adults can read. “Exhibits should support family interaction and provide space for parents to explain and mediate children’s attention” (Hornecker & Keynes, 2008).

Summary

This chapter attempts to document theories and research of museum interactivity, museum education and interface design, as well as the trend of multi-touch tabletop application in the public space. Literature reveals that interactivity is one of the most important design tools that attract visitors to step into museums. A combination of ordinary displays of objects and images with creative interactions provides an effective method for designers and museum experts to make the visitor experience more dynamic and impressive. It also helps visitors transmit knowledge that they learn in museums into daily life, which is an important measurement for the success of museum education. Usually, visitors who visit museums are composed of families with children and teenagers. Large museums also attract travelers who are visiting the city. They all come with personal contexts and expectations, so that museum curators and designers utilize constructivist theories from education to construct exhibits and visitor experiences that can be adapted by the visitor. Museum curators and designers treat visitors as participants in the meaning-making process; this means that interpretations and contributions from the visitor have been anticipated within the story that the exhibit attempts to tell. Interactivity provides more possibilities for visitors to participate in exhibits physically and mentally.

The literature also suggests that multi-touch tabletop applications have great potential in future use. Compared with the mature practical value of small-scale multi-touch devices, such as smart phones and tablets, applications of large-scale multi-touch technology still need more research and experimentation. In general, tabletop applications work effectively in a public

space, especially in the context of the museum. They attract visitors' attention and engage them to spend more time on content, which is the goal of the museum staff who are teaching information through exhibits. Based on the need to create immersive visitor experience, science and natural history museums have made impressive efforts into developing digital interactives, including multi-touch tabletop applications. These applications also enable collaboration of multiple users, which increases social interaction among visitors in a group.

However, the interactivity in art museums is so limited that visitors might be losing their interests in visiting art museums, and even appreciating art. As the places that collect, preserve, and present artworks, art museums are functioning very well. However, as educative and informative centers, art museums are becoming high culture institutions. Art museums' collections might be a significant reason for this situation. For instance, modern art and contemporary art are usually very difficult for visitors to interpret, especially if they lack an art history and education background. The public thinks art museums seem far away from their daily life because art collections appear difficult to understand. This impression is disadvantageous for the development of art and the promotion of art museums. Furthermore, art museums mainly emphasize visual interpretation of their artworks and ignore the wide range hands-on activities that art could encourage. Because the success of museum education in part measured by the visitiors' ability to use information gained in the museum in other settings, the use of interactive displays can help museums achieve their goals. Because of its success in other public spaces, it is likleyy that the of multi-touch tabletop applications in terms of its success in other public spaces.

Because digital interactives have been shown to work well with exhibits in other museums, art museums have also started following this trend. Diverse apps on smart phones and tablets have become popular in art museums, and attempt to build museums without walls. These

apps have limitations although they function effectively. They remain limited to a passive cataloging of artworks, and are based on data rather than exploration. So they are usually too personal to share. The screen size is also too small to interact with. Compared to science museums and natural history museums, art museums have not fully taken advantages of the benefit of the multi-touch tabletop application. The tabletop application has great potential to change passive visitor experience into an active one, especially for families and school groups. Through content and interactions, the museum staff would have a dynamic channel to deliver diverse themes with multimedia, including audio, video, animation, game, social media, and even digital drawing programs. They could also guide visitors to make deep interpretations so visitors could have immersive experience from the exhibit's contents.

CHAPTER 3: METHODOLOGY

Introduction

Based on the advantages of immersive interactions, a conceptual prototype that incorporates museum interactivity, museum education, art education and multi-touch interactive design has been developed. It is titled *What Inspires You?* The interaction attempts to build a bridge between daily life and personal experience by engaging visitors to learn how inspirations affect the process of art creation. This prototype provides a potential approach to make up for a lack of interactivity in art museums by using a large-scale multi-touch tabletop as the channel. It triggers communication between art museums and visitors in order to make the visitor experience meaningful and individualized.

Prototyping is a valid methodology widely used in many design fields, such as exhibition design, museum design and interactive design. To design an effective prototype, extensive field observations on museum digital interactives around the United States were conducted. Case studies have been documented and analyzed, then used as references during the prototype ideation stage and the design process.

Usability test was not included in this study. Therefore, assessments of its effectiveness with regard to usability were not measured. Two tables of criteria were summarized from the literature and used as checklists to define the conceptual functions of the prototype.

Field Observations

The museum world has attempted to involve multi-touch technology into their exhibits in order to engage visitors physically and mentally. In this section, a series of existing multi-touch interactives are documented and analyzed. Most of these interactives are developed by science museums and natural history museums because they usually have more freedom to incorporate

objects and contents into interactive programs regarding themes of exhibits compared to art museums. They also have achieved some success, according to reactions from visitors. The interactives from art museums, although much more limited, are also introduced in this section.

Field Observations at Science Museums

"Create a Tornado"

"Create a Tornado" is one of a series of multi-touch tabletop interactives in the Museum of Science and Industry in Chicago (Figure 11, Figure 12, Figure 13, and Figure 14). It teaches visitors how to generate a tornado under certain weather conditions. Size of this kiosk is about 30 inches long and 20 inches wide. It allows one to two persons to stand in front of it and share information simultaneously, in which one visitor is the main player while the other participates as an assistant who make suggestions and comments (Figure 11). Once the visitor touches the screen, a female narrator shows up and introduces basic knowledge of tornado (Figure 12). Then the visitor starts generating a tornado on the screen by controlling three panels: upper/lower air temperature, upper/lower air speed and upper/lower air moisture (Figure 13). If the three panels work well together, a tornado will be generated successfully (Figure 14), vice versa. This interactive tabletop has simple and clear interface with arrows, symbols and indicative colors, which represents orientations and temperatures. It is so easy to operate and understand that it attracts a large number of visitors to explore knowledge of tornado in an immersive exhibit environment with other scientific interactives around. It also encourages social interaction among visitors who share their interactive experience while engaging in this application.

Figure 11. Welcoming screen of "Create a Tornado."

Figure 12. A female narrator explaining the basic science behind tornadoes in "Create a Tornado."

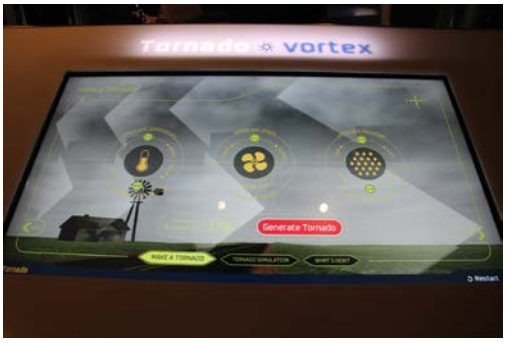


Figure 13. Interface of the control panels in "Create a Tornado."

Figure 14. "Create a Tornado" panels working together to generate a tornado.

"Electromagnetic Spectrum"

"Electromagnetic Spectrum" is another multi-touch tabletop interactive in the Museum of Science and Industry (Figure 15,Figure 16, Figure 17, and Figure 18). It is a long horizontal tabletop display, which allows many users to interact with simultaneously (Figure 15). The interface design focuses on content, which is to present what an object looks like under different electromagnetic spectrums (Figure 16). This long touch screen surface has been divided into eight categories with labels and info on both long sides (Figure 17). Some folder-like cards are randomly placed in the space. Visitors are able to move them from one end to the other by simply dragging and rotating them around with fingers (Figure 18). Icons are located on the lower right corner of each card to offer more information. Menus are brought to visitors by clicking on either side of each category. The interactive experience costs minimal learning time and efforts for each visitor. It also encourages conversations among a group of visitors about content and experience. However, it doesn't attract visitors to dig into in-depth knowledge of each category. Visitors mainly focus on browsing what every object looks like under different spectrums instead of exploring more background information.

Figure 15. A long, horizontal tabletop for user interaction in " Electromagnetic Spectrum."

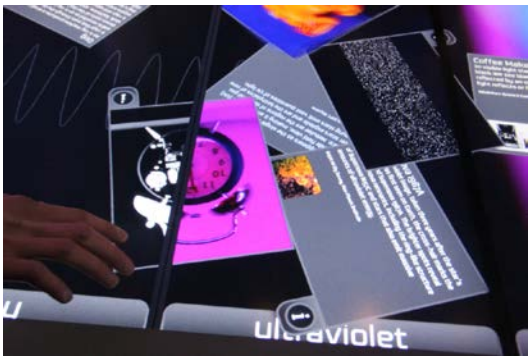


Figure 16. Appearance changes under different EM spectra in "Electromagnetic Spectrum."

Figure 17. Both sides of the "Electromagnetic Spectrum" display provide users with information.

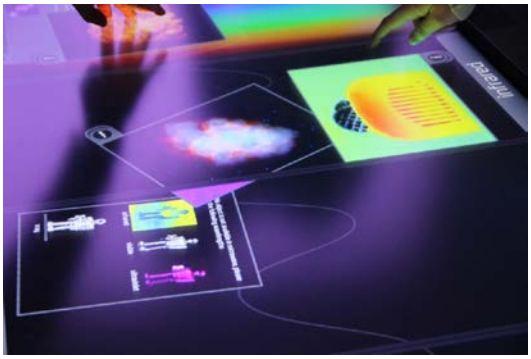


Figure 18. Visitors interact with "Electromagnetic Spectrum" by dragging and rotating cards.

<u>“Academy Lab”</u>

“Academy Lab” is a vertical touch screen display installed on a wall outside of an exhibiting lab in California Academy of Science, San Francisco (Figure 19, Figure 20, Figure 21, and Figure 22). It provides background information about projects that the lab is involved with.

By navigating through this application, the visitor gets to know where and why scientists go to conduct researches, what they are working on, and how they use this lab (Figure 19). The main content is conveyed through a large number of pictures, videos and a small quantity of articles (Figure 20). Each scientist and their research area becomes a category, which not only makes navigation clear but also promotes scientists and projects from this institute. Visitors are able to navigate through all sections and categories easily through its well-designed interface. The graphical treatment includes flat rectangles that work with a simple grid, and changing colors that are noticeable enough to highlight activated buttons (Figure 21). This application tells impressive stories of dedicated scientists and their work from this lab by engaging visitors to connect this application and the real lab that is right behind through locations and contents (Figure 22).

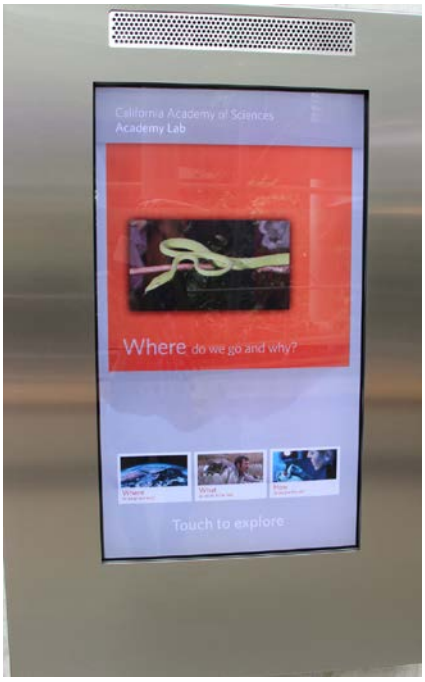


Figure 19. Welcoming screen for "Academy Lab."

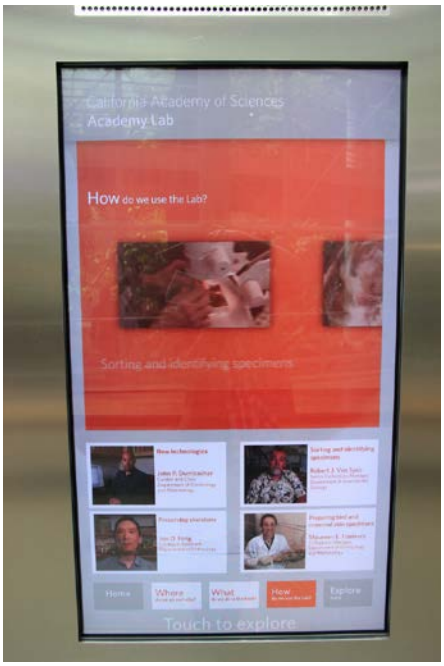


Figure 20. The interface of a subsection of "Academy Lab."

Figure 21. Video screenshot of "Academy Lab" with an activated button.

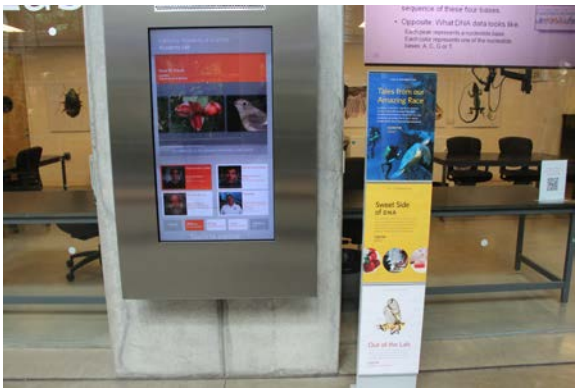


Figure 22. The "Academy Lab" display in front of the real lab the installation describes.

Field Observations at Natural History Museums

Interactive Kiosk for Fish Species

When curators and designers attempt to display an array of fish based on different species, it is hard to label each of them in appropriate heights and sizes for visitors to read. This interactive kiosk, which serves visitors in the American Museum of Natural History of New York, solves this problem wisely (Figure 23, Figure 24, Figure 25, and Figure 26). It gives curators and designers enough freedom to arrange locations of fish based on species by providing a simulation of the large wall diagram (Figure 23) on the screen (Figure 24). Visitors are able to both enjoy the massive and immersive display of diverse fish on a big wall and look into each one of them through touching a screen in front of the display to get rich background information (Figure 25). This is a successful example of an exhibit that incorporates physical display and digital interactivity seamlessly. Visitors find the combination surprisingly useful and interesting. However, the screen size is too small to show necessary details (Figure 26). For example, some fish on the screen are so small that they are difficult to be touched by a finger. Lengthy text on a single screen also exhausts visitors' eyes and reduces their interests in content, because visitors usually don't like reading much during visit.

Figure 23. The large wall diagram of the exhibit.

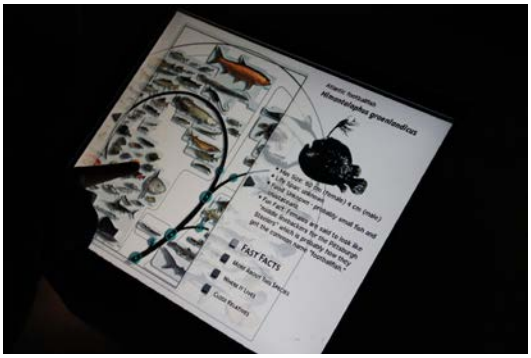


Figure 24. Simulated display on screen.

Figure 25. A visitor interacting with the program.

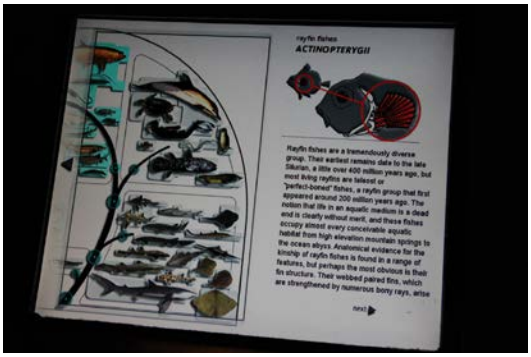


Figure 26. Screenshot highlighting the problematic small interface of the program.

Video Game for Ancient Hunting Life

This video game functions as a part of an exhibit that shows ancient life of Central America from a perspective of anthropology in the Field Museum of Chicago (Figure 27 and Figure 28). Every aspect of the ancient life has been presented to visitors through diverse approaches of exhibition design. This game takes over the function of showing what a hunter's work was like in ancient Central America. Visitors, especially children, are fascinated with this game because they are challenged to keep a certain amount of food supply through hunting and herding (Figure 27). They are supposed to play the role of a hunter and experience ancient ways of agriculture in a simulated computing context (Figure 28). This game utilizes existing gaming methods to set up tasks, which tends to defeat novice players a couple of times before they achieve success. After these failures, some players might lose interests and confidence in this process and finally give up. They can still get some impressions about hunting life in ancient Central America. In addition to the small size of the interactive screen, the task of the game is so challenging that it requires only one player to concentrate on the content, which fails to encourage social interactions among visitors most of time.

Figure 27. A visitor interacting with the game.

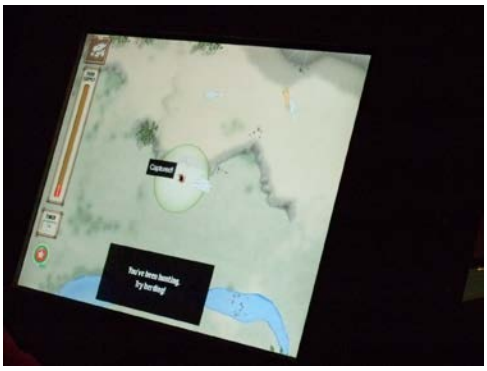


Figure 28. A screenshot of the game.

Early Human Study

This interactive application is installed in an exhibit of early human study (figure 29) in the National Museum of Natural History, Washington DC (Figure 29, Figure 30, Figure 31, and Figure 32). It reveals inner connections and changes among skulls of early humans (Figure 30), human species and family trees (Figure 31). To interact with it, visitors only need to touch buttons on scrollbars from left to right or top to bottom. Visitors are able to see differences among skulls and three hypotheses of family trees over time (Figure 32). Since the interaction is simple, it is easy for visitors to understand the content through visual images and simple animations. However, the content and the interaction are too shallow to explore. Visitors lose interest quickly after browsing each category. This interaction, to some extent, is still playing the role of a dominant lecturer, which is out-of-date in museum education because the passive interaction doesn't empower visitors to have their own choices.

Figure 29. Display of early human skulls from the exhibit.

Figure 30. Interface of the first category.

Figure 31. Interface of the third category.

Figure 32. Movement of portraits along button moves.

Field Observation at Art Museums

<u>"Who Were The Karoliks?"</u>

"Who were the Karoliks?" is an old touch screen tabletop application developed for Boston Fine Arts Museum (Figure 33, Figure 34, Figure 35, and Figure 36). The content includes two sections (Figure 33): Karoliks art collections (Figure 34) and family members of Karoliks who contributed to Boston Fine Arts Museum as curators and collectors (Figure 35). It is

installed in a box-like kiosk with a small screen of a desktop computer, which only allows one person to interact with it. The main function of this kiosk is to present images and provide information with a small quantity of texts, so the visitor would not feel tired while reading them. Content of this application, including a large amount of images, relevant texts and video interview with one of Karoliks, deliver rich and diverse information (Figure 36). The interactive experience also empowers visitors through easy navigation and clear information architecture. However, the interface looks old-fashioned and dull, probably because it was designed years ago. It is not attractive enough for visitors who walk by to stay and explore during their visit in an art museum where they are surrounded by more attractive aesthetic pieces. The size of the touch screen is too small to interact as a group, which fails to provide opportunities of generating social interaction among a group. Furthermore, the application is only capable for providing background information, which gives passive experiences to visitors. The visitor is not allowed to contribute any creative input or open-ended answer to this application, which weakens the learning experience.

Figure 33. A two-section interface.

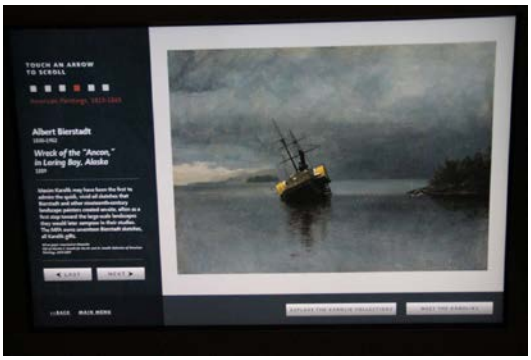


Figure 34. Interface for the art collection.

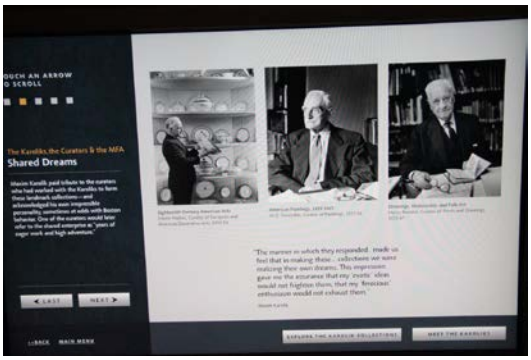


Figure 35. Interface showing Karoliks family members.

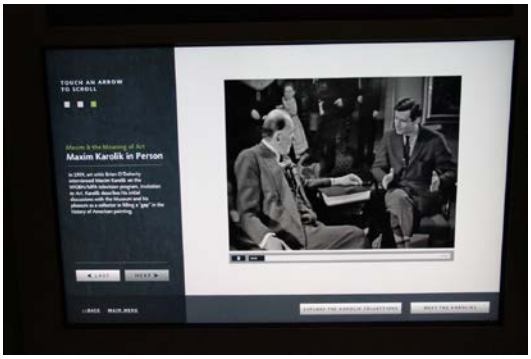


Figure 36. Embedded video.

Digital Portfolio of Japanese Paintings

The digital portfolio of Japanese paintings is operated on iPads in the Japanese art section of the Metropolitan Museum of Art, New York (Figure 37 and Figure 38). It is installed in a resting area where the interior environment is designed in a traditional Japanese style. The portfolio shows a series of artworks from a Japanese painter with images in high quality. The interaction follows basic gestures that an iPad usually employs, such as swipe, pinch and flick,

with which visitors has been very familiar nowadays (Figure 37). This portfolio fails to sustain interests of visitors because it only contains several paintings. There is no other level for visitors to look into. The function of this portfolio is basically the same as what art museums are normally doing in their exhibits, which is displaying collections, even though the digital portfolio on an iPad is showing additional pieces not on display (Figure 38). Moreover, images showed from the portfolio are not authentic compared to original pieces in ordinary exhibits; visitors want to experience authenticity during their visit. There is no significant breakthrough embedded into this digital portfolio regarding visitor experience.

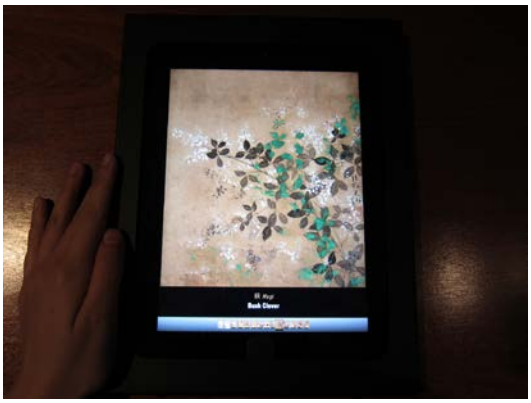


Figure 37. Interface of the portfolio on an iPad.

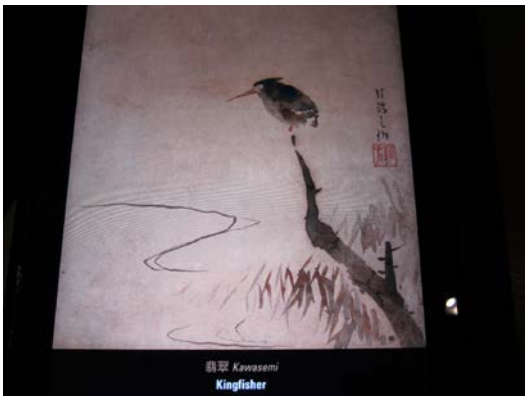


Figure 38. Detail of the portfolio.

Digital Exhibit of Artifacts

The digital exhibit on iPads is developed by Chicago Fine Arts Institute to provide further information about artworks in exhibits (Figure 39, Figure 40, Figure 41, Figure 42, Figure 43, and Figure 44). The application is designed in an elegant manner with a simple and clean interface, clear and smooth navigation and rich background information on each artifact (Figure 39). The visitor can flick on each piece of artwork on the homepage (Figure 40) to take a close look at details (Figure 41) and explore additional relevant stories (Figure 42). Along with images of high quality, it also embeds video clips and dynamic interactions to engage visitors. There are some potential features added into this application compared to other ineffective applications in art museums. For example, it gives some freedom to visitors for constructing their own experience with the exhibits. However, the interaction between the visitor and the application is still limited to a one-way relationship between information receiver and information giver. Visitors are still playing a passive role in this relationship.

These iPads are installed on either elegant kiosks (Figure 43) or long benches (Figure 44) that are in front of artifacts. In theory, visitors should be able to enjoy observing displayed artworks while following the accompanying information on an iPad. The combination between the physical location and the digital exhibit is supposed to provide visitors a personal experience with the artworks, especially for individual visitors. However, according to observations by the museum staff, visitors usually concentrate on the digital exhibit instead of the original pieces in front of them; this misses the point of the museum's interactions, which was to augment the real pieces, not overpower them.

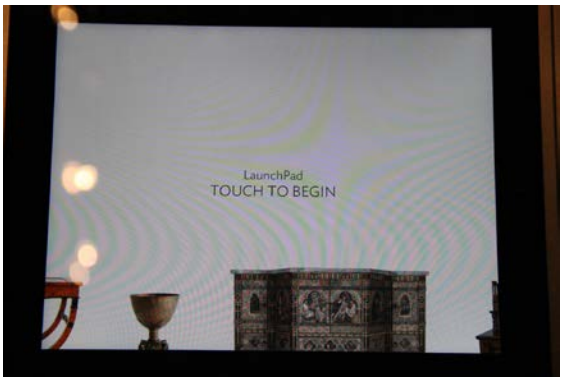


Figure 39. Welcoming screen of the digital exhibit.

Figure 40. Homepage displaying various artifacts.

Figure 41. Detailed view of an artifact.

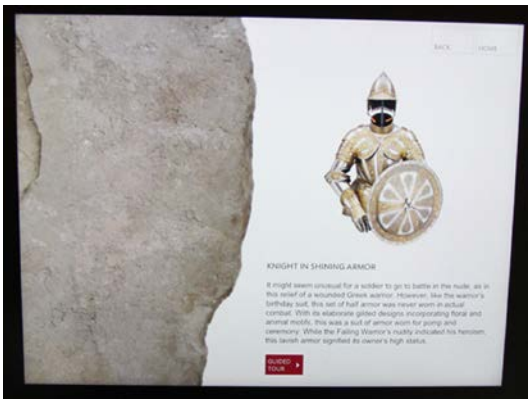


Figure 42. Details and description of an artifact.

Figure 43. Freestanding iPad display.

Figure 44. Integration of iPad display with seating.

Summary

This field observation demonstrates that multi-touch interactives are being widely applied in the museum world.

A matrix has been developed (Table 1) based on theories from the literature review that documents the nine various interactives based on three different types of museums from the field observation. This table shows that science museums and natural history museums are doing better job in designing and cooperating digital interaction into exhibits than art museums. Some art museum interactives are equipped with valuable educational content and a usable interface, which is sufficient to tell a complex story. Some of them, however, can barely attract visitors to spend time to explore the content. Furthermore, most art museum interactives are still either playing a role of a dominant lecturer or they are engaging a passive participant. Mutual interactions between interactives and visitors are hardly encouraged in the art museum. Visitors have no opportunity to input creative responses to the interactions or enjoy open-ended learning experiences. This results in a failure to construct visitors' personal meanings of art exhibits, because they are passive information receivers instead of active creators while using the interactives.

These observations support the conclusion of the literature review, which is that the interactives in art museums remain limited to a passive cataloging of artworks instead of an active learning experience. The interactives from the science museums and the natural history museums, by comparison, do encourage open-ended and active learning experiences. Therefore, the observations suggest that a successful interactive application should be created for art museums through cooperation and coordination among multiple areas, such as exhibition design, museum interactivity, museum education and multi-touch interface design.

Table 1. The presence of effective criteria for museum interactivity as observed in three types of museums.

Criteria	Science Museum			Natural History Museum			Art Museum		
	Tornado	Spectrum	Lab	Fish	Video Game	Human Study	Karoliks	Portfolio	Artifacts
Deliver message effectively	yes	yes	yes	yes	yes	yes	yes	yes	yes
Attract visitor's attention	yes	yes	yes	yes	yes	yes	no	no	yes
Keep visitor's attention	yes	no	yes	yes	yes	no	no	no	yes
Provide information for exhibits	yes	yes	yes	yes	yes	yes	yes	no	no
Provide open-ended experience	yes	yes	no	yes	yes	no	no	no	no
Facilitate social interaction	yes	yes	no	yes	no	yes	no	no	no
Engage hands-on activity	yes	no	no	no	yes	no	no	no	no
Multiple levels of content	yes	no	yes	no	yes	no	yes	no	yes
Effective storytelling	yes	no	yes	yes	yes	yes	yes	no	yes
Smooth interaction	yes	yes	yes	no	yes	yes	yes	yes	yes

The Conceptual Prototype for an Art Museum

Based on the literature review and field observations, a conceptural prototype for a large, multi-touch display for use in art museums was developed for this study.

The following sections introduce the conceptual prototype process, including reasons for developing the prototype, selections of instructional content, interactions designed for instruction, basic features of the prototype, information architecture and related theories, design treatments, interface examples and criteria considered important for the design.

Rationales for Designing the Prototype

Rationales Supported by Literature Review

Based on the research conducted in previous chapters, there are many reasons to design conceptual prototypes that enhance interactivity in art museums.

Interactivity has been instrumental in helping change the public's perception of museums from boring educational centers to active learning centers. Digital interactives, such as large-scale multi-touch applications, have already been widely accepted and applied by science

museums and natural history museums for educating and attracting visitors. In order to compete with the entertainment industry and other interactive media, museums are using interactive communication as a new approach to provide immersive learning experience, replacing one-way instruction in all kinds of museums, including art museums.

From the perspective of exhibition design, digital interactives are effective storytelling tools. Exhibitions are now judged by the quality of their stories and presentation instead of merely displaying collections. Digital interactives are able to integrate multimedia, such as images, videos, audio, games, social network and more, into the story-telling. Visitors are empowered by creating and experiencing stories. Stories in art museums, by their nature, are relatively passive. It is not easy for visitors who don't have a rich background of art history and art criticism to fully interpret the stories behind works of art. Digital interactives, however, have the potential to tell attractive stories about these collections based on the intent of the curators.

Digital interactives also provide a practical approach to make art education more accessible to ordinary people in art museums; visitors have more opportunity and freedom to access information about exhibits with the help of digital interactives. These interactions could increase visitors' interest in learning, especially when compared to art museums that traditionally rely on lectures to support exhibits. Furthermore, visitors could even be able to create art, comment on their own experience, and appreciate others' artwork through functions offered by the interactive application. In this way, it would be easier for visitors to relate to art in the context of their daily life.

Discovery and *constructivism* as pedagogies are the theoretical foundation for art museums to develop open-ended interactives, which could change the role of art museums from a dominant lecturer to an educational facilitator. Learning is a very personal experience that

depends on a variety of individual characteristics. Visitors tend to interpret art based on their own experiences and ideologies. Digital interactives have both the potential and capacity to encourage these unique art interpretations to take place during visits. In this way, visitors could be empowered and educated.

Due to the static content of art exhibits, art museums have difficulty engaging children and teenagers. In general, children and teenagers need interesting attractions in order to appreciate art museums. The literature review reveals that large-scale multi-touch interactives tend to fascinate children and teenagers in public spaces. Children and teenagers tend to spend more time exploring interactive content, which is attractive to parents as well. This could be an optimal scenario for art museums.

Collaboration and social interaction are also needed in art museums since visitors are, to some extent, isolated. Large-scale multi-touch interactives create more opportunities for social interaction, which helps visitors learn and create valuable social experiences. According to these theories and information discussed in the literature review, a conceptual prototype to create open-ended digital interactives could help produce more engaging and effective art museums.

Rationales Supported by Field Observation

Results from field observations indicate that art museums need to catch up with their peers in the museum world in terms of interactivity. Gaps were observed between art museums and science/natural history museums. Interactives in science/natural history museums tend to involve more hands-on experience rather than simply displaying catalogs of collections. They encourage the concept that people learn through trial and error, which is an effective way to explore and learn.

The art museums observed tended to continue showing collections and background information through digital catalogs where visitors passively browse items and attempt to learn them by memorizing the information. There were few hands-on activities or open-ended explorations in terms of digital interactivity. However, in the context of the art museum, digital interactives are very accessible for visitors. The cataloging style implies that art museums are dominant lecturers, which can be traced back to 1960s when art museum educators were playing a role of both lecturers and art historians at the same time. Other than images and texts, the cataloging style observed sometimes included multimedia, such as audio and videos. However, open-ended learning experiences were absent, so visitors didn't have the opportunity for creative input or personal expression.

Digital interactives in the art museums observed barely attract visitors because of their poor design and sparse contents compared to those seen in science/natural history museums. Under these conditions, visitors lose interest in interacting with digital interactive applications after a short time. Because the average time that visitors spend on one exhibit is an important measurement for evaluating if an exhibit is successful, most digital interactives fail on this task. According to field observations, poor user interface and user experience design fail to engage visitors effectively. Visitors also seem bored if the content is not presented in multiple layers, since this fails to fulfill everyone's needs in a group or provide rich information. This was observed in the digital portfolio of Japanese paintings in Metropolitan Museum of Art.

Furthermore, the art museums observed fail to leverage the output of visitors' creative participation through email or social networks. Some science museums and natural history museums have already started utilizing email and social networks to empower visitors. In this way, souvenirs can encourage visitors to return. Art museums have the potential to entice new

visitors and get them to return by encouraging them to create art using digital interactives and share it through social networks and email.

Introduction of Instructional Content

Modern Art as the Main Theme

The key to successful visitor learning is to bridge the original contexts of museum objects the context of a visitor's everyday life. (Froes et al., 2011; Falk & Dierking, 2000) Modern art, however, is particularly difficult for visitors to interpret or even apply to everyday life. In general, visitors tend to spend more time with classical art. This is especially true of children, because the messages conveyed by the pieces are relatively evident. It is also relatively easy for visitors to generate ideas and discussions based on classical art. However, visitors usually feel powerless and confused when understanding modern art because it is full of non-representational art forms and diverse art expressions. Modern art leaves visitors with an impression that they are not well educated enough to appreciate art nowadays because they don't know about art history or art criticism. This frustrating experience may result in negative attitudes from visitors regarding modern art. However, modern art is significant to learn about because art is always developing over time. Artwork from modern artists reflects and presents our contemporary world from another point of view. Art museums go to great effort to conserve masterpieces from each time period and encourage new art. If visitors find themselves having a difficult time appreciating modern art, art museums may need more a more meaningful approach to help educate visitors.

Furthermore, modern art encourages unique interpretations from individuals. Some artists even engage viewers to help complete their artworks in the context of an exhibit. The interaction between viewers, art, and artists becomes more and more dynamic and experiential. At the same

time, the boundary between modern art and daily life often blurs in terms of the philosophies and content that artists utilize. Therefore, interactions with open-ended engagement and creative input could contribute to the learning experience about modern art because the meaning-making process would be similar to that of modern art. There is no right or wrong answer in the open-ended interactions. Discovery and individual interpretation are encouraged to create a personal connection between art and a visitor's daily life.

Therefore, modern art was selected as the main theme for the prototype, since it is an ideal breakthrough point for experimenting in new approaches for digital interactivity in art museums.

Image and Music as Main Categories

Frames of Mind: The Theory of Multiple Intelligences by Howard Gardner proposes a model of intelligence that categorizes people's abilities into several criteria. (1983). In this book, the model is composed of linguistic intelligence, musical intelligence, logical-mathematical intelligence, spatial intelligence, body-kinesthetic intelligence and personal intelligence.

Spatial intelligence now is usually referred as visual intelligence, which deals with spatial judgment and the ability to visualize with the mind's eye. Musical intelligence has to do with sensitivity to sounds, rhythms, tones and music. Compared with other intelligences, these two intelligences belong to the arts and have a mutual relationship through artistic creation. Some artists were inspired by music, such as Bearden and Kandinsky. Some composers were inspired by images, such as Petrovich and his Piano suite, "Pictures at an Exhibition." Image and music are important inspirational resources for modern artists during the creative process. Furthermore, some contemporary art forms, such as video and installation, involve auditory elements.

Art museums tend to emphasize visual intelligence in the museum education. However, art museums have attempted to involve musical elements into exhibits and activities through various ways because of the deep connection between these two areas. Some visitors will find that music is a new way to engage with art, which other will be able to learn something about music because of their interest in art. This symbiotic relationship will reach a wide range of visitors. Therefore, image and music have been selected as the two main categories for this prototype.

Intention of Instructional Content

The instructional content used for this prototype was developed carefully according to principles of art education. Multiculturalism and gender were carefully considered through selection of images, music and artists displayed in the *learning* section.

European art and American art are still being widely and deeply introduced in classes and museums, to the point that people sometimes ignore art from other cultures. Yet, contemporary art is now more multicultural than before. Therefore, during the selection of the content, diverse art genres based on different cultures were included. In addition to western art, African art and Asian art were also selected based on a range of ethnic groups, cultural origins, and geographical factors. Visitors can learn that African art sparked the passion of Picasso, and Japonism impacted Cassat. African American culture is shown through Jazz and artworks of Bearden. Non-mainstream music style, such as post punk, was also included in this list. Motion picture, as the only representative from the combination between art and technology, introduced the great potential of new art forms based on technology.

The other inclusive factor is gender. With the influence of feminism and the movement for women's rights, the influence of women has increased. This change can also be seen in the

development of art. Women are not only the objects in art, but also the creators of art. In order to emphasize this gender diversity, Cassat was chosen as the pioneer of modern female artists who are playing a significant role in the current artistic world.

Interactions Designed for Instruction

Interactions Functioning in the Meaning-Making Process

Diverse interactions have been thoughtfully designed to scaffold a meaning-making process for visitors. The prototype includes two warm-up games, learning materials on image, music as inspirational resources, a digital drawing activity, commenting and sharing functions, and a virtual exhibit. These interactions allow visitors to have a dynamic and exploratory experience.

Warm-up games and learning materials are two sequential steps in the prototype. Based on the normal procedure of education in classroom environments, warm-up games capture the attention from students in order to introduce new learning materials later on. At the same time, warm-up games provide visitors an opportunity to preview the deeper content of the application. Learning materials offer background information about warm-up games and reveal instructional content for visitors to dig into.

After learning instructional content, a digital drawing activity allows visitors to create their own artworks by following inspirational resources that they have chosen in previous steps. This activity encourages creative inputs and open-ended engagements. There is no right or wrong answer in this hands-on activity. While they are choosing inspirational resources, visitors are able to browse existing examples done by other visitors and artists. Existing examples give visitors a hint to what they are going to do in the next step, so that they will have a clear picture in their minds before they start the drawing activity. Digital drawing tools, including brushes and

patterns in various sizes, also help visitors to shape their imaginations and put them into reality in a short time.

Commenting and sharing play important roles in the meaning-making process, and therefore the prototype attempts to encourage open-ended engagements and social interactions both onsite and virtually. Leaving comments helps visitors organize and digest their learning experience. It also allows visitors to contribute to the virtual discussion by sharing their own thoughts and feelings. Reading others' comments broadens visitors' horizons and provides interesting topics for them to talk about within a group. The sharing function encourages visitors to display their artwork in the virtual visitor gallery embedded in this application. They may also be encouraged by friends after posting their own artwork onto Facebook. Displaying one's work and receiving feedback from others are powerful methods in art education in order to boost one's self-confidence in art creation. The sharing function also allows visitors to bring their artwork home as a souvenir from the art museum through email. They may email the artwork to themselves and friends; once home, they can print out their creations and hang them on the wall. This reminds them of their interesting and meaningful experience in the art museum. Visitors also have the accessibility to browse other visitors' artworks. They may show their appreciation by clicking to "vote" for their favorites.

The optimal meaning-making process, which is constructed by these interactions, starts from warm-up games and ends at the virtual exhibit section.[1] The visitor's curiosity is supposed to be roused through playing warm-up games. After the games, they start feeling interested in the background information of the game. Then, they learn about inspiration and the creative process of modern artists from the instructional content. Then they are invited to engage in an artistic

[1] This process is shown on Table 2 (page 86) through the information architecture of the prototype.

process by choosing inspirational resources and creating their own artwork. After the hands-on activity, they are invited to digest and enhance their learning experience through comments. They are able to share their artwork and browse others' artwork so that they can receive and give encouragement.

These interactions, however, are relatively independent. They have been divided into three sections considering the rationale of operation. Each section functions even if visitors do not complete or engage with each section. The independency of sections ensures that visitors have the freedom to interrupt their interaction at any time during the meaning-making process, but will still take away some meaningful information and will have had a meaningful experience.

During this process, visitors are constructing their own meaningful understanding and knowledge about how art inspiration works in modern art. They are also building self-confidence in art creation on their own.

Designing Interactions According to Theories of Constructivism

Research from past century has resulted in the broad agreement that learning is an active process that is modulated by the learner's previous experience, culture, and learning environment. Constructivists believe that, for true learning to take place, people must construct their own meaningful and personal knowledge bases through active learning based on a foundation of prior experience and knowledge. These knowledge bases are also the result of people's unique backgrounds and personal contexts. Falk and Dierking believe that learning in museums is a fundamentally social experience, which is affected by social cognition, culture, communities of learners, story-telling and modeling (2000). Learning requires an ability to transfer from one context to another in order to digest and use knowledge that one learns from exhibits.

Interactions designed for this prototype are informed by theories of constructivism. The setting of the open-ended engagement respects visitors' previous experience, culture, knowledge, and other contexts. The instructional content presents information from the multicultural perspective. The drawing activity allows visitors to express themselves with few constraints. It also respects visitors' creations. Making an art representation of something is a way to construct and demonstrate one's understanding from their experience and knowledge (Clements & Wachowiak, 2010). Meanwhile, the comment function works in the same way. There are no standard answers for questions. Visitors are encouraged to share their thoughts or even come up with new questions under the guidance of existing ones. In this circumstance, visitors are to be seen less as problem solvers and more as problem seekers or raisers.

The learning experience provided by this prototype emphasizes self-exploration as well as social interaction. According to the "Contextual Model of Learning," the sociocultural context influences learning, such as within-group discussions. In the prototype, the warm-up games, the drawing activity and the comment function all help create social interaction within a small group, because up to three visitors will be able to stand in front of the application and share information displayed on large big touch screen.

In this prototype, the entire learning experience has been divided into three sections. Visitors are empowered to choose any section to explore, but are still able to take away meaningful information out of the interaction because the three learning sections are relatively independent from each other. This setting puts visitors into an active role in the learning process, since visitors are in charge of their own learning pace, which helps construct visitors' own personal knowledge bases.

Basic Features of the Prototype

Size

The size of a multi-touch tabletop surface depends on the function and purpose of the application. In general, the larger size not only allows larger amounts of information to be displayed and interacted with but also encourages social interaction and collaboration among users (Ryall et al., 2004). Research has shown that there is a rational relationship between table size and group size. A larger tabletop surface has a greater ability to attract people in a group. Therefore, the size of the prototype is 43 inches long and 28 inches wide, which is large enough for up to three people to use at once.

Orientation

Related research suggests that a horizontal tabletop in a workplace is more engaging and friendly for a group working together than a vertical tabletop, an orientation typically utilized in a commercial environment (Rogers & Lindley, 2004). Therefore, the orientation of the prototype is horizontal, which creates a socially cohesive and conductive atmosphere.

Optimal Location

Because the prototype is designed for an art museum to provide hands-on interactive opportunities for visitors, the optimal location is in a resting area of an art museum where visitors can sit down on a bench and educate themselves as they relax. Based on the theme of the prototype, the prototype can be also installed inside or outside of a modern art exhibit.

Duration of the Interaction

According to a paper-based user test conducted to predict the duration of the interaction, a typical visitor would need to spend roughly 20 minutes to interact with all three sections. However, the duration for each section can vary depending on the visitor's interest. The visitor is

also able to control the length of the interaction by the numbers of sections that they choose to interact with.

Target Audience

The target audience of this prototype is the visitor of an art museum. Primary audiences are families with children, including teenagers, and school groups. Children and teenagers are easily attracted by a multi-touch tabletop and tend to spend more time exploring it (Marshall et al., 2011). The research also shows parents usually try to guide their children during interactions and engage in educational conversations with them on certain topics (Falk & Dierking, 2002). Furthermore, single visitors can also enjoy interactive experience with this prototype because it is still designed for one person to operate.

Educational Content

Because the prototype attempts to build a bridge between modern art and daily life, the content focuses on inspirations of creativity. The goal is to reveal that the public is also able to enjoy art creation, once they learn to discover the beauty in the daily life. Selected inspirations have been limited to “image” and “music,” which are important inspirations for art yet easy to overlook by non-artists.

The content includes three sections: *learning* (“What inspires artists”), *doing* (“What inspires you”), and *sharing* (“What inspires others”). The *learning* section contains two warm-up games before the main part of the learning material that contains images, music and text. The *doing* section allows visitors to choose inspirations that they are interested in, draw a picture and make comments on their learning experience. The *sharing* section displays drawings that visitors have done and comments that they have made.

Information Architecture of the Prototype

Introduction of the Information Architecture

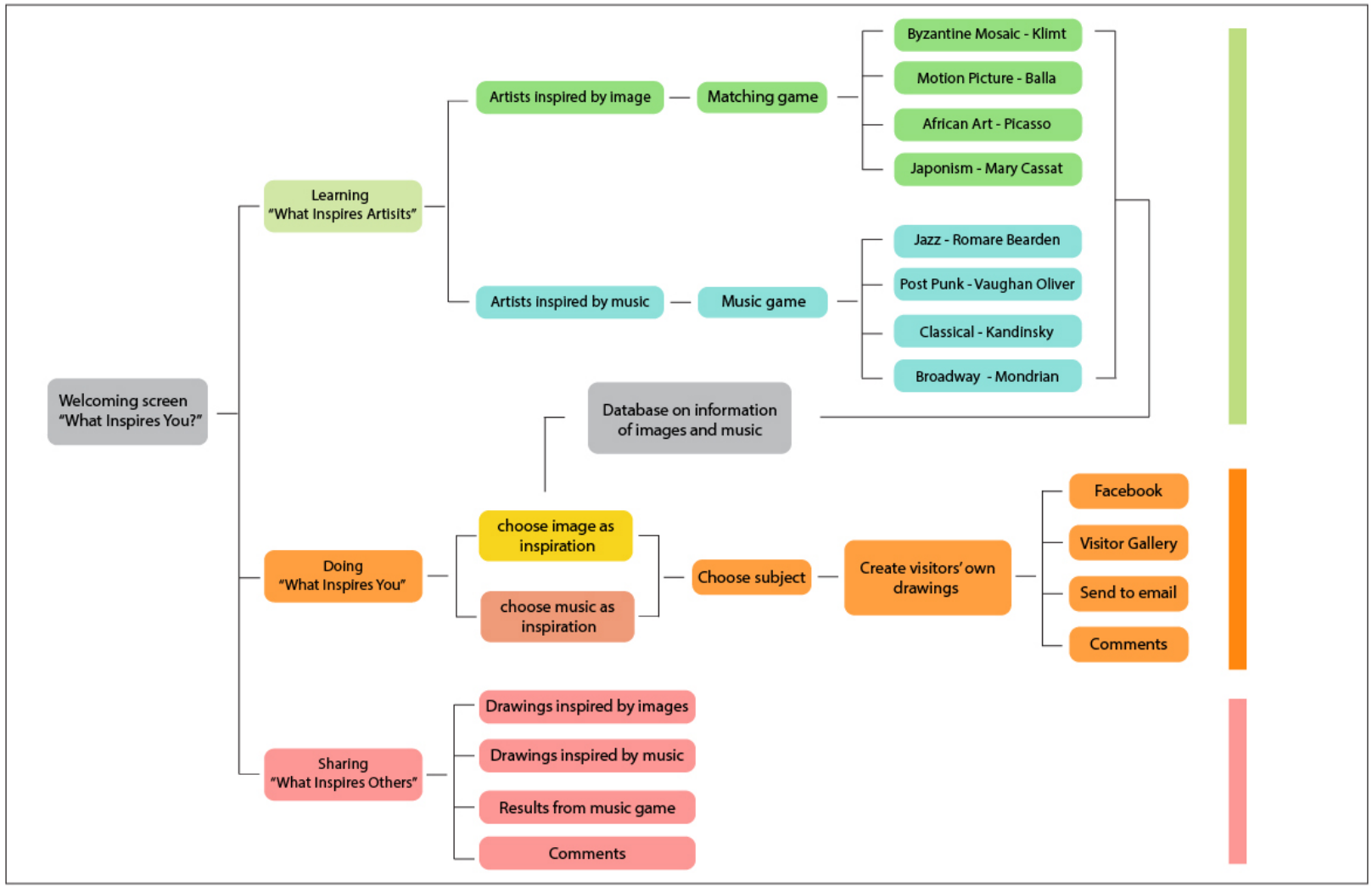
To ensure that the prototype delivers information reliably and effectively, the information architecture (Table 3) has been carefully designed as a main guide in the developing process to optimize the visitor experience. The information architecture reveals both educational value and entertainment value of this prototype because it contains rich information, hands-on activity and social media function. This integrated, yet open-ended system empowers visitors to enjoy their learning process.

The visitor touches a welcoming screen (gray) with the title “What Inspires You?” to start interacting with the whole system, which is supported by the information architecture. This information architecture includes the three content sections: the first section (green) focuses on *learning*, which integrates warm-up games and learning materials in two sequential steps. In the normal setting of education in the classroom, warm-up games are useful for attracting students and introducing new learning materials. The visitor is supposed to receive information about the theme after going through this section. The second section (orange) provides a hands-on opportunity for *doing*: visitors create their own drawings with inspirations and subjects that they are fond of. The visitor chooses potential inspirations and subjects first. While they are browsing and choosing images and music as the inspiration, optional background information has been provided for each image and music through a database (gray). Visitors are encouraged to browse the background information to learn more about art and inspiration. Then they will draw a picture by using brushes and colors based on what they have chosen in the previous steps. Once their drawings are done, they may comment on their own creative experience, send the drawings to themselves and post them onto Facebook and the visitor gallery. The third section (pink)

focuses on *sharing* drawings from visitors based on two categories of inspiration (image and music) as well as comments that visitors have made in the second section. Visitors are able to respond to the work and the thoughts that others have shared by flicking stars to “like” them.

The relation among each section is closely connected so visitors can get the optimal learning experience if they go through all three sections sequentially. However, each section still performs well as individual sections when visitors don’t have enough time or interest to complete the sequence.

Table 2. The information architecture of the prototype.



Theories Used in the Information Architecture

To make the prototype socially interactive and educationally attractive, several concepts have been used in designing the information architecture. The warm-up game in the *learning* section follows the procedure of education in school, especially art education, to make new learning materials easier to digest. Multiculturalism in the context of art education also affects the selection of learning materials in the *learning* section. Artists and art formats from diverse cultural backgrounds have been demonstrated in this section, such as Japanese art, African art, feminist art, motion pictures, tribe music, and punk music.

Constructivism in the context of museum interactivity and education also plays an important role to strengthen the content of the prototype. Based on the goal open-endedness in constructivism, the *doing* section collects responses of visitors to the experience, while the *sharing* section displays these responses to other visitors. The visitors interpret and create art in different ways according to their own contexts, which also influences their motivations and emotions in the learning process. Therefore, two sections build a mutual channel for the visitor to construct a new experience with contents created on their own. It helps achieve the goal that the prototype encourages the visitor to discover beauty in daily life and feel confident to create art.

Furthermore, the information architecture is structured to create a unique and immersive interactive experience for the visitor to learn in the art museum by telling an open-ended story about how people get inspired to create art with multimedia and smooth interaction.

Designing the Interface

The basic interface and fundamental interactions have been designed for the interactive art museum prototype. Design treatments focus on the content. This prototype is different from ordinary museum interactives because it combines a complex system, an open-ended solution

and a large multi-touch surface. Therefore, the design has been carefully and thoughtfully carried out after research (Figure 45).

Figure 45. Welcome screen of "What Inspires You?" prototype.

Design Treatments

Metaphor

The hexagon (Figure 46) is used as a basic design element in this prototype. It is also a metaphor for visitors to learn and interpret the interface. The hexagon has six sides. Each side can connect to one of six sides of another hexagon. A group of hexagons build a net into various sizes and shapes, which implies endless possibilities due to its infinite number of relationships with other hexagons. Each hexagon indicates one element in daily life. Numerous elements create endless possibilities of life as well as creativity. Visitors are invited to find out the possibility of creativity from the relationship between daily elements and art while interacting with this prototype

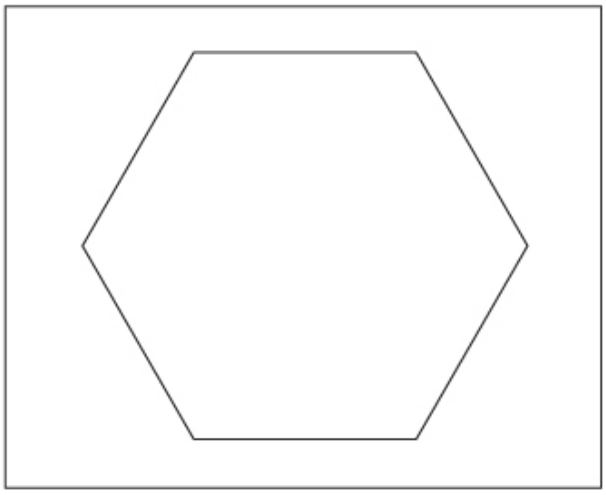


Figure 46. Hexagon as metaphor in the prototype.

Grid System

To design the grid system that builds layouts of the interface, the hexagon is chosen to be the basic element. This grid is composed by approximately 10×17 hexagons (Figure 47), which provides a vast array of choices of vertical, horizontal and diagonal lines (Figure 48). Hexagons are easy to identify in the interface, and are used repeatedly as a main design treatment. The hexagon grid helps reinforce the theme.

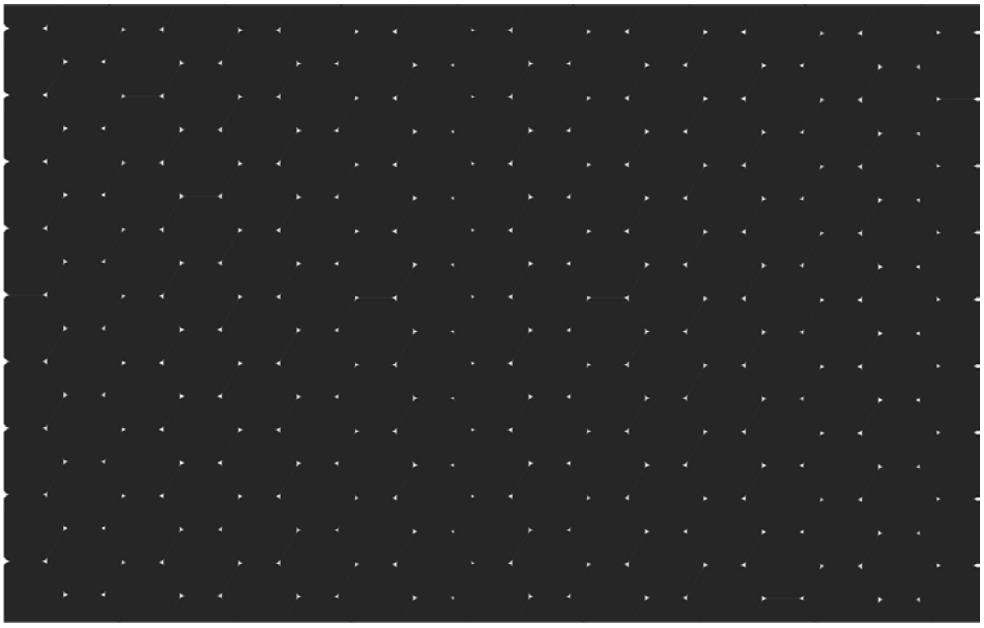


Figure 47. Hexagons as a basic element of the grid system.

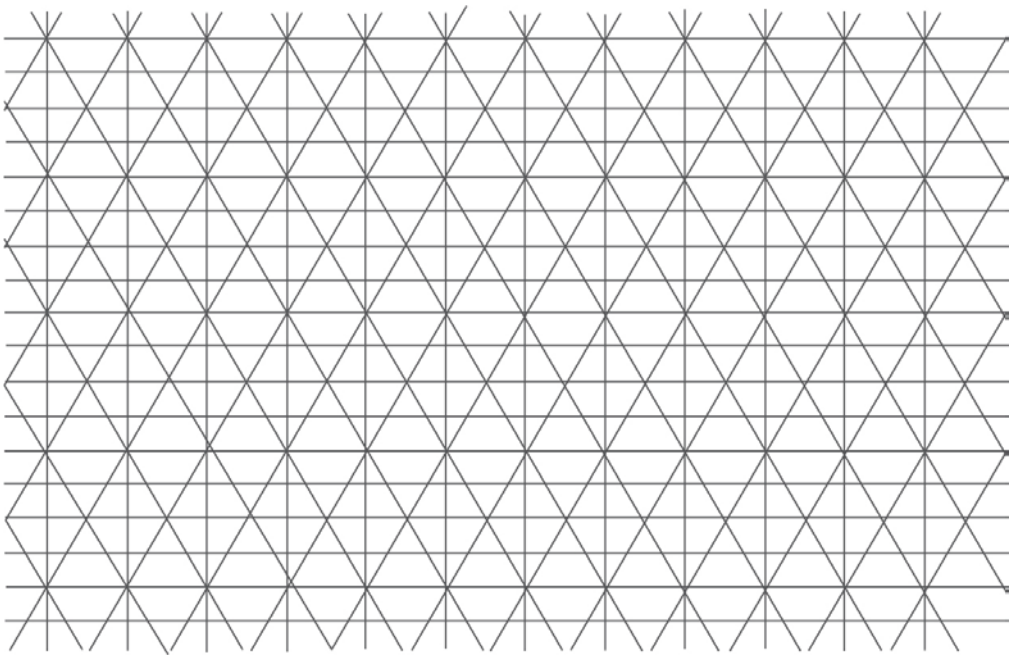


Figure 48. The simplified grid system.

Colors

Black, white and gray are three neutral colors that have been often used as background in the environment of the art museum and gallery. These three colors subordinate to the colors of artworks. The interface uses dark gray as the background color and white as the color of the navigation bar for this reason.

To differentiate each section and each subsection, color-coding is used in the interface design. Color-coding provides an effective approach to categorize the contents visually. In this prototype, green represents the learning section (“What Inspired Artists”). Orange represents the doing section (“What Inspired You”). Pink represents the sharing section (“What Inspired Others”).

Fonts

Britannic Bold (Figure 49) is an interesting font that combines classical and modern tastes due to its special treatment of serifs. Usually, serifed fonts are widely used for body text in

print. Britannic Bold is a screen-safe font because its legibility is fairly good on computer screens. The capital letters do not have obvious serifs, and some letters in the lower case have certain features of serifs. As a consequence, this font is mainly designed for headings. As the font of the heading, it looks active, fun and elegant. It is interesting enough to catch the attention of children and teenagers who are the main target audiences of this prototype.

Figure 49. Britannic Bold.

Helvetica Neue Light (Figure 50) is a variation of the Helvetica font, which maintains simple, minimalistic, and elegant characteristics of the original Helvetica. However, Helvetica Neue is slightly less round than the original Helvetica. This fact can be used to create a modern look for the text in the interface and improve legibility. Helvetica Neue Light is a sans-serif font, which is also considered to be easy and comfortable to read on computer screens, especially for large blocks of texts.

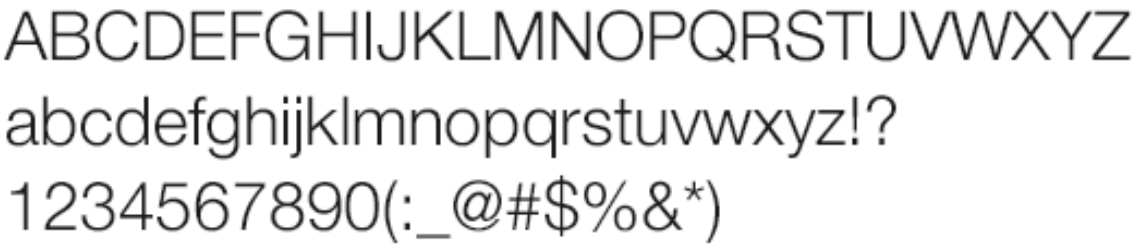


Figure 50. Helvetica Neue Light.

Gestures Used for Interaction

Finger gestures are used to interact with the prototype, including flick, drag and pinch. They are simple, direct, and easy to learn. According to NUI, the learning process of an interface design in the walk-up-and-use context should be invisible and successive. Smooth interaction needs gestures that the visitor is familiar with. Gestures used in this prototype are typical ones that have been widely used by visitors in their daily life. Inspired by the field research of "TouristPlanner", the visitor is able to start interacting with this prototype in no time by following their experience of interacting with other kinds of interfaces (Marshall et al., 2011).

There is one exception of the use of gestures in the prototype. In the hands-on step of the *doing* section, visitors need to treat their fingers as art tools, such as brushes, pencils, or pens. Fortunately, the transition from the finger to the art tool is a frequent occurrence in people's childhood. As a consequence, people adjust to this transition intuitively. Many drawing apps for multi-touch devices have also cultivated this skill in users. Furthermore, people prefer this tangible input style rather than a mouse-based input style to interact with objects. Tangible experience makes learning and problem-solving easier than indirect experience (Antle et al., 2009).

Design of the Interface for Each Step

Design of the interface is based on the information architecture on Table 2.

Figure 51 shows the welcoming screen of the prototype. This is shown in gray in the information architecture on Table 2.

Figure 52 shows the main navigation screen for the three sections. Small arrows on each hexagon imply the learning sequence. The hexagon button is the primary navigation tool. The navigation bar, which is located at the bottom edge, is the secondary tool.

Figure 53 shows the main navigation screen for the three sections. “What Inspires Artists?” (the *learning* section) is activated.

Figure 54 shows the navigation screen of the *learning* section (“What Inspires Artists?”) This section is shown in green in the information architecture on Table 2. Visitors can choose artists inspired either by image or music. The instruction is located at the top left corner.

Figure 55 shows the interface when the button “Artists Inspired by Image” is activated in the navigation screen of the *learning* section.

Figure 56 shows the interface of the matching game (warm-up game). It appears right after visitors choosing “Artists Inspired by Image” in the previous step. Visitors can always skip the game by flicking the button on the navigation bar.

Figure 57 invites visitors to match cards between row 1 and row 2. A correct match is confirmed by a green background around the cards and a “snap-together” effect.

Figure 58 shows the interface when the correct pair of images is matched successfully. This pair moves to the left side through a simple animated effect. “Learn More” button also appears underneath of the correct pair to offer the visitor more information about how this artist was inspired by this image or style.

Figure 59 shows the interface when the four pairs have been successfully matched. Visitors can choose one pair to start learning more background information about image as inspiration.

Figure 60 demonstrates that an incorrect match is shown through cards with red background. Two cards will go back to their original positions automatically after the incorrect match.

Figure 61 shows the interface when visitors come to additional learning material with images and texts after choosing one pair to learn more (Figure 59). Hexagon buttons are most related to this step. The white navigation bar remains secondary.

Figure 62 shows the interface when visitors come to the warm-up game for music. If the visitor chooses the button “Artists Inspired by Music” through the navigation screen of the *learning* section (Figure 54), they would be invited to start the music game. As a first step, visitors choose one piece of music to start the game.

Figure 63 invites visitors to choose one shape that can describe their feelings to this piece of music (“Broadway” in this case). Visitors can always skip the game.

Figure 64 invites visitors to continue by arranging the chosen shape through a controlling panel underneath the displaying window, which includes repetition, size, angle, size gradient, blur and curve.

Figure 65 shows that visitors can also choose up to four different colors and adjust color gradient, transparency and orientation.

Figure 66 shows that a small window pops up after submit the final result of the music game. Visitors may choose to learn more about music as inspiration or see what other visitors have done in this game (“Learn more…” is activated in this case).

Figure 67 shows the navigation screen of the learning material of music. After choosing to learn more about music as inspiration in the previous step (Figure 66), visitors need to choose from one of four buttons that show different artists inspired by four different music genres. (“Who Is Inspired by Jazz?” is activated in this case.)

Figure 68 shows the step that provides the learning material with images and texts. Visitors are able to both browse text and images about the artist, and listen to the piece of music that inspired the artist to create this work.

Figure 69 shows the welcoming screen for the *doing* section ("What Inspires You?"). This section is shown in orange in the information architecture on Table 2. In this section, visitors are invited to draw a picture by following one inspirational resource chosen from image/music and one subject chosen from daily objects.

Figure 70 shows the navigation screen of the *doing* section. Visitors are invited to choose one category that inspires them. They can select image or music.

Figure 71 invites the visitor to choose an image that inspires them. The interface includes two rows. The top row shows images that visitors can choose from, while the bottom row shows drawings of other visitors based on images, which can be activated through flicking.

Figure 72 shows the interface when one image in the top row is chosen.

Figure 73 shows the interface after selecting an image in the previous step (Figure 72). A pop-up window appears to provide options for visitors: choose this image, learn more about this image and choose another image.

Figure 74 shows the interface when "Choose this image" is activated. The next step is choosing a subject from daily objects (Figure 78).

Figure 75 shows the interface of music (after Figure 70). The visitor is invited to choose a piece of music that inspires them. The interface includes two rows. Top row shows music that visitors can choose from. Bottom row shows drawings of other visitors based on music, which can be activated through flicking.

Figure 76 shows the interface when a piece of music in the top row is chosen.

Figure 77 shows a pop-up window that provides options for visitors. Visitors have freedom to choose this music (the activated one), learn more about this music, or choose another piece of music through this window.

Figure 78 shows the interface of transition from image/music to subject.

Figure 79 shows the interface of subject. After choosing an image or a piece of music as inspiration, visitors need to select from a collection of daily object as the subject for the drawing activity. The top row shows subjects that visitors can choose from. The bottom row shows drawings of other visitors based on various subjects, which can be activated through flicking.

Figure 80 shows a pop-up window that provides options for visitors after choosing one subject. Visitors can either choose this subject or go back to the previous step (Figure 79) to choose another subject through this window.

Figure 81 shows an animated tutorial for the drawing step. Once visitors come to the drawing step, a short animated tutorial will guide them to explore around the interface. Visitors can always skip this tutorial.

Figure 82 shows the continuing tutorial that guides visitors to explore around the drawing tools.

Figure 83 invites visitors to start creating their own drawings after the tutorial.

Figure 84 focuses on the button of “Show Images”, which shows images that visitors have chosen in previous steps as references in the drawing process. After this process, visitors can send and share their artworks by flicking button of “Send & Share.”

Figure 85 shows the interface of “Send & Share.” It allows visitors to share their drawings to Facebook and the visitor gallery (the *sharing* section). Visitors can also send drawings through emails and leave a comment on their learning experience.

Figure 86 shows the interface of “Send to email”. Visitors are free to change the title of the email and add more email addresses in this dialog box.

Figure 87 shows the sending process, which is through the animated “Send” button.

Figure 88 shows the “Leave a comment” interface. Visitors are invited to select a question from the “Question list” on the left side; the six questions lead them to think deeply about their learning process. The answer is limited to 100 words.

Figure 89 shows the interface when one question from the “Question list” is being chosen. One comment of 14 words (86 words remaining) has been typed in the box and is being submitted to the *sharing* section.

Figure 90 shows the navigation screen of the *sharing* section (“What Inspires Others?”) This section is shown in pink in the information architecture in Table 2. In this section, visitors are invited to browse drawings made by other visitors, results from the music game and comments gathered from other visitors. (“Drawings inspired by image” is activated in this case.)

Figure 91 shows the interface of “Drawings Inspired by Images.” It displays eight small frames. Each frame would contain a different drawing made by visitors. Visitors can browse all drawings page by page.

Figure 92 invites visitors to “like” the drawing by flicking the star. They can also look into more details by flicking an enlarge button (the right one). Frames can be resized with two fingers.

Figure 93 shows the interface when the detail of one drawing pops up. Once visitors flick the enlarge button, they will get information about the drawing in detail, including inspirational resources and comments. Visitors can also “like” the drawing and go back to the small frame.

Figure 94 shows the interface of “Comments,” where collects comments from visitors. There are six questions in total according to the comment step in second section (Figure 88 and Figure 89). Visitors can scroll down each group of hexagons to browse more answers.

Figure 95 shows the interface when one comment is activated and “liked”. In addition to “like” the answer, visitors can also scroll texts down in each hexagon to read more.

Figure 51. Welcoming Screen of the prototype.

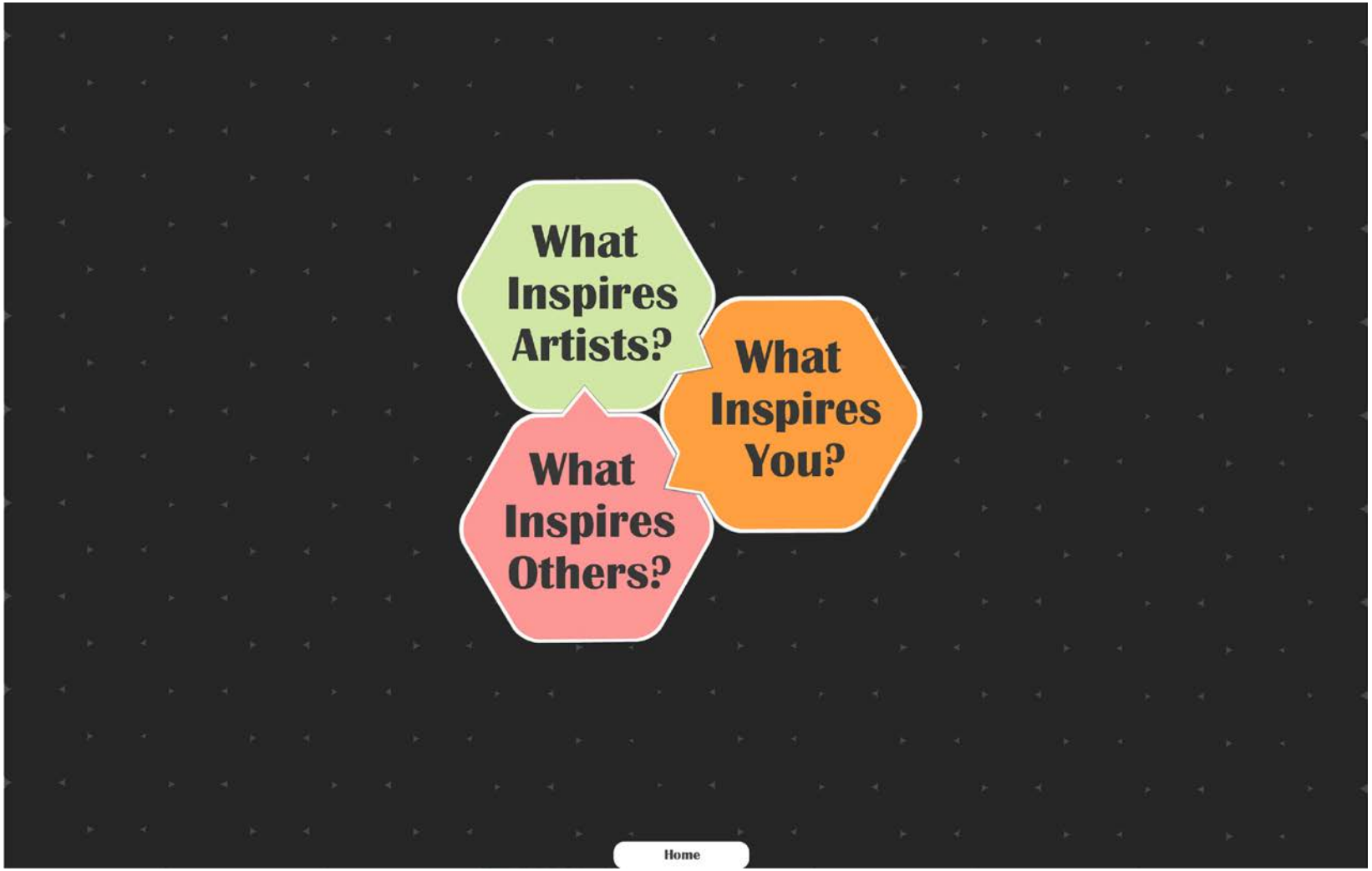


Figure 52. The main navigation screen for the three sections (no items selected).

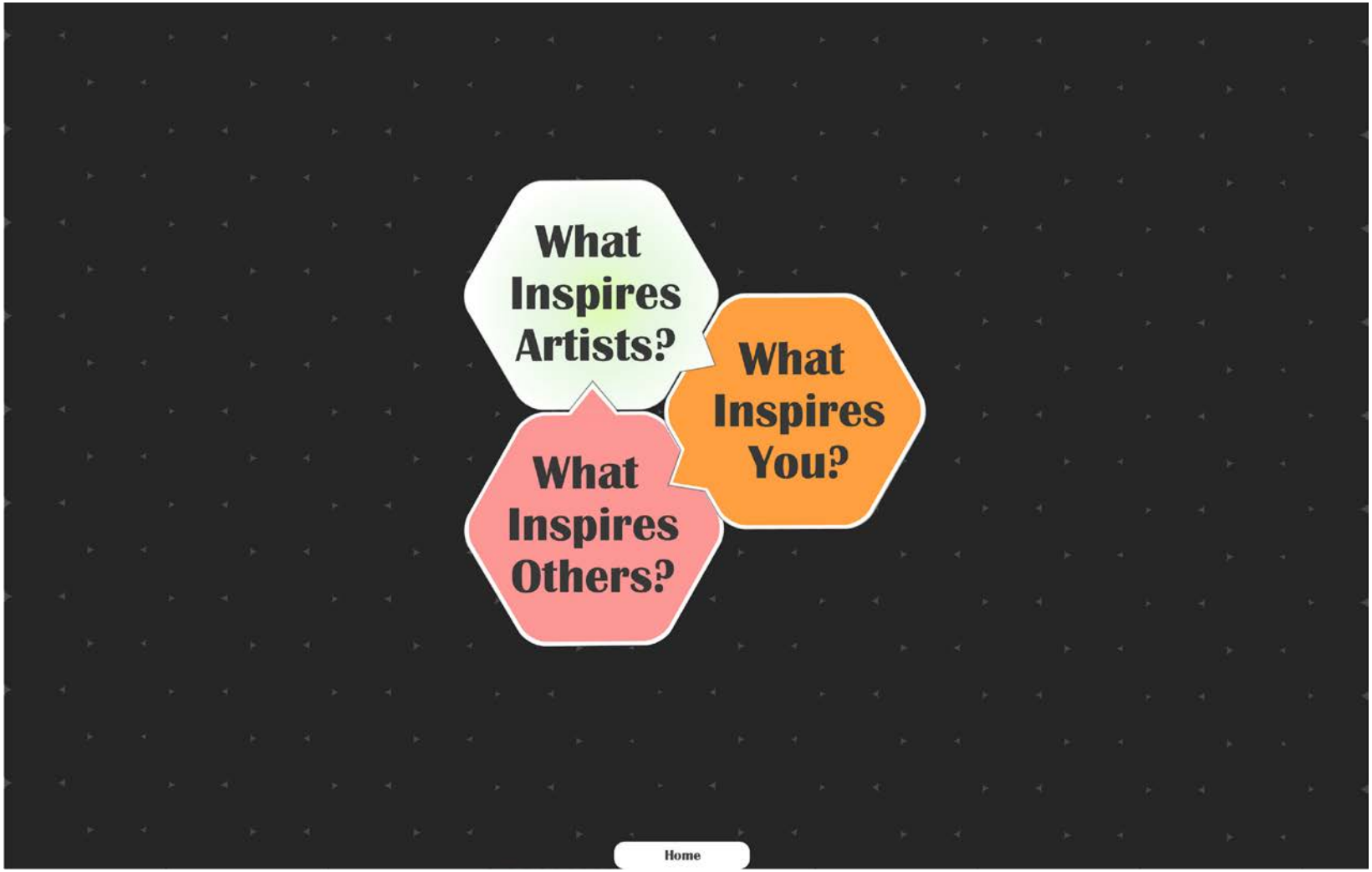


Figure 53. The main navigation screen for the three sections with "What Inspires Artists" selected.

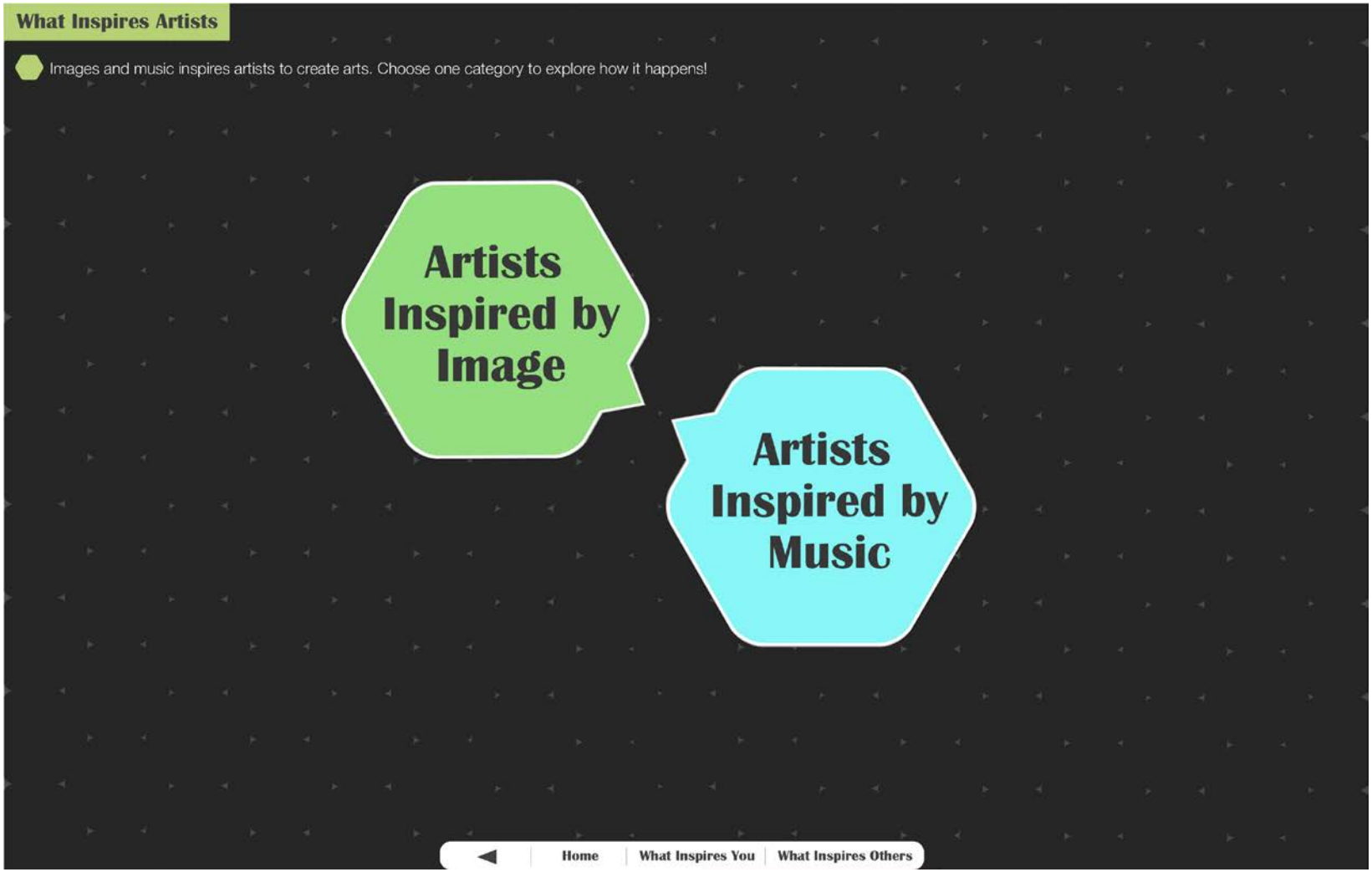


Figure 54. Navigation screen for the *learning* section.

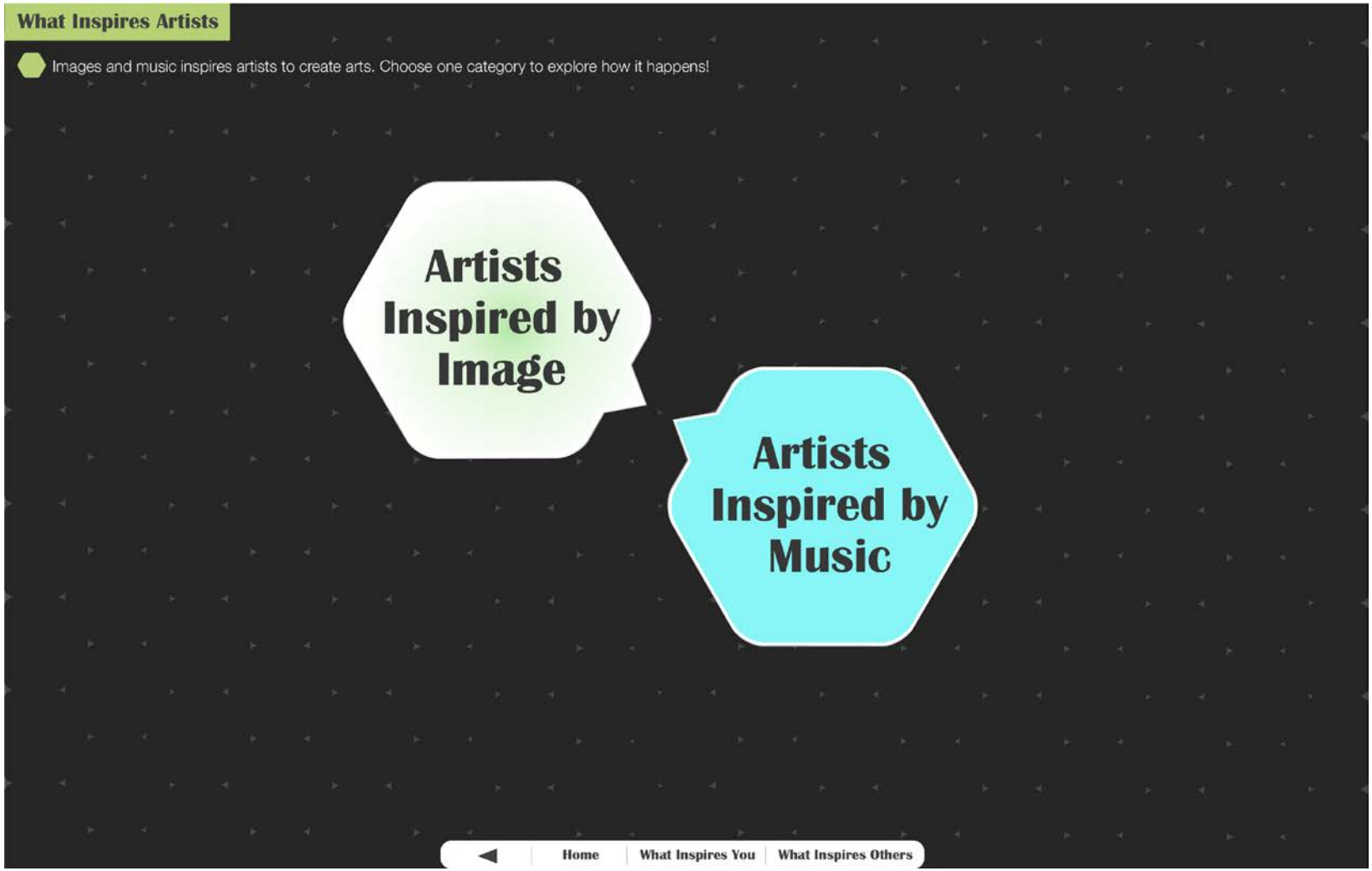


Figure 55. Navigation screen for the *learning* section with "Artists Inspired by Image" selected.

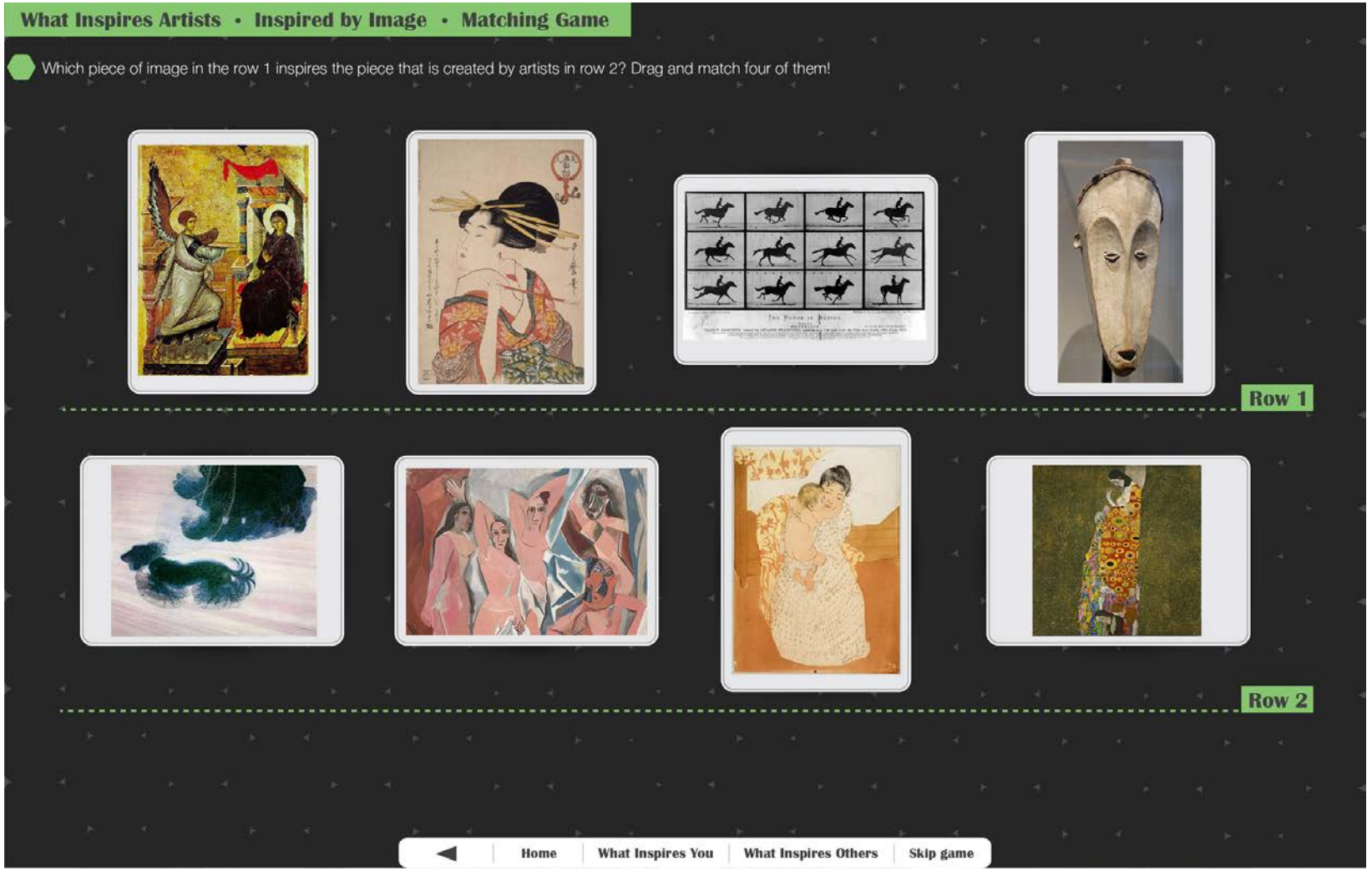


Figure 56. The *learning* section A-1: a warm-up matching game.

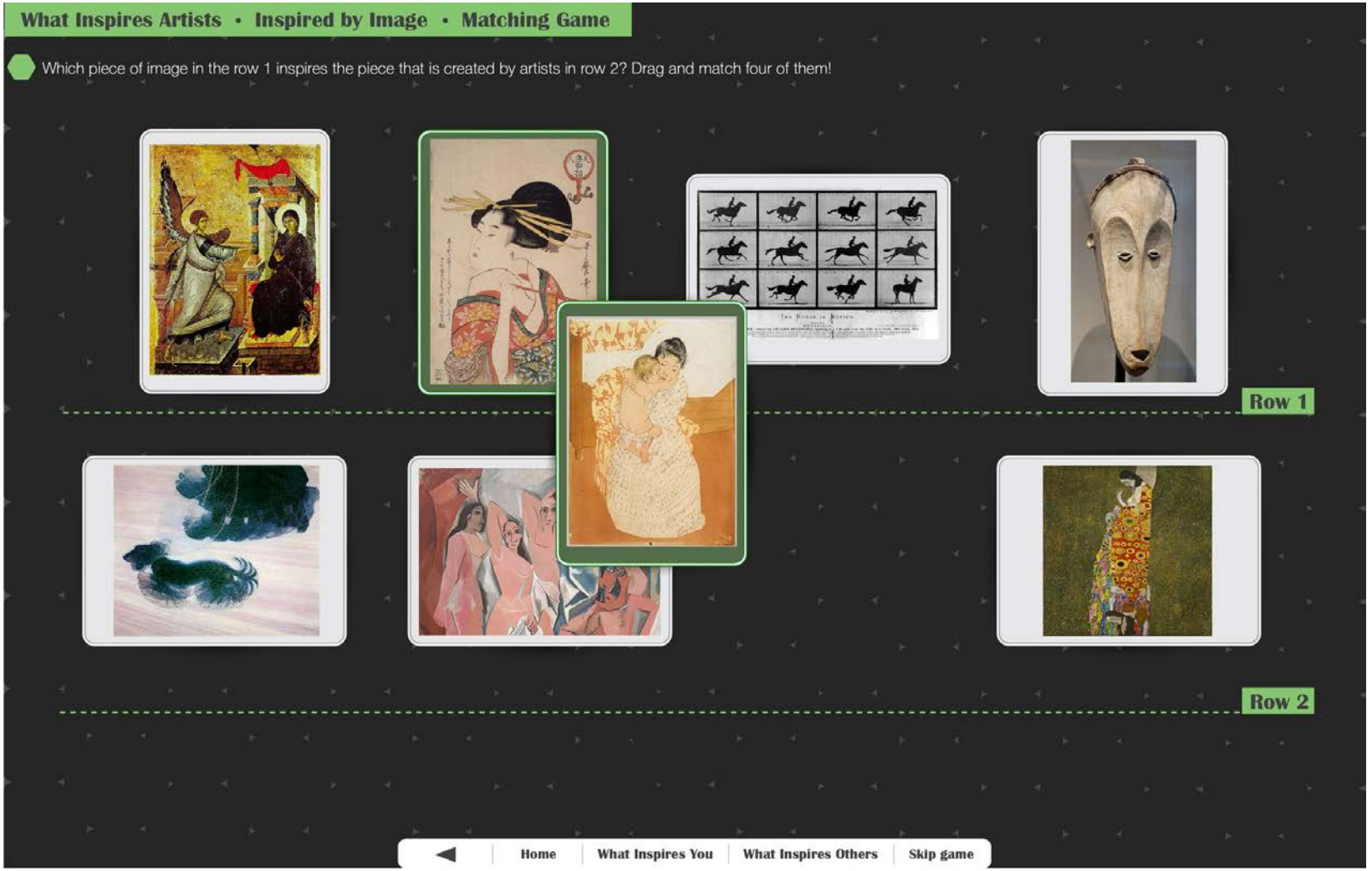


Figure 57. The *learning* section A-2: matching cards through the touch interface.

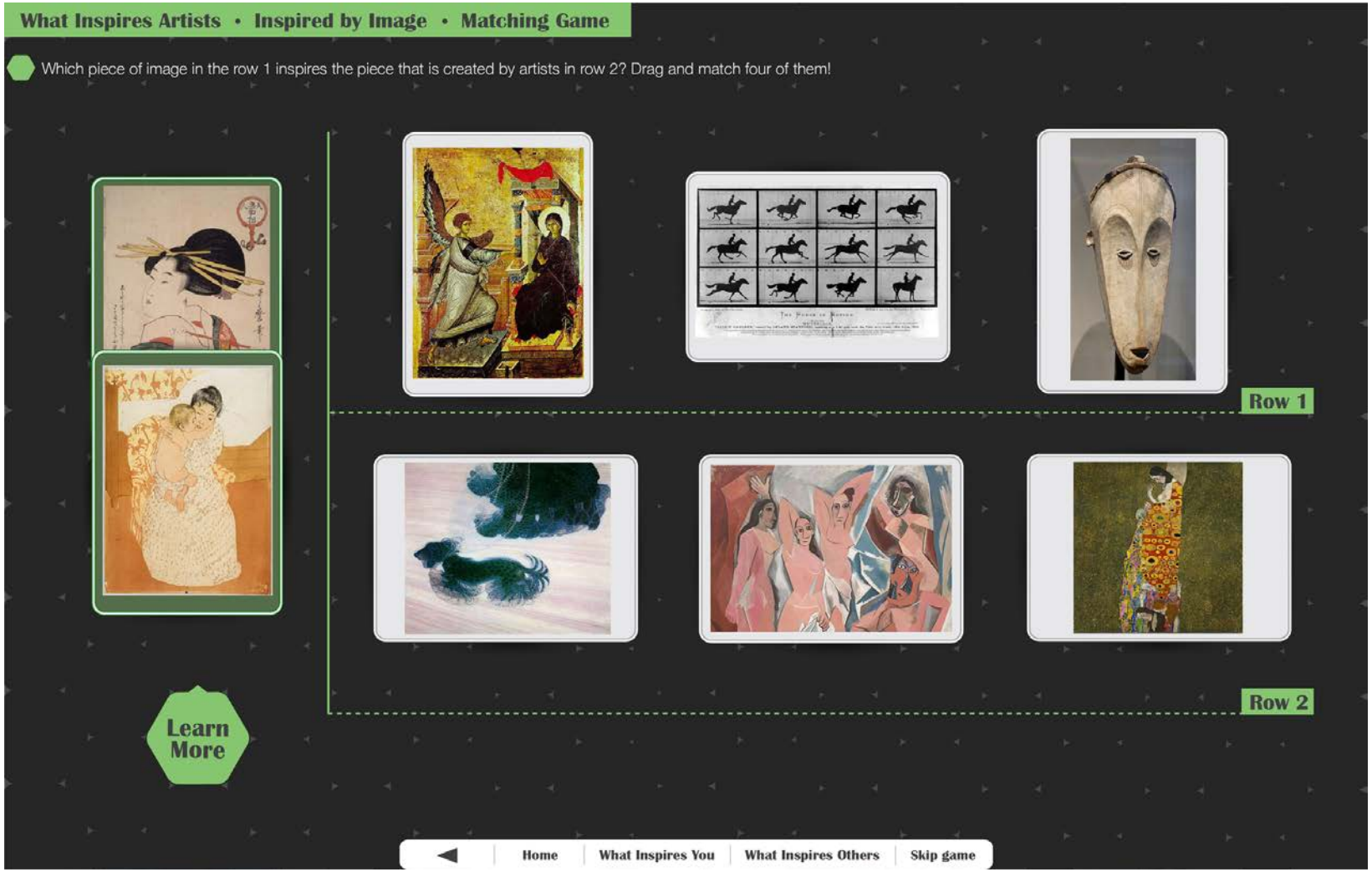


Figure 58. The *learning* section A-3: correctly matched cards.

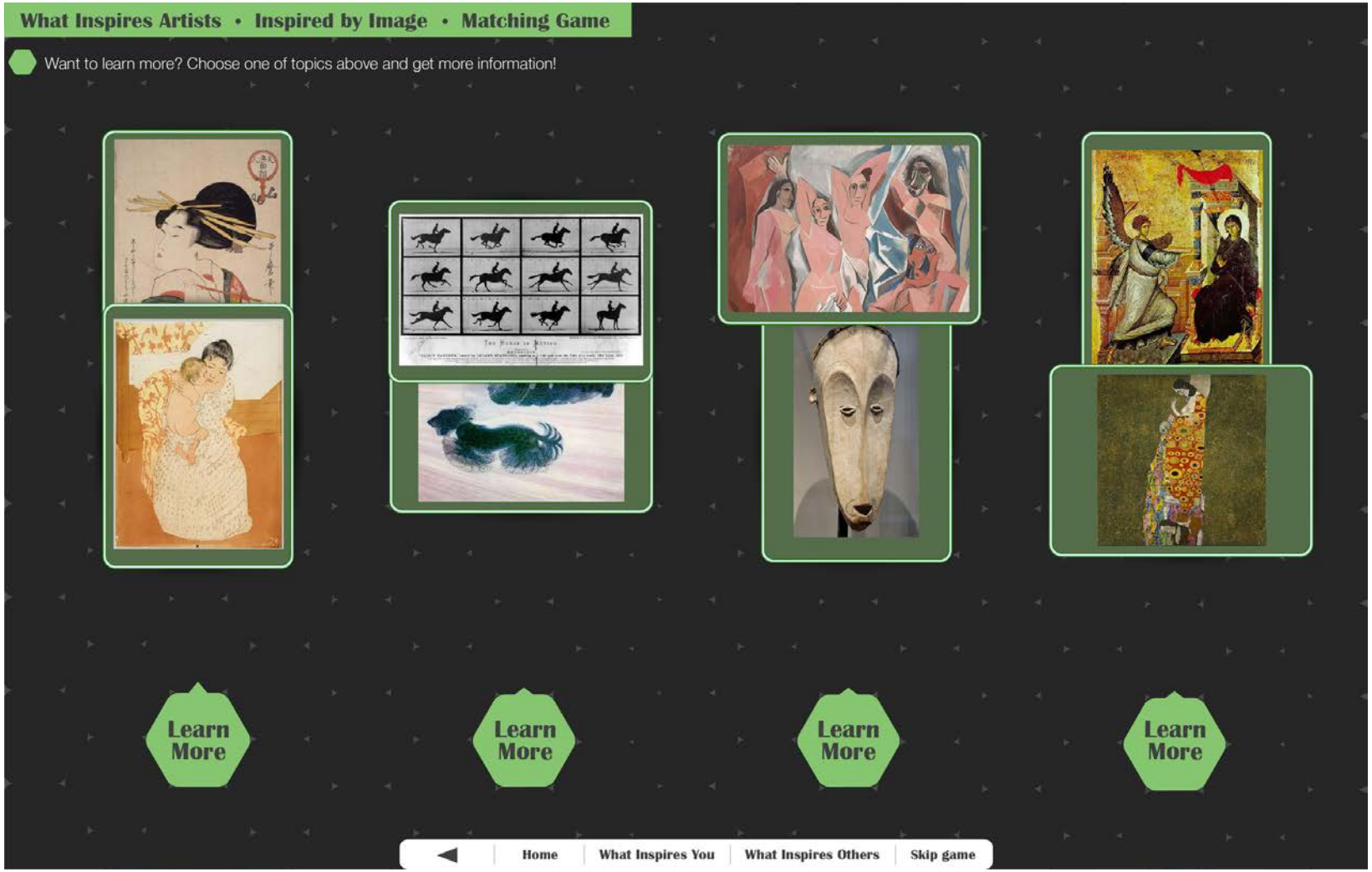


Figure 59. The *learning* section A-4: all cards correctly matched.

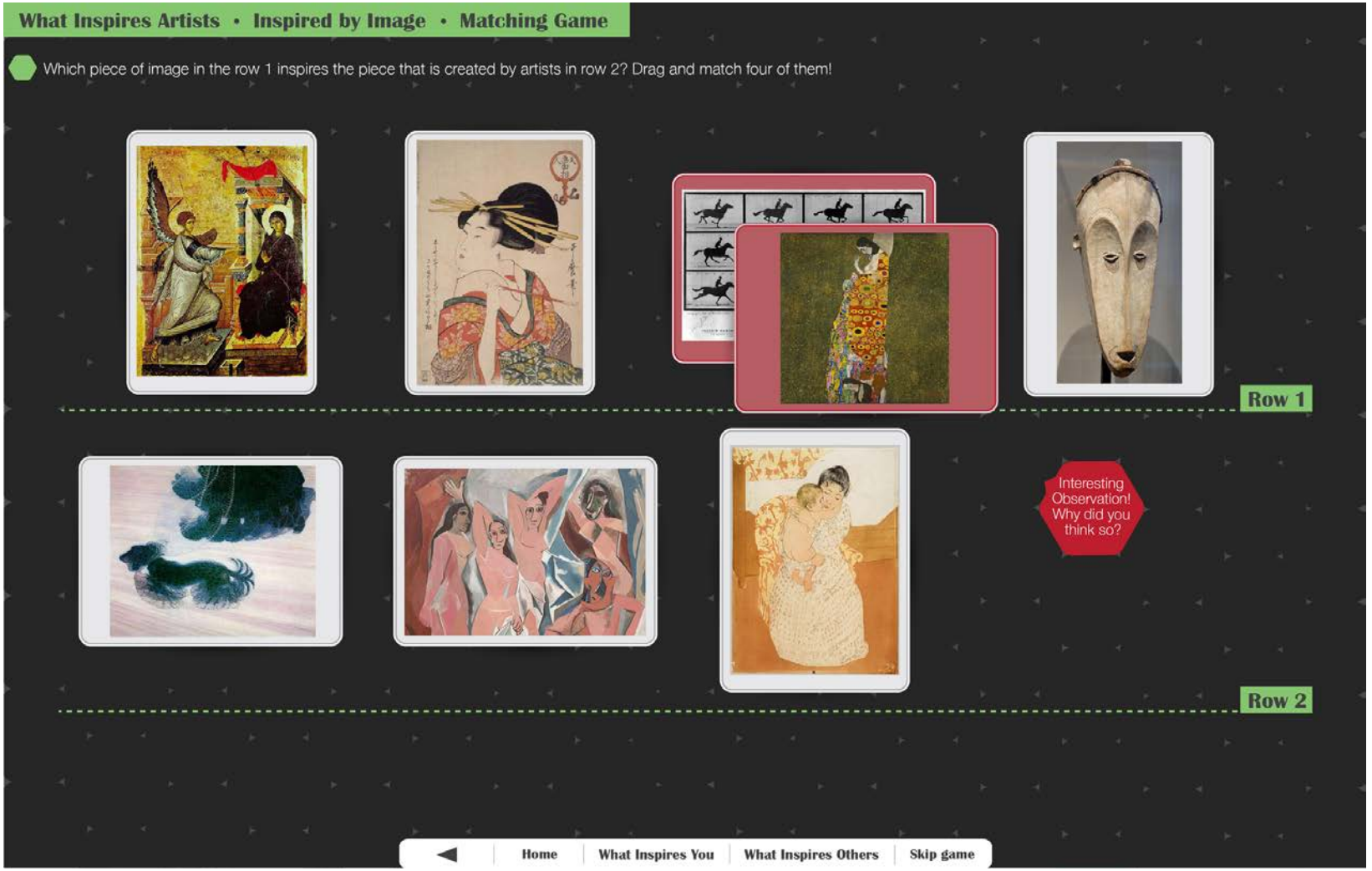


Figure 60. The *learning* section A-5: an incorrect match.

Figure 61. The *learning* section A-6: additional learning material about the inspiration of artists, such as Picasso.

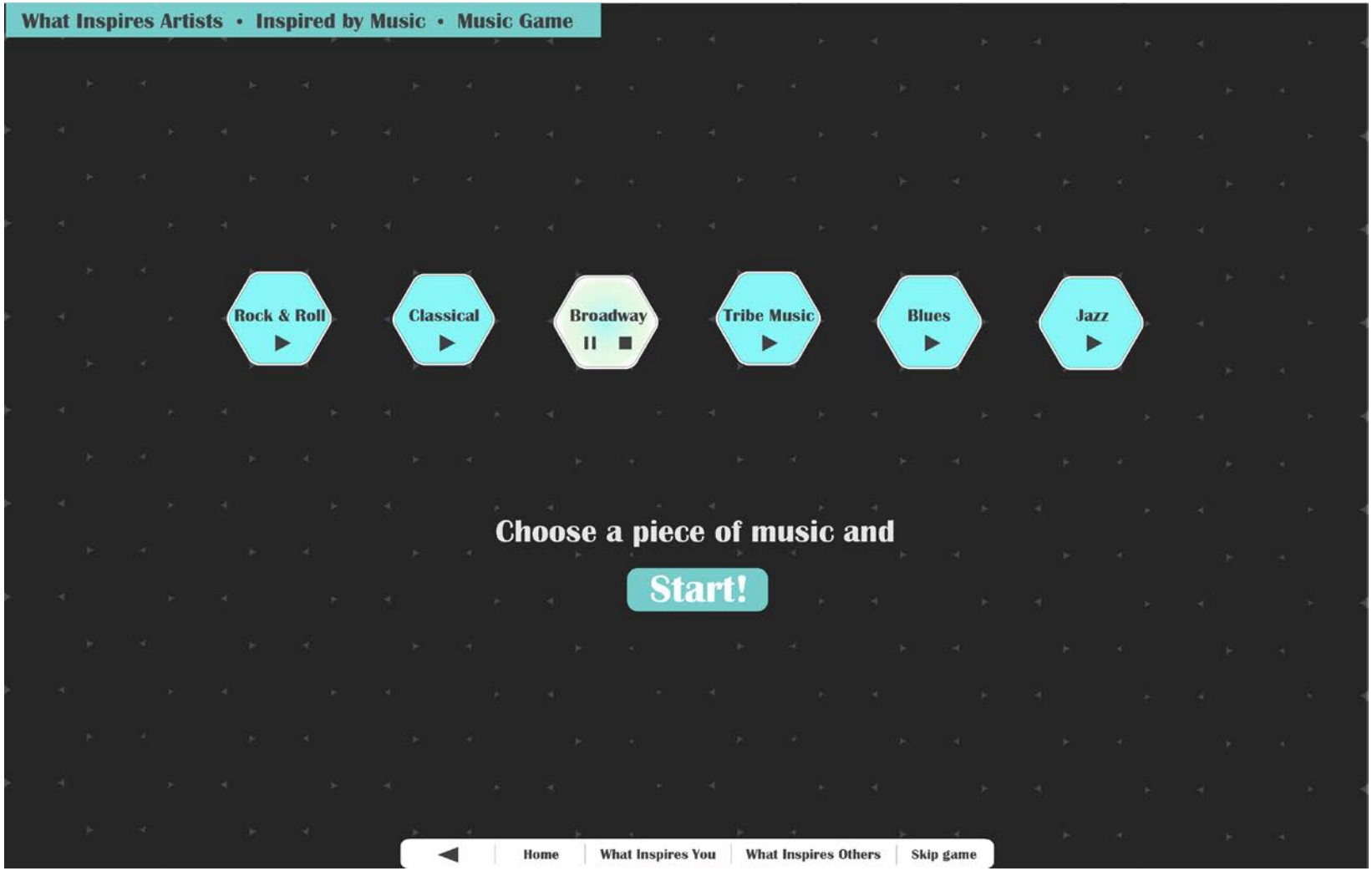


Figure 62. The *learning* section B-1: the music-based warm-up activity.

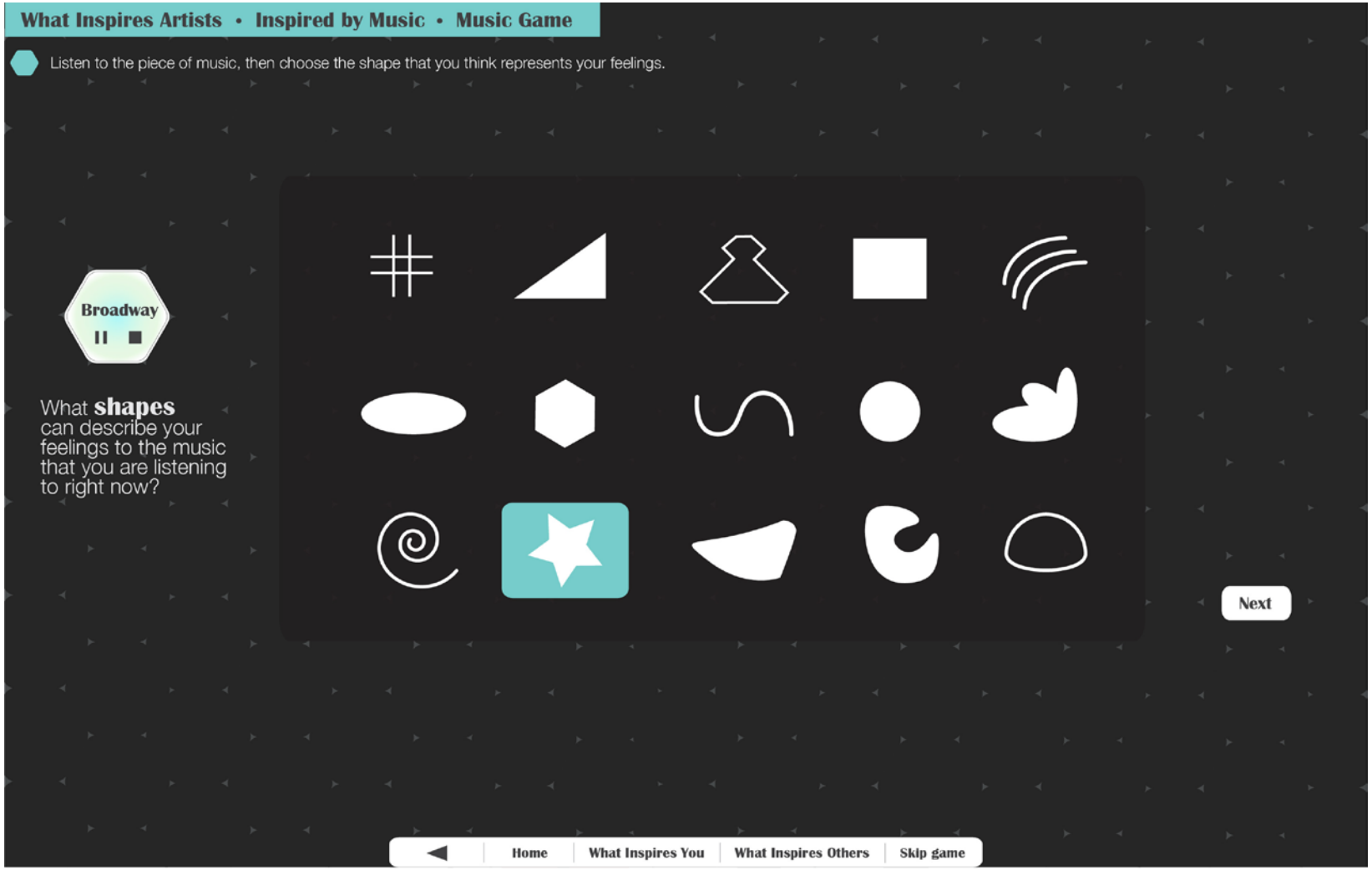


Figure 63. The *learning* section B-2: Connecting shapes with how music makes the listener feel.

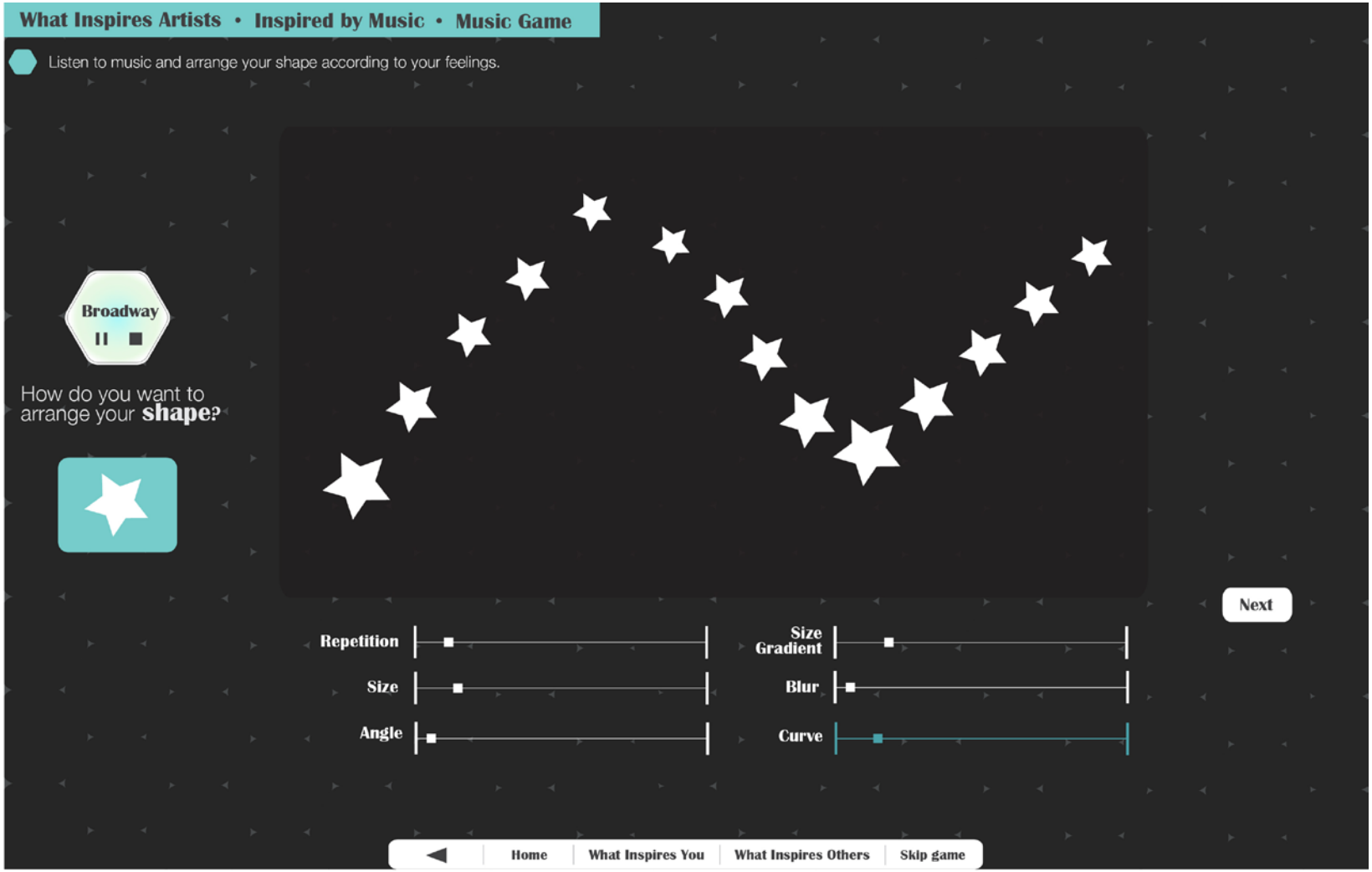


Figure 64. The *learning* section B-3: arranging shapes.

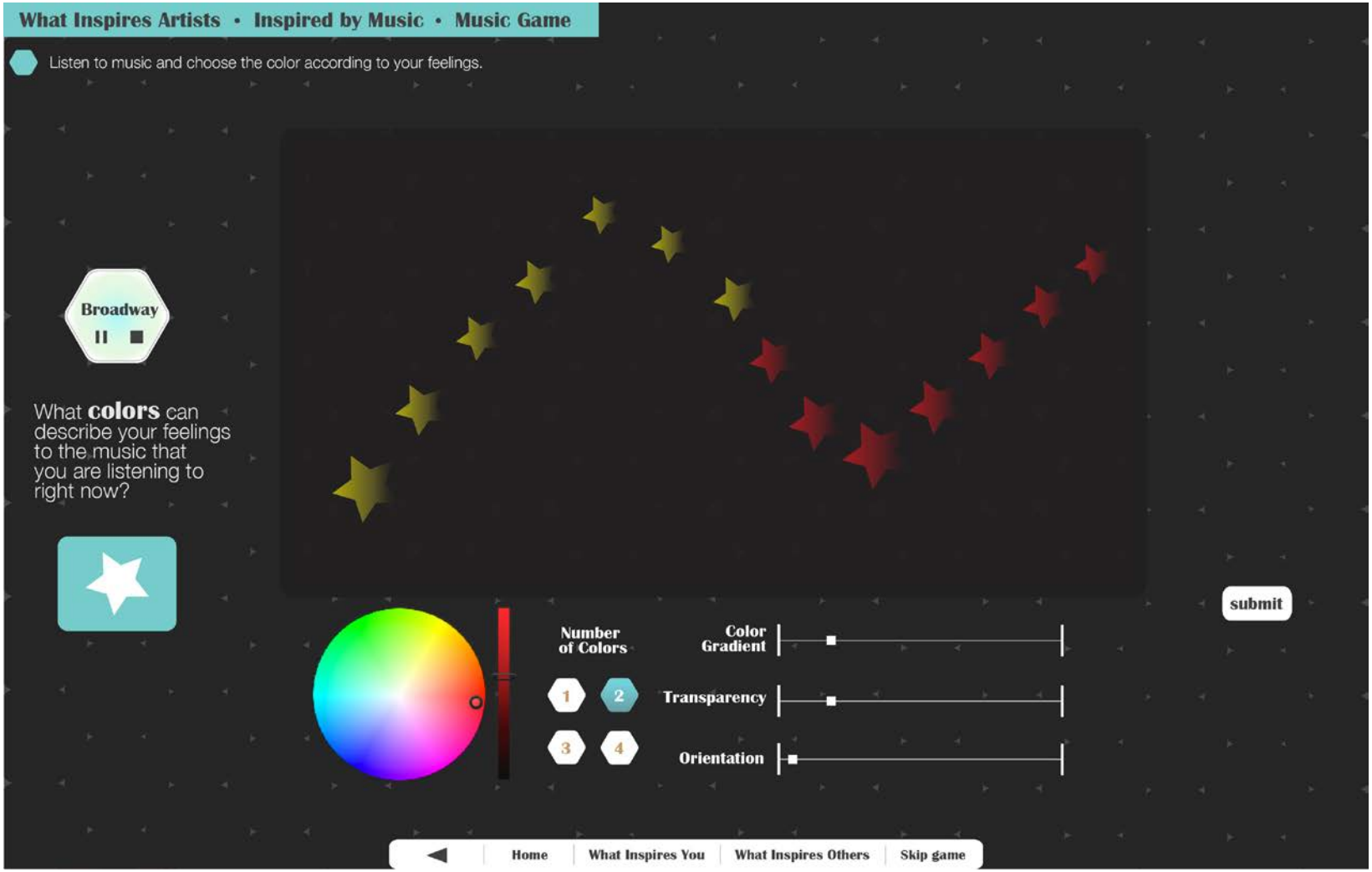


Figure 65. The *learning* section B-4: adding color to shapes.

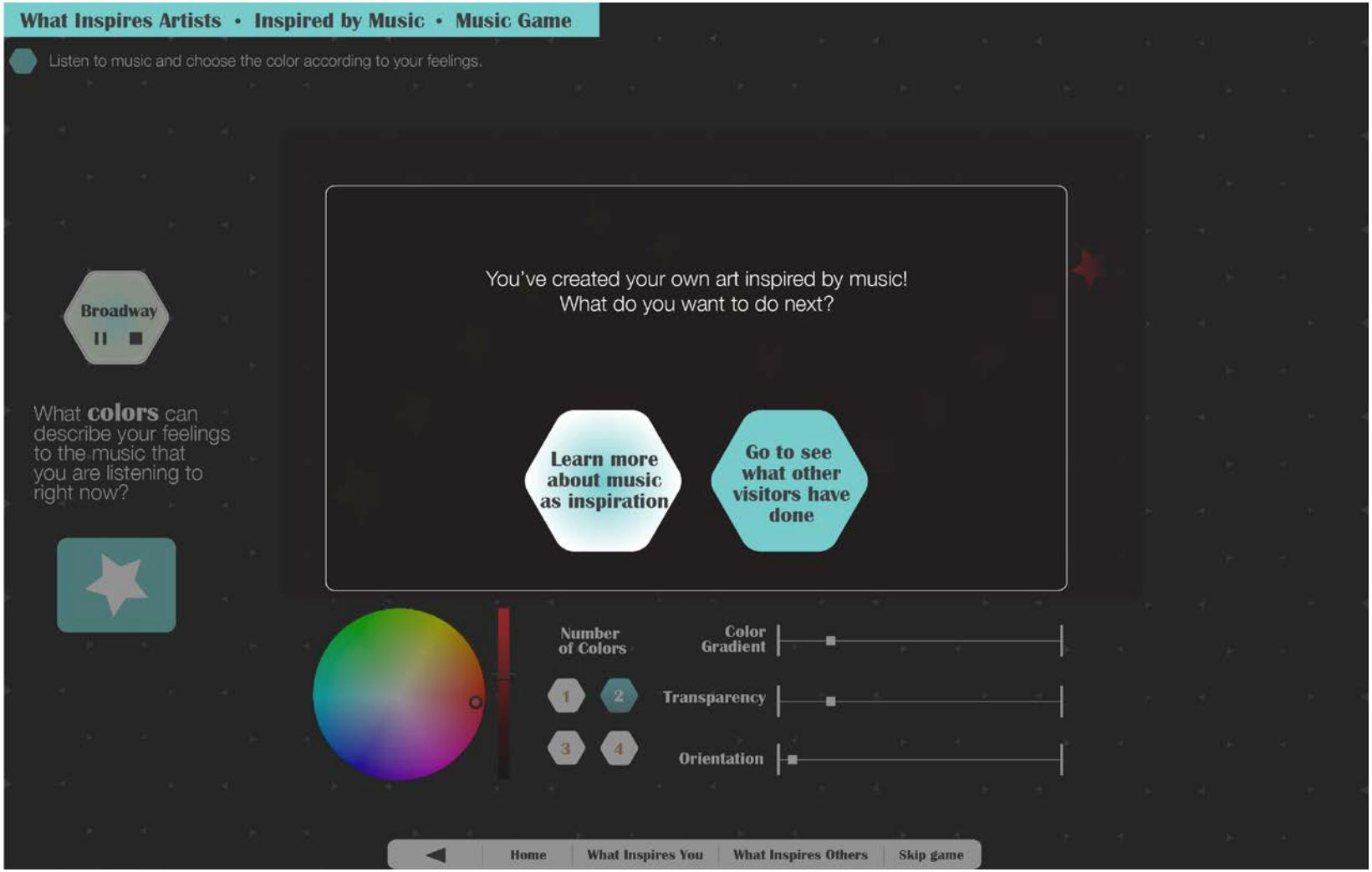


Figure 66. The *learning* section B-5: completed user-created music-inspired art with "learn more" selected.

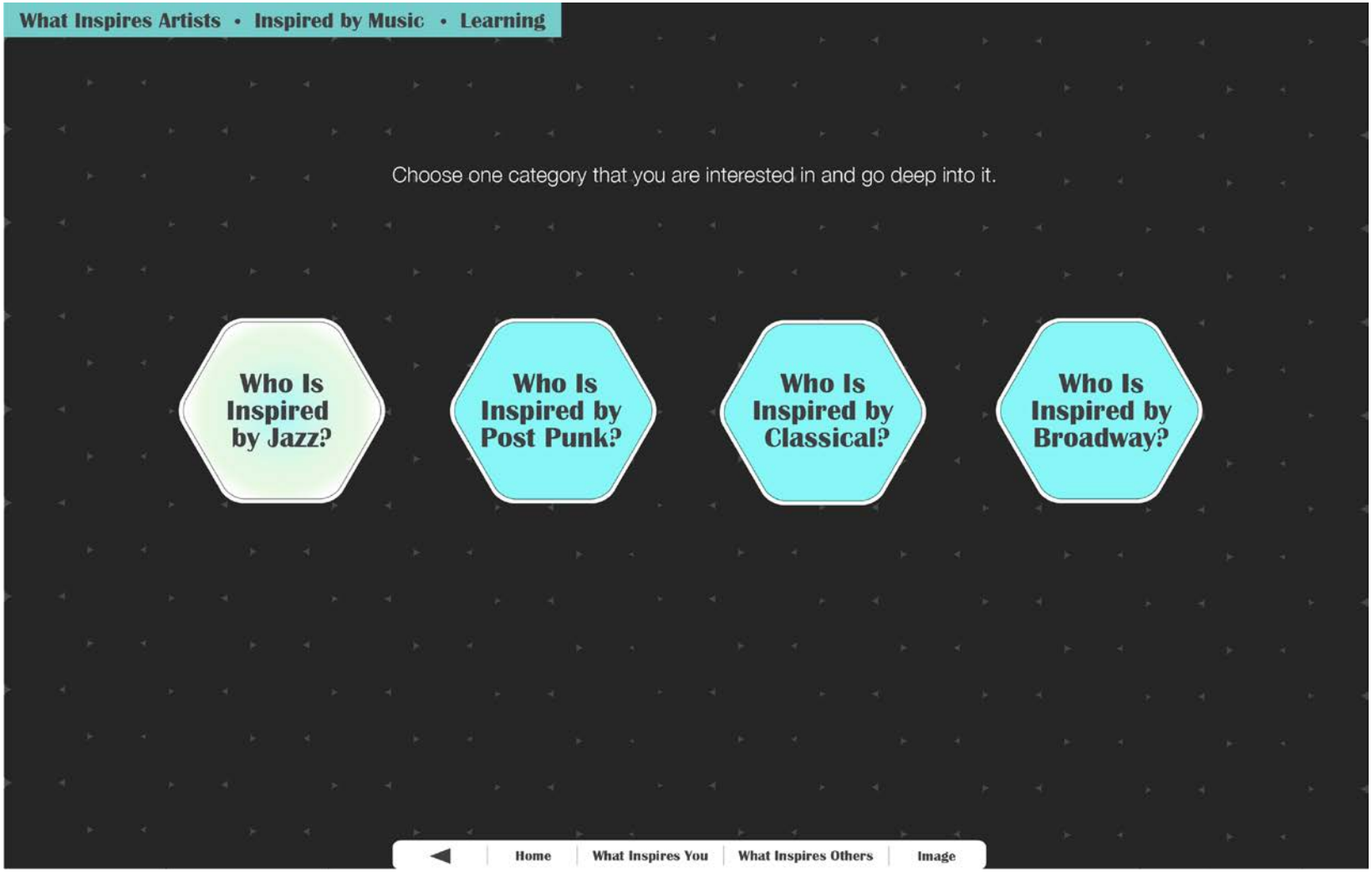


Figure 67. The *learning* section B-6: the navigation screen for music-based learning material.

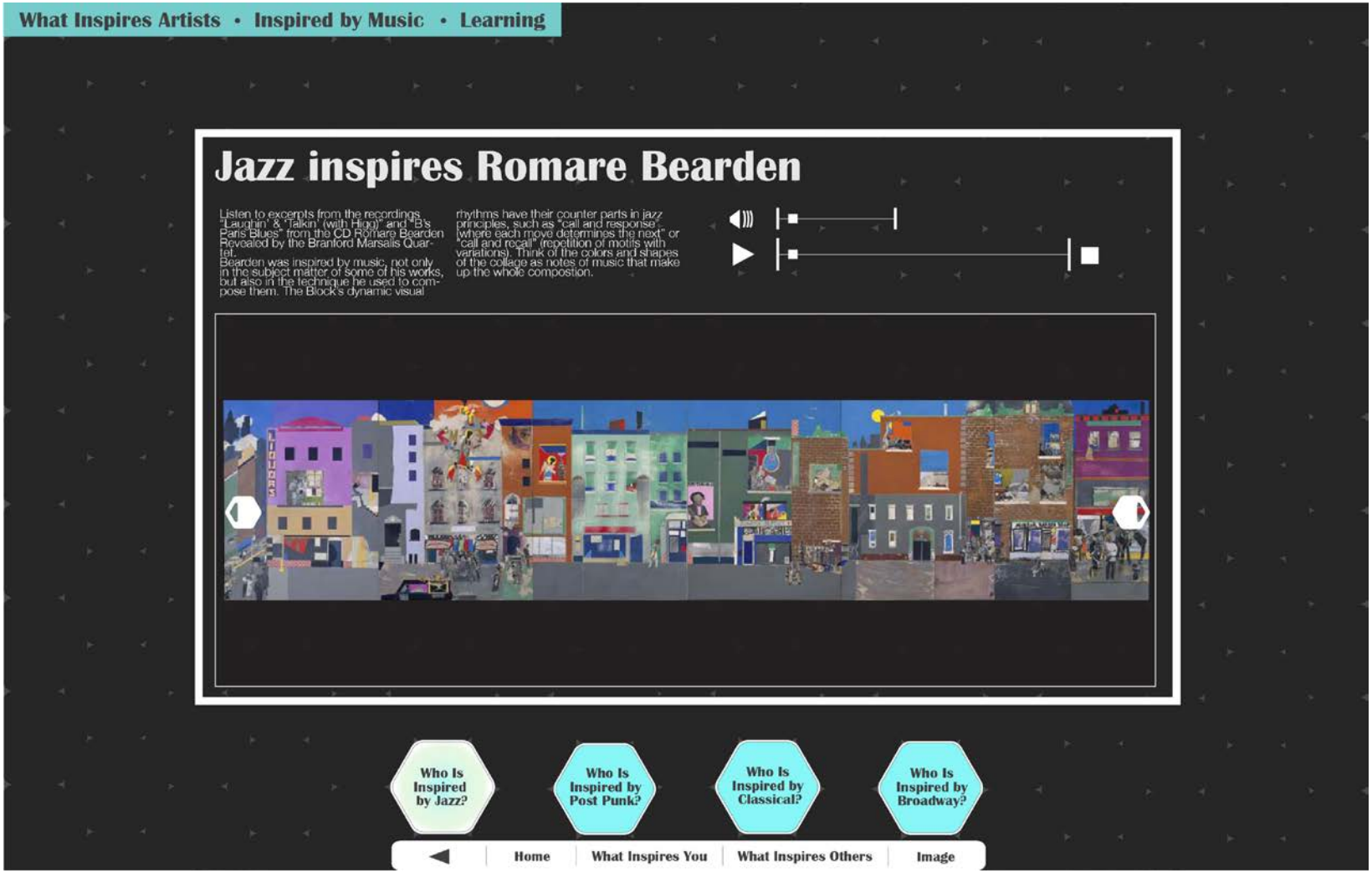


Figure 68. The *learning* section B-7: available learning material for a music-inspired artist.

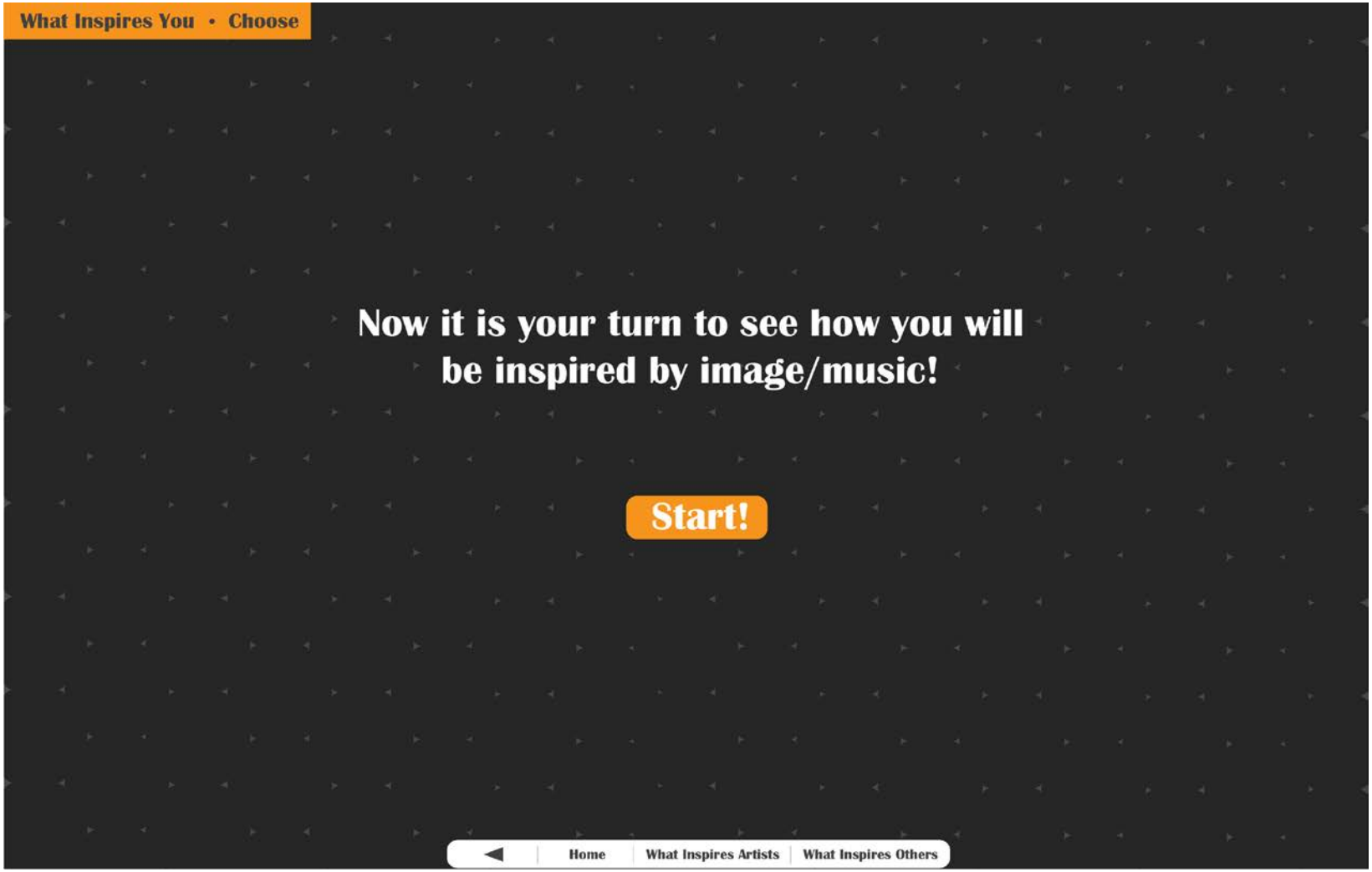


Figure 69. The *doing* section: The welcoming screen of "What Inspires You."

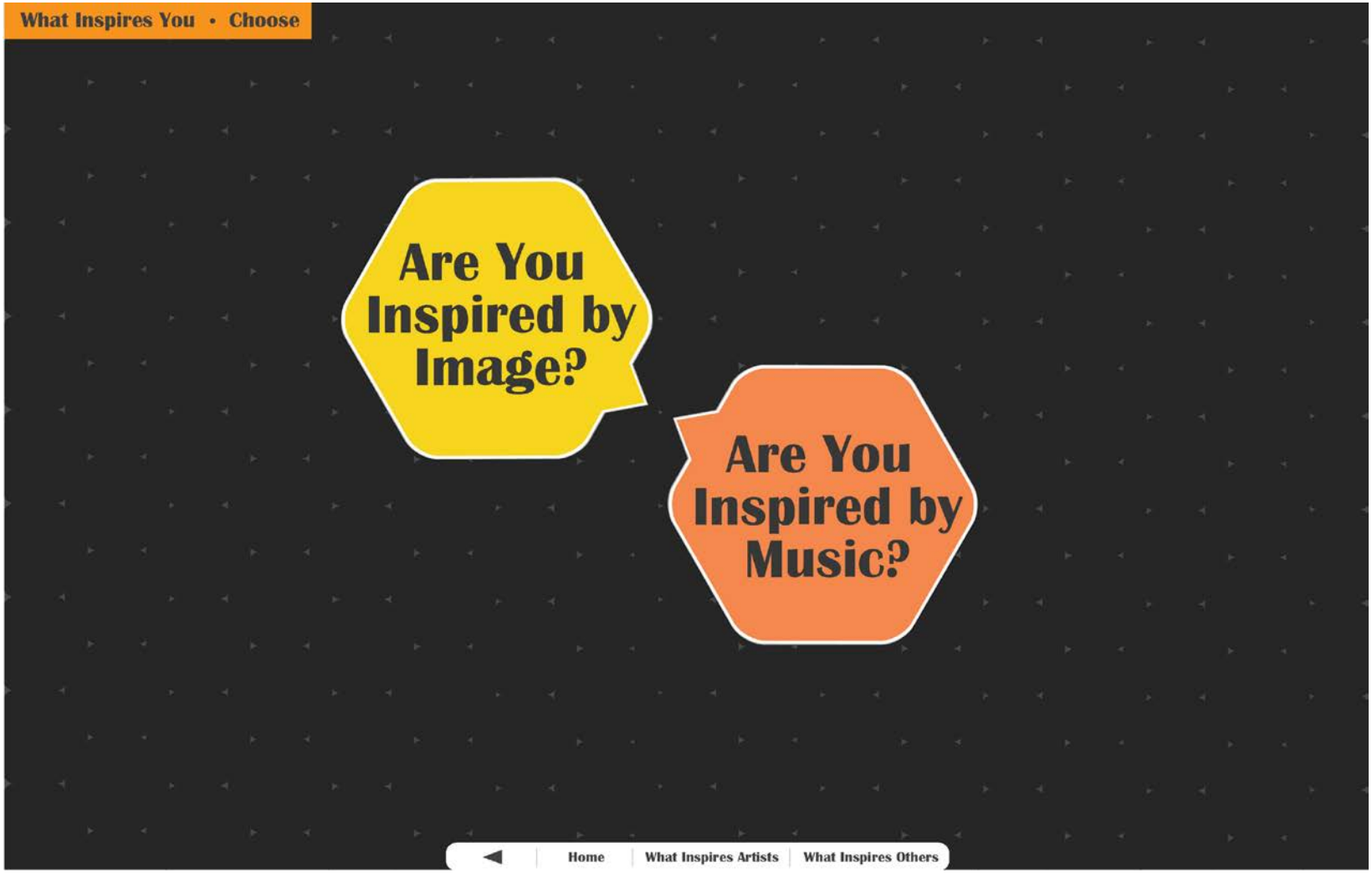


Figure 70. The *doing* section: Navigation screen.

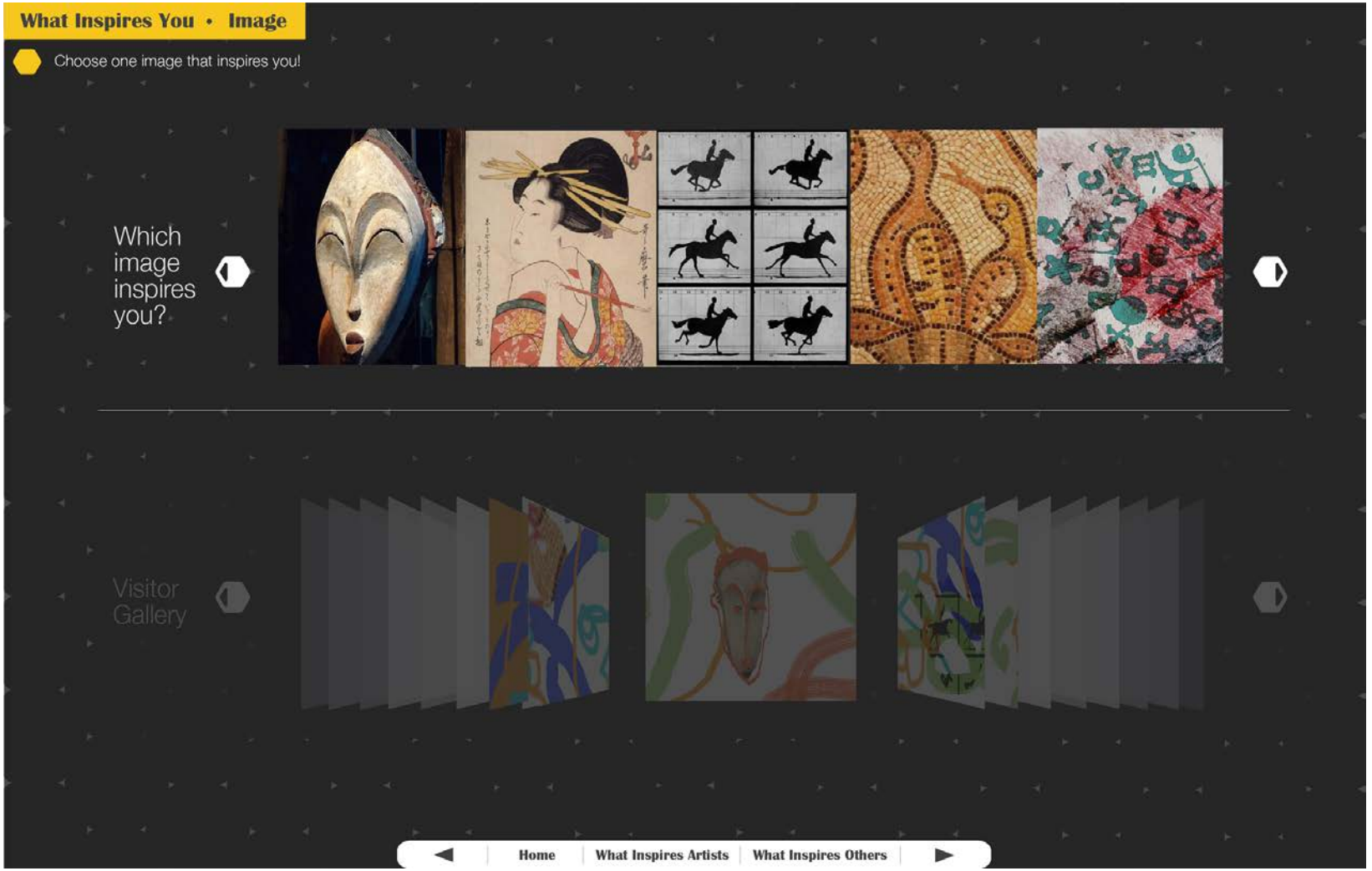


Figure 71. The *doing* section A-1: images available to inspire the user.

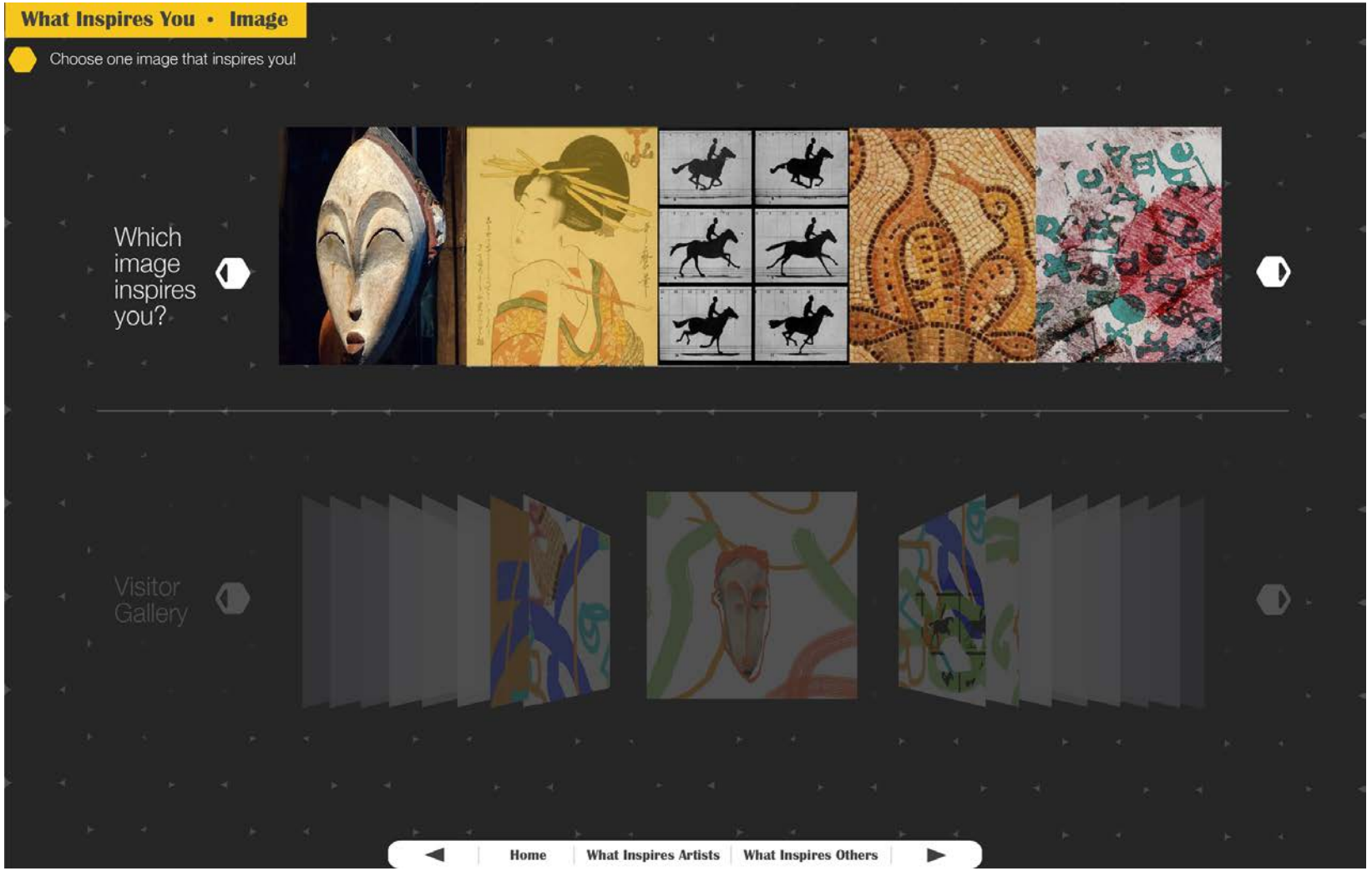


Figure 72. The *doing* section A-2: an item from the top row selected.

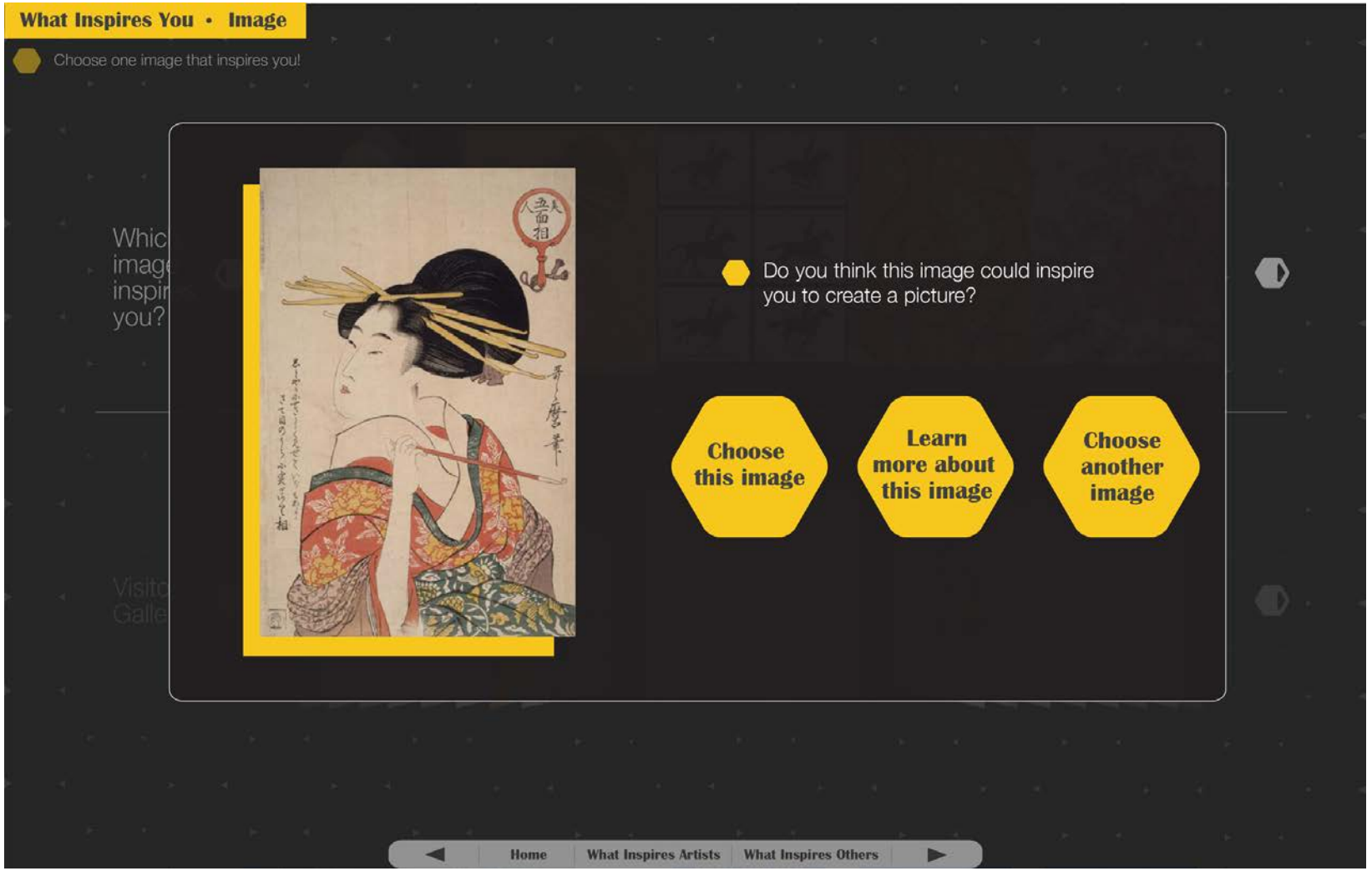


Figure 73. The *doing* section A-3: Window with user options pops up after image selection.

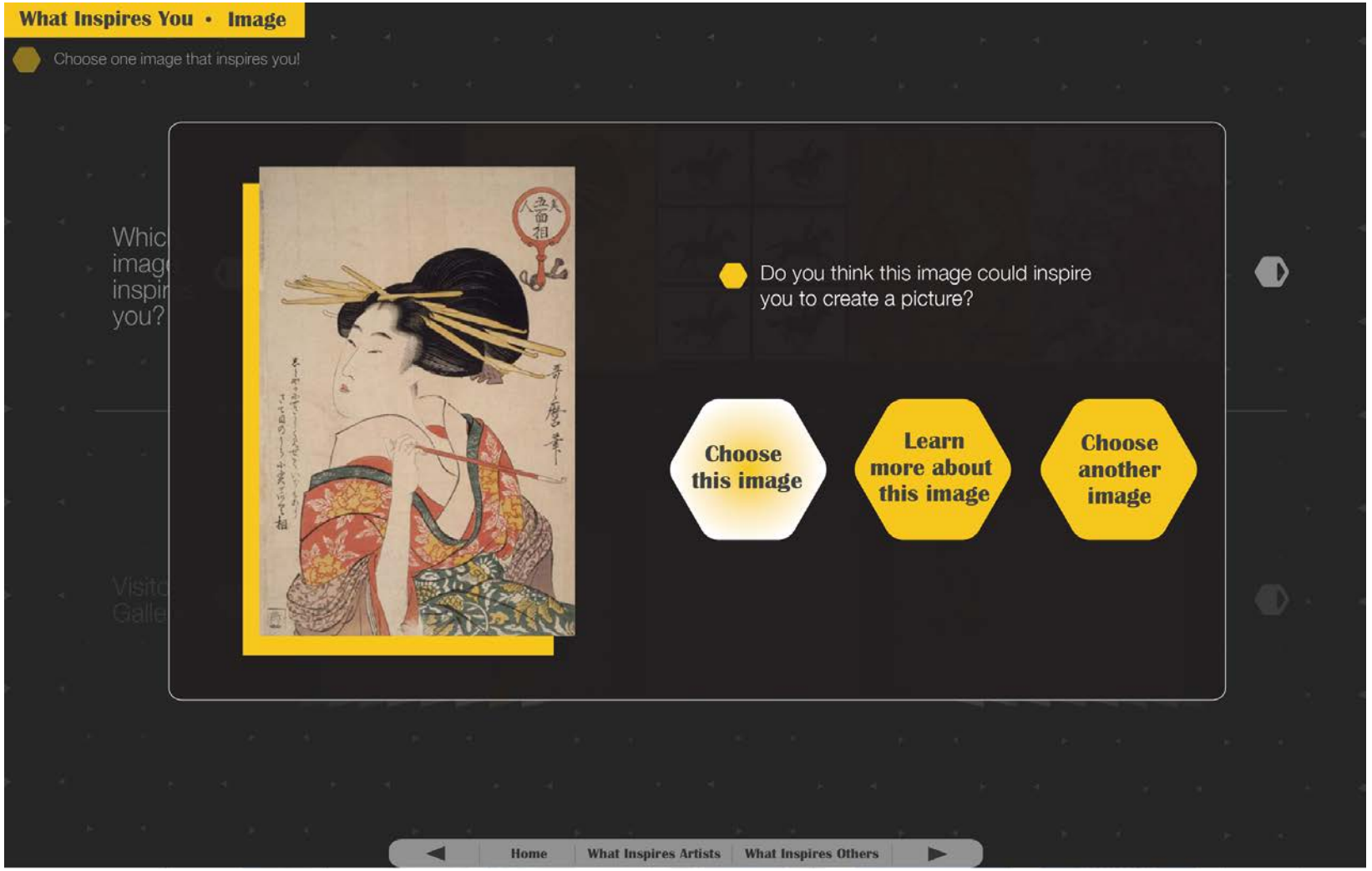


Figure 74. The *doing* section A-4: pop-up interface with "Choose this image" selected.

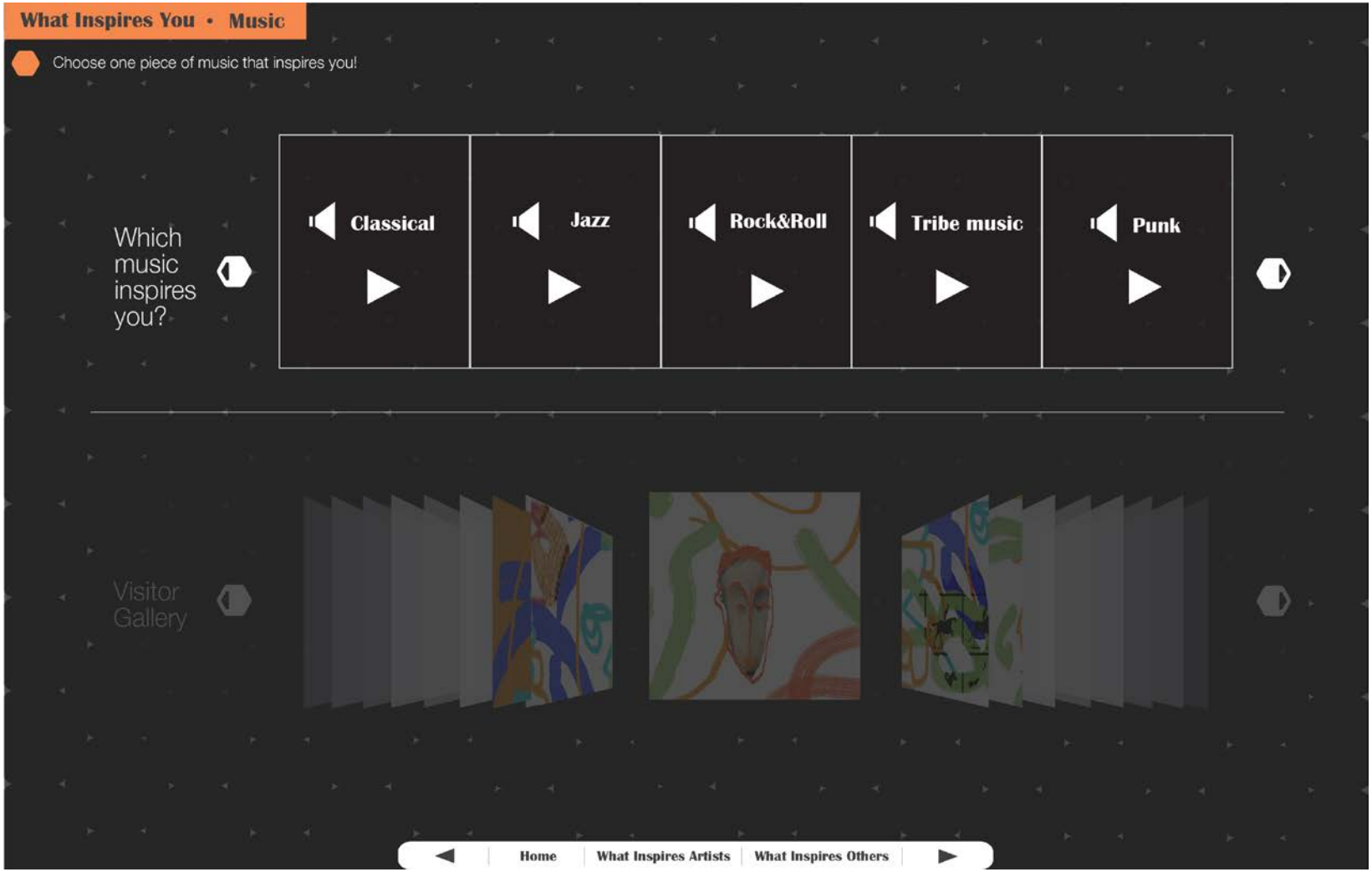


Figure 75. The *doing* section B-1: interface for selecting music for inspiration (follows screen shown in Figure 70.

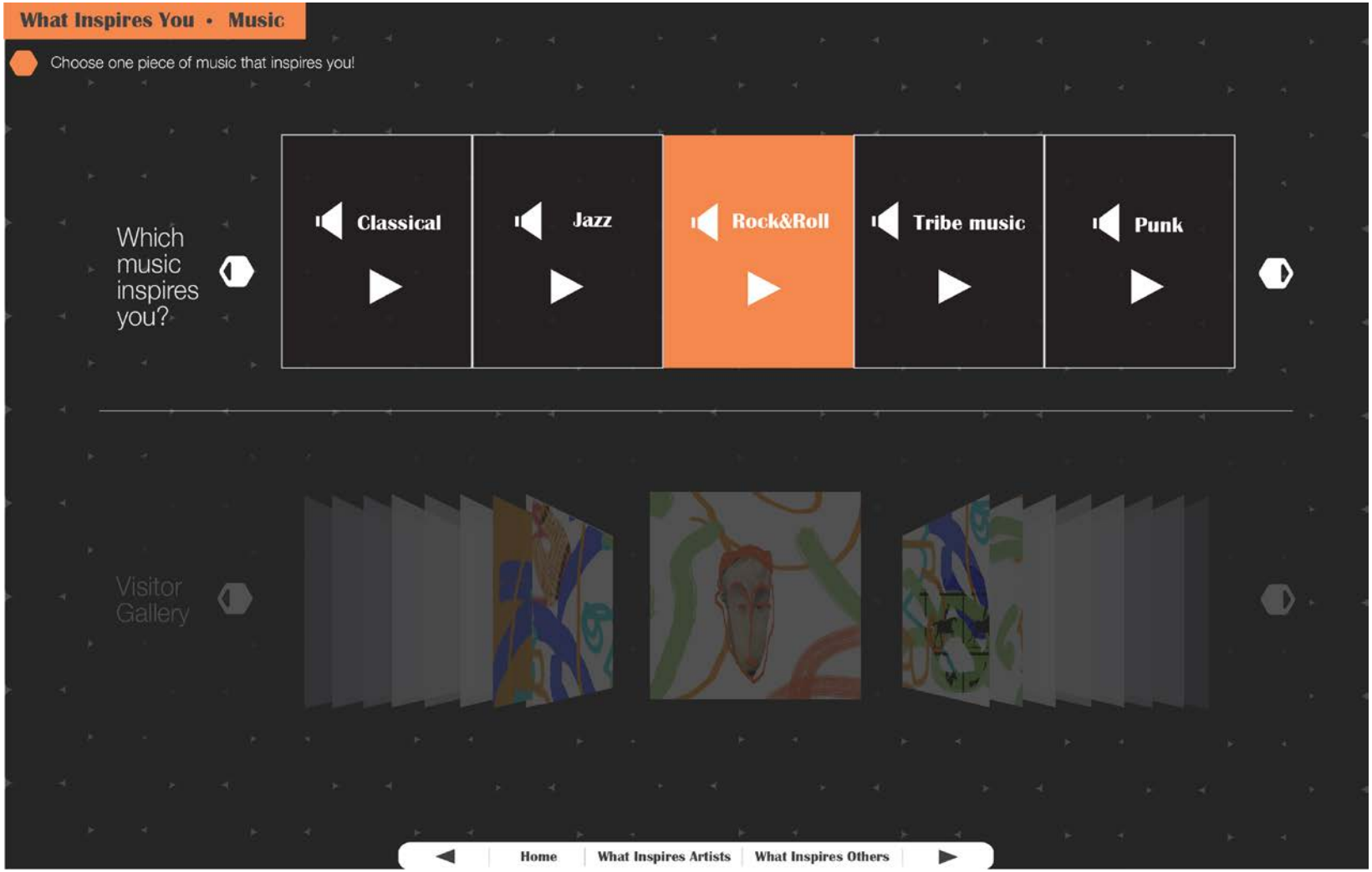


Figure 76. The *doing* section B-2: interface when a piece of music is selected.

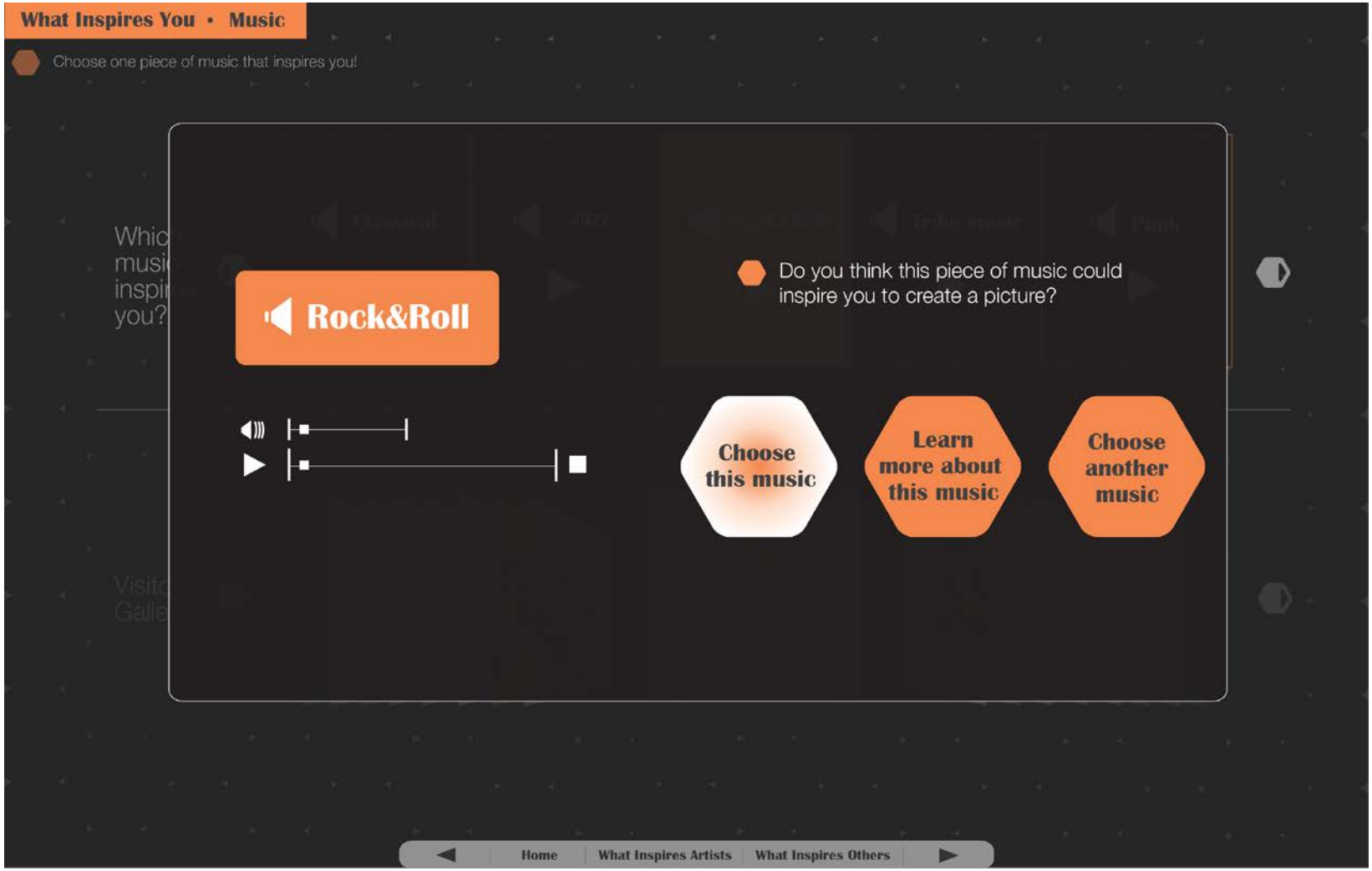


Figure 77. The *doing* section B-3: Window with user options pops up after music selection.

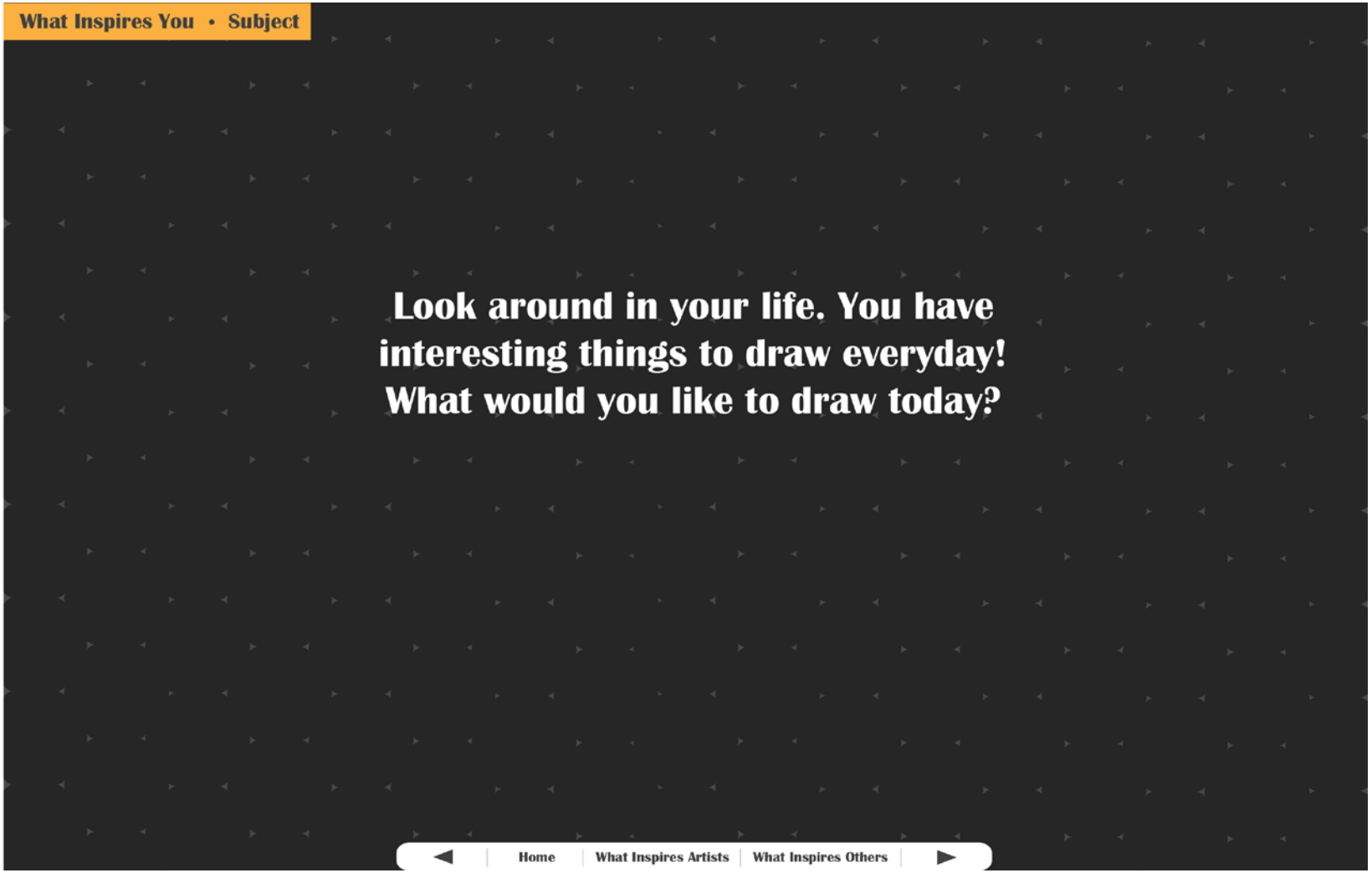


Figure 78. The *doing* section C-1: Transition from image or music to subject.

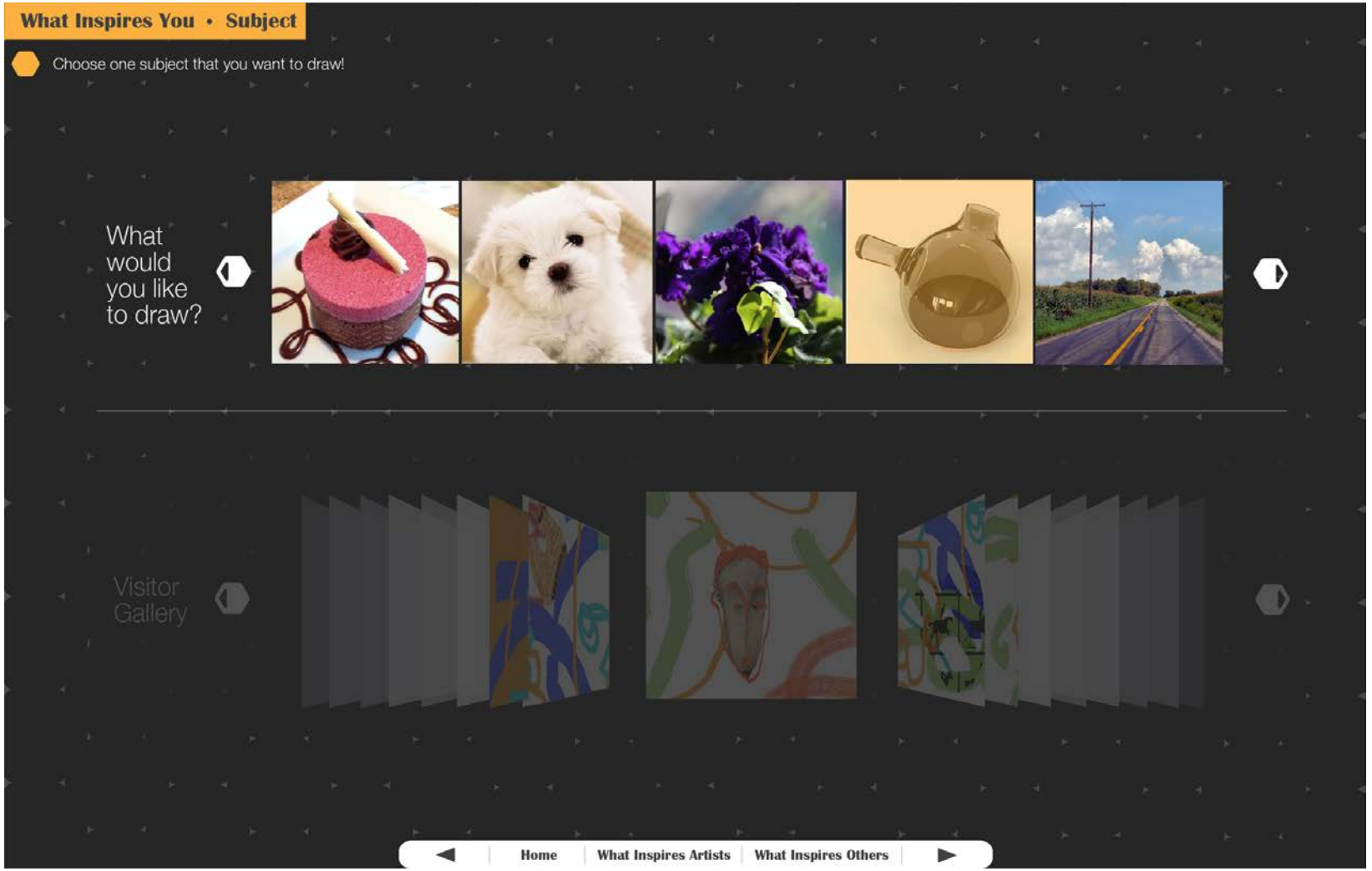


Figure 79. The *doing* section C-2: subject interface.

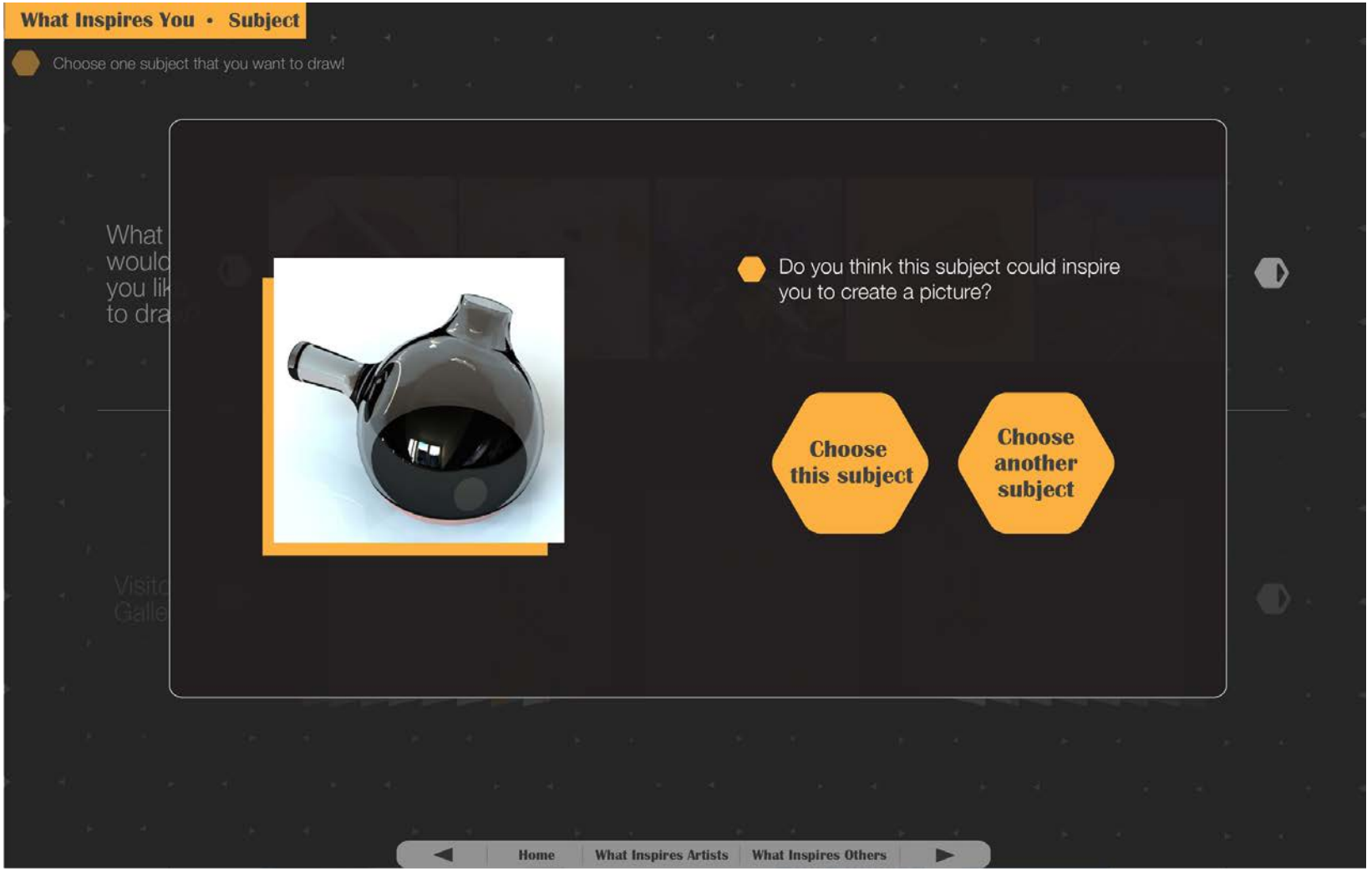


Figure 80. The *doing* section C-3: Window with user options pops up after subject selection.

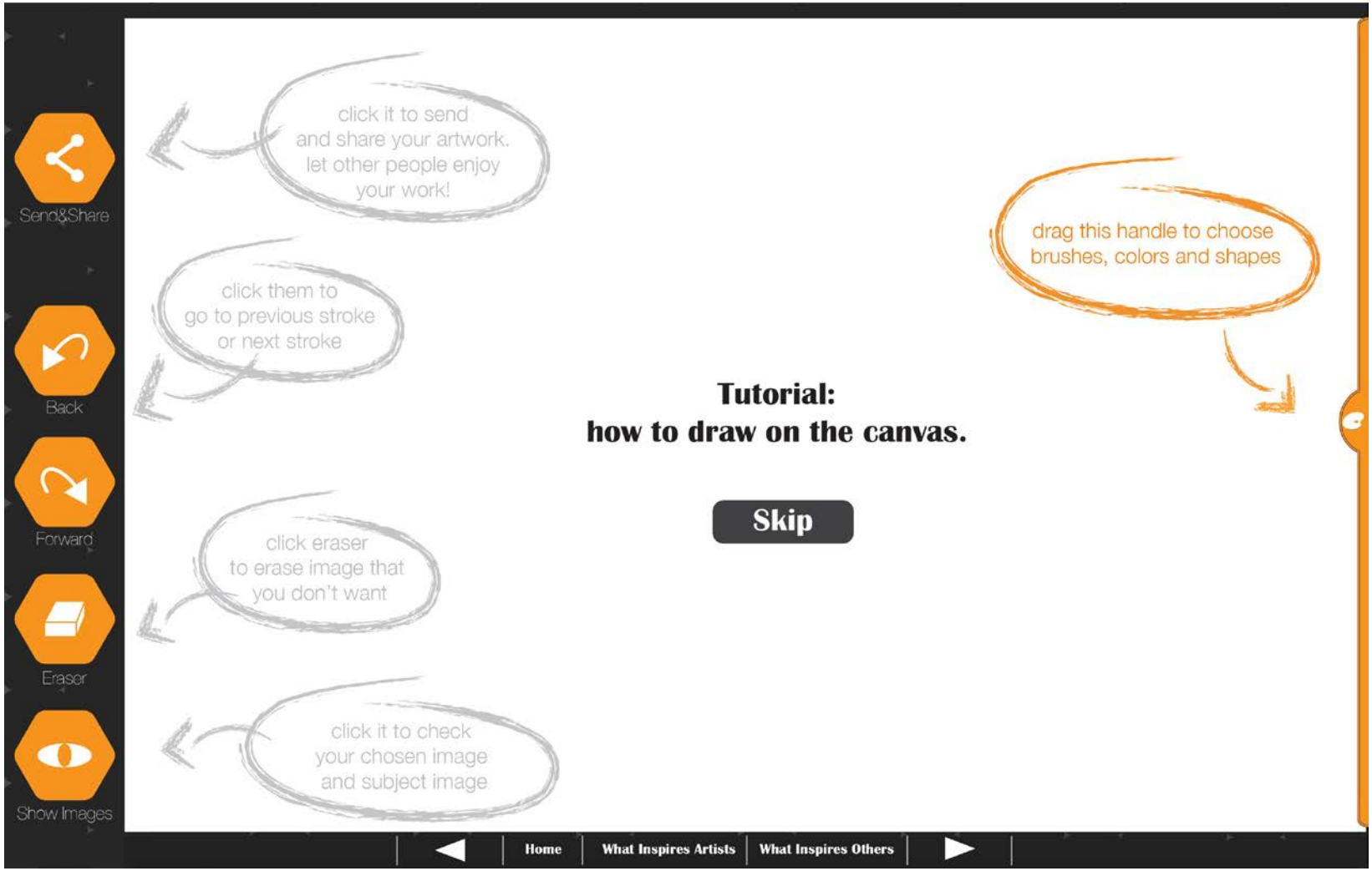


Figure 81. The *doing* section D-1: screenshot from animated tutorial for drawing step.

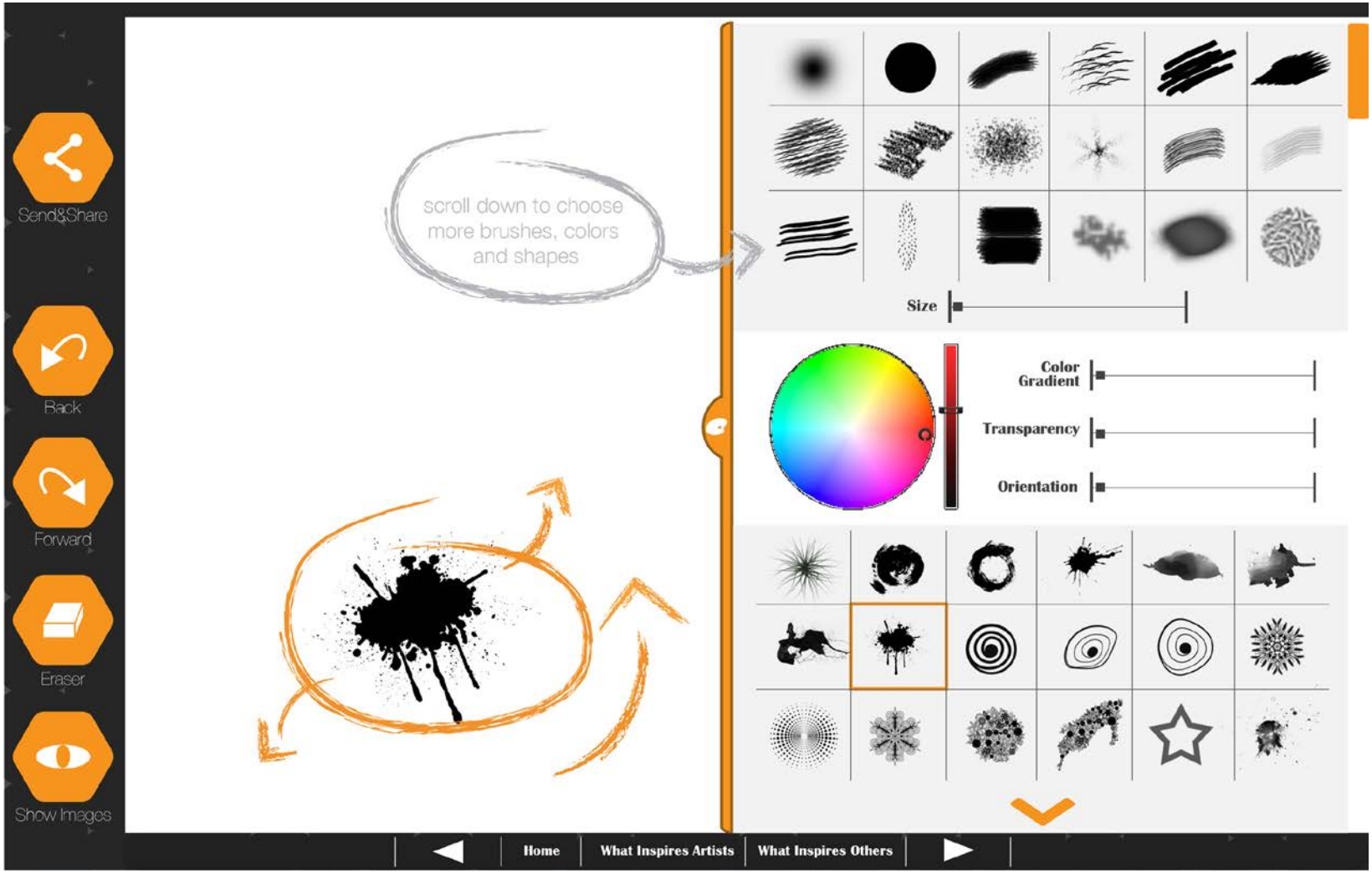


Figure 82. The *doing* section D-2: second screenshot from tutorial, guiding visitor through available drawing tools.

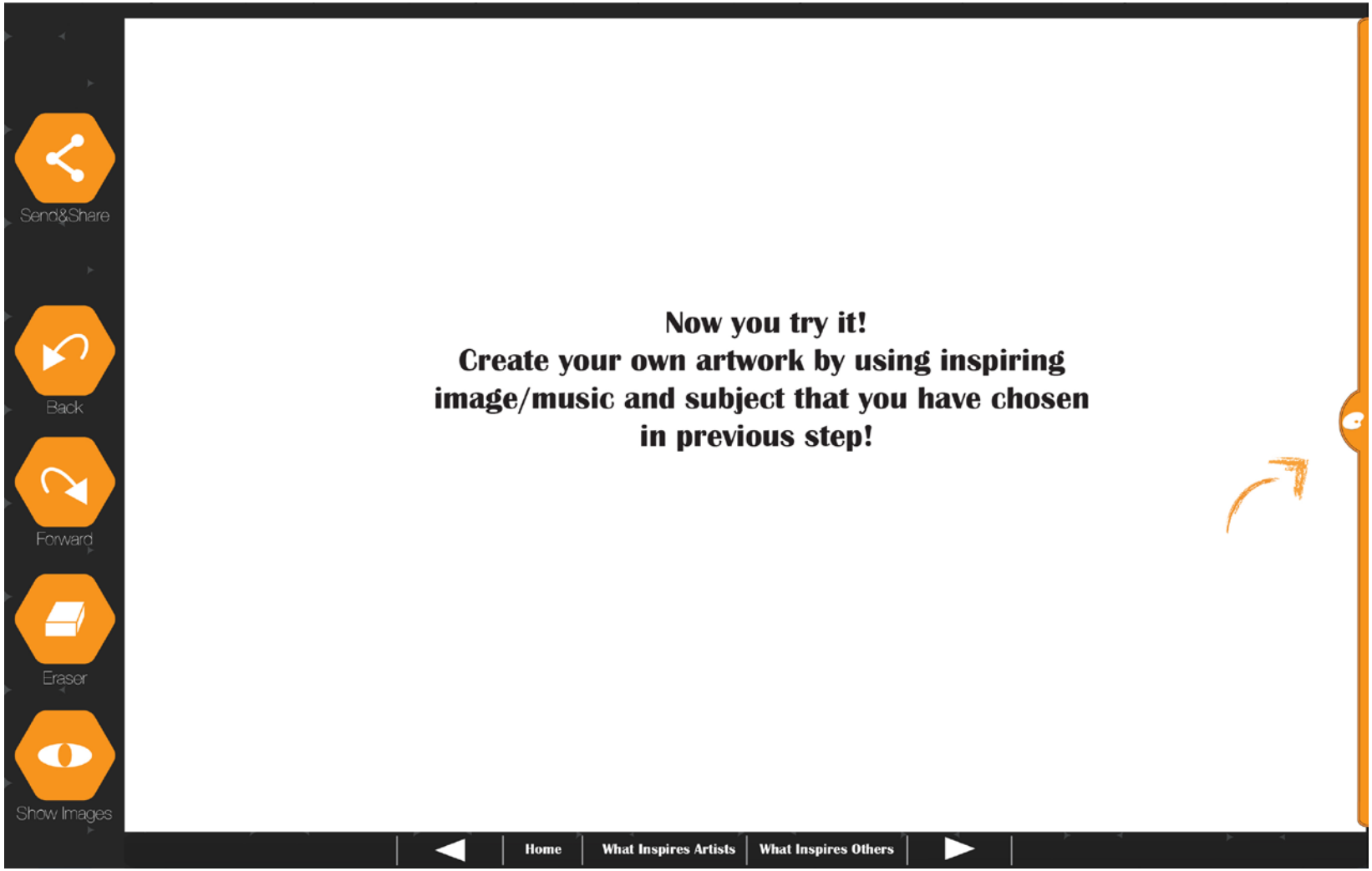


Figure 83. The doing section D-3: invitation to begin drawing that displays after tutorial.

Figure 84. The *doing* section D-4: the "Show Images" option allows users to see images that other visitors have chosen as references for drawing.

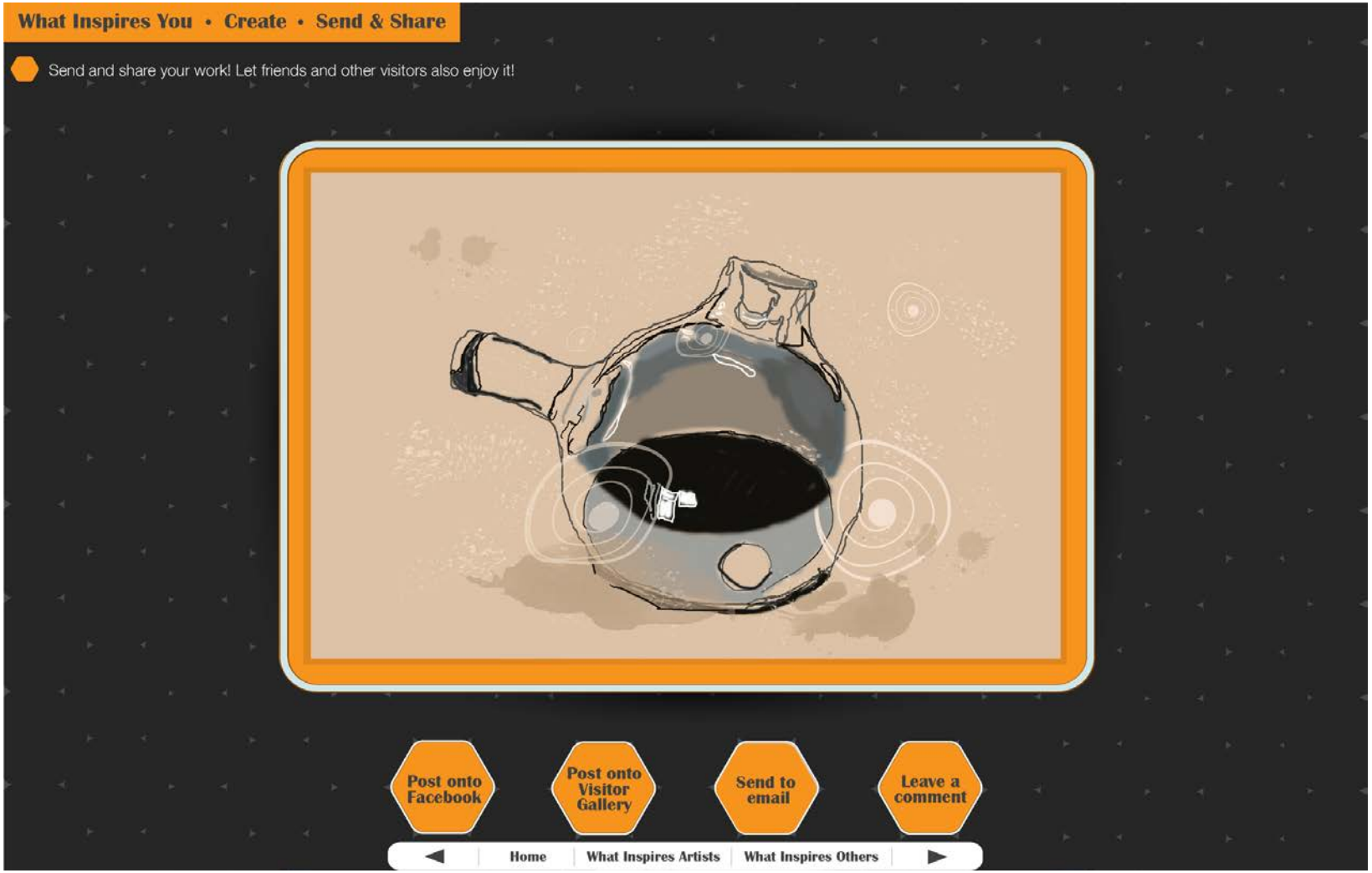


Figure 85. The *doing* section E-1: the "Send and Share" interface.

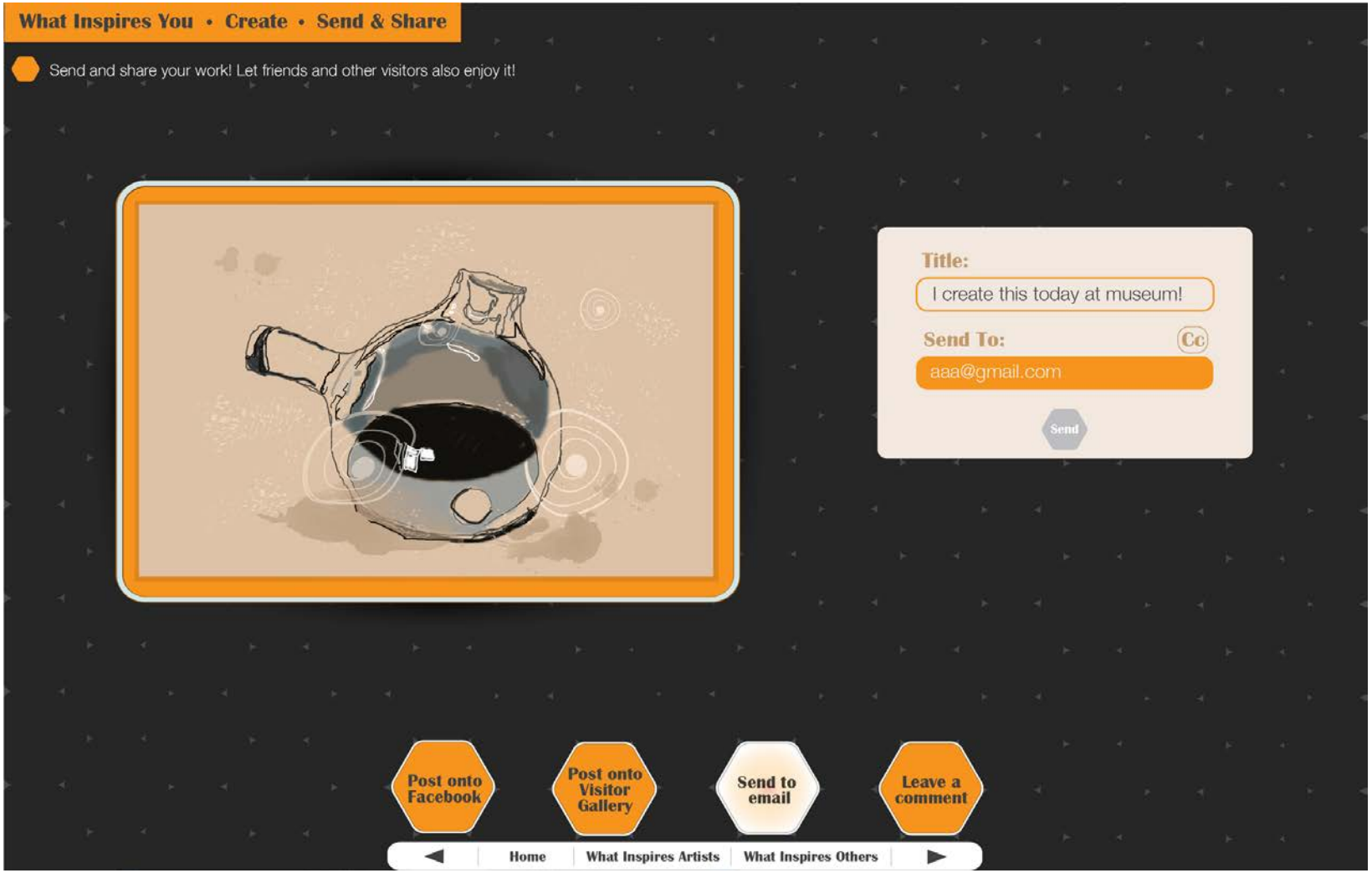


Figure 86. The *doing* section E-2: the "Send to email" interface.

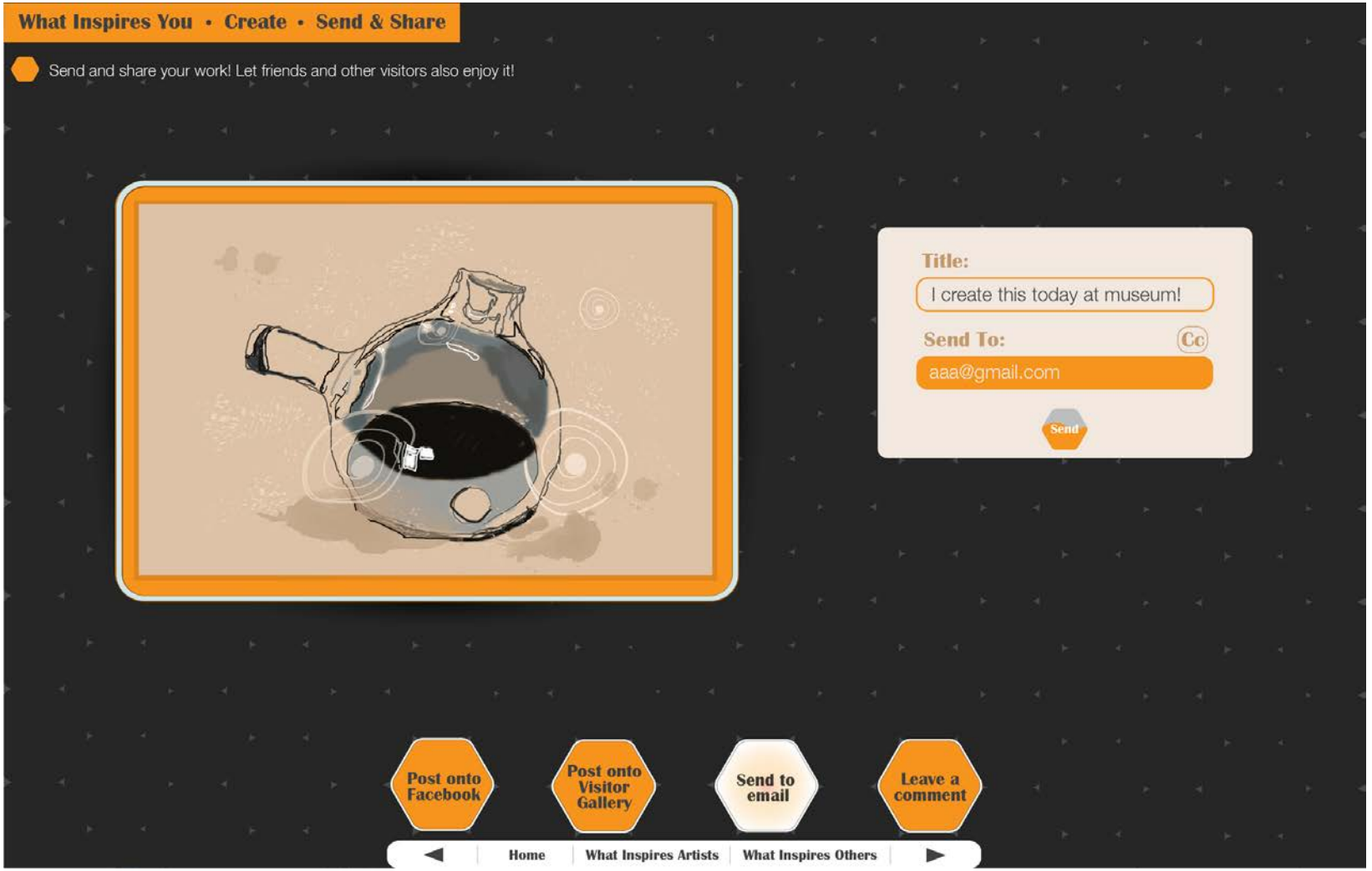


Figure 87. The *doing* section E-3: the sending process with the animated "Send" button activated.

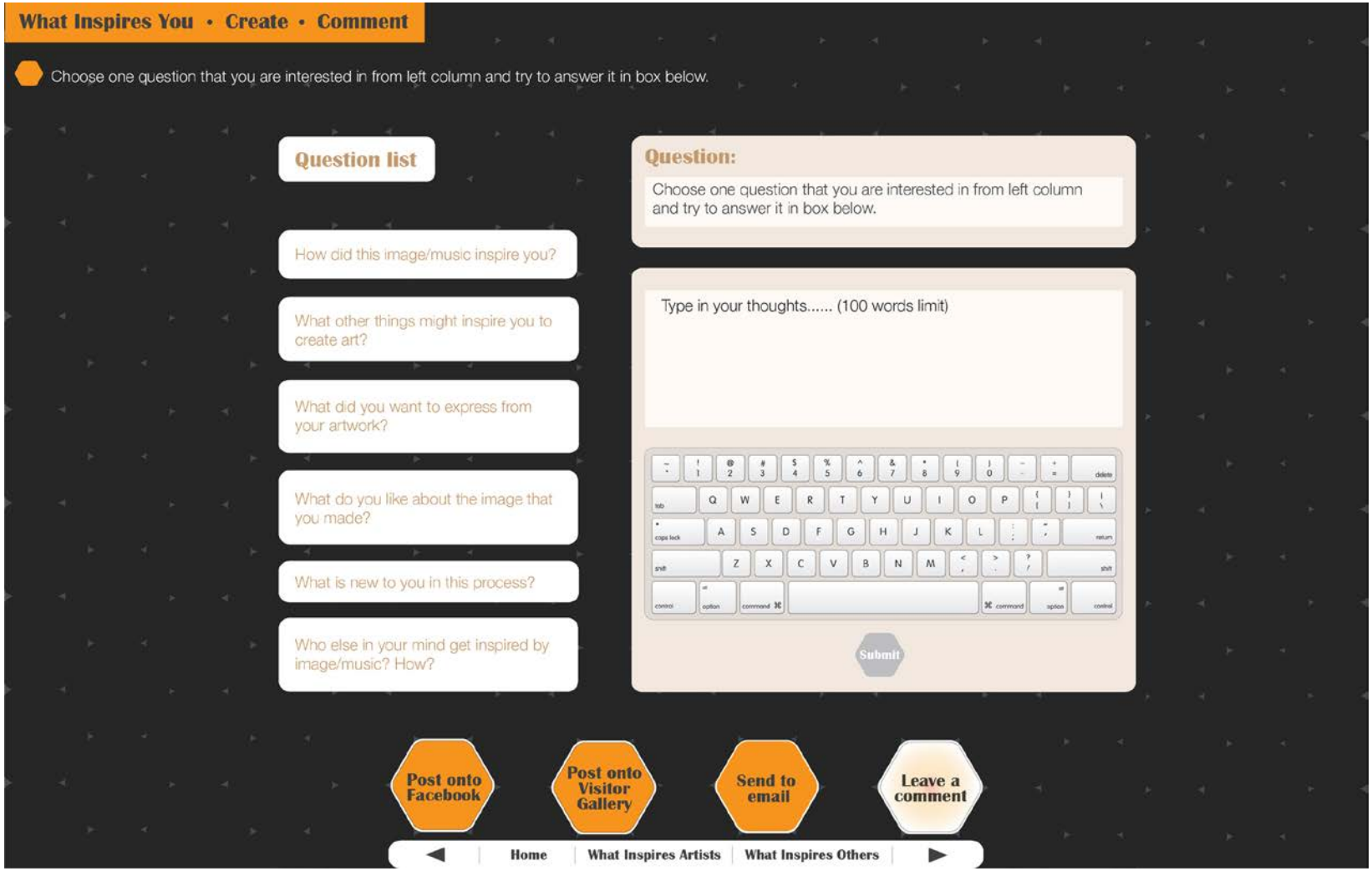


Figure 88. The *doing* section E-4: The "Leave a comment" dialog option.

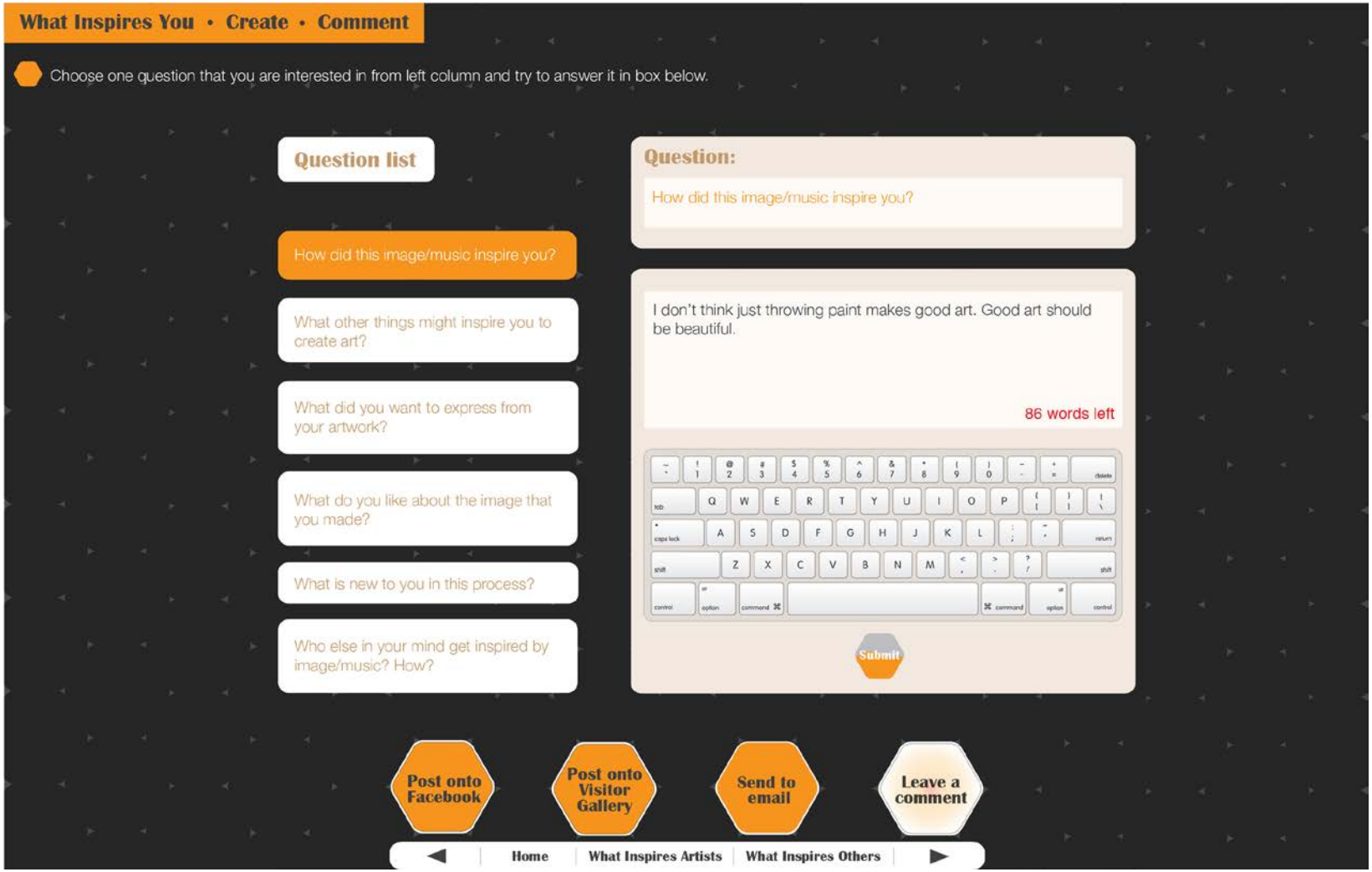


Figure 89. The *doing* section E-5: the "Leave a comment" dialog screen with an in-progress response to a prompt from the "Question list" on the left.

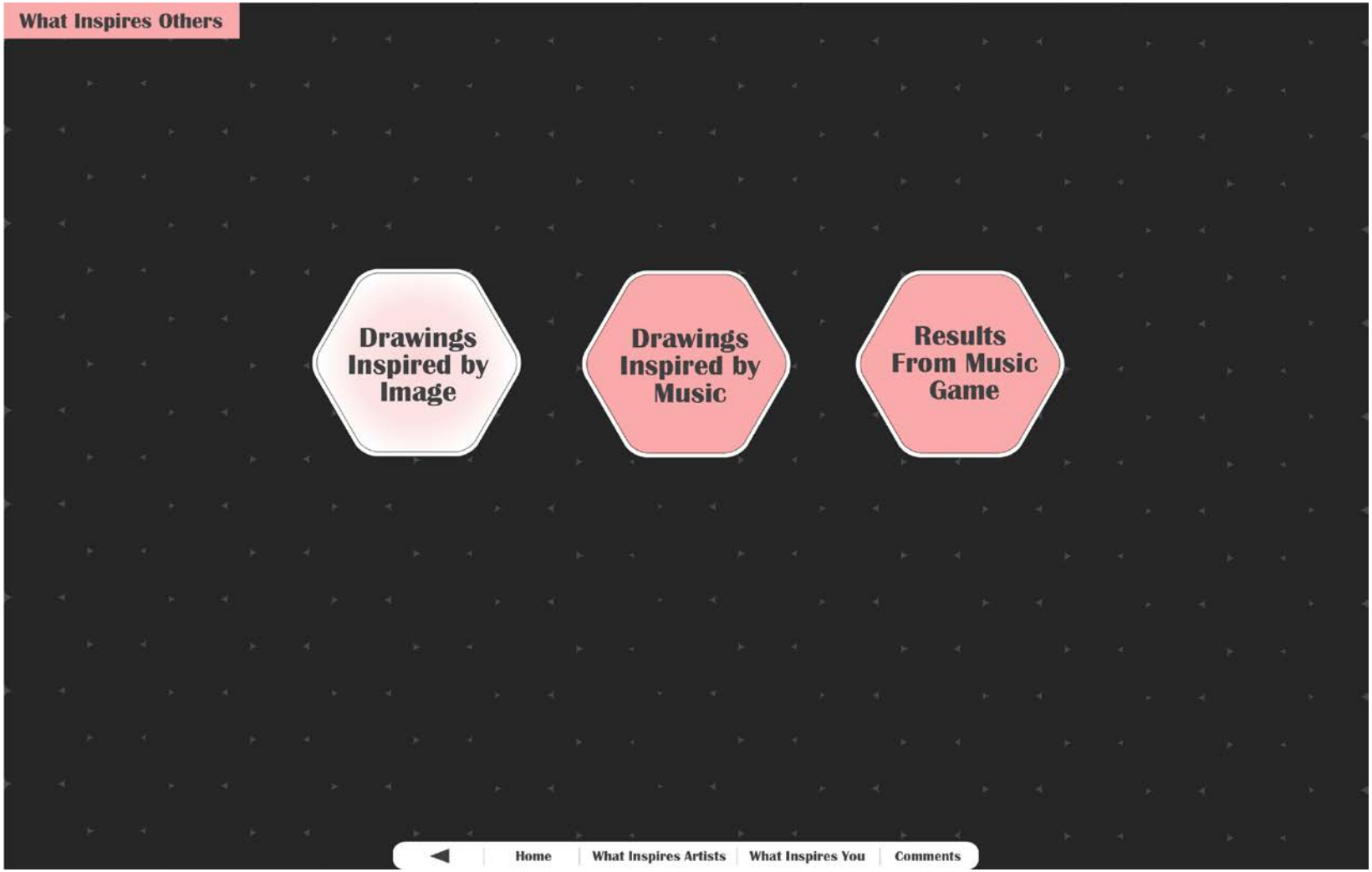


Figure 90. The *sharing* section: the navigation screen.

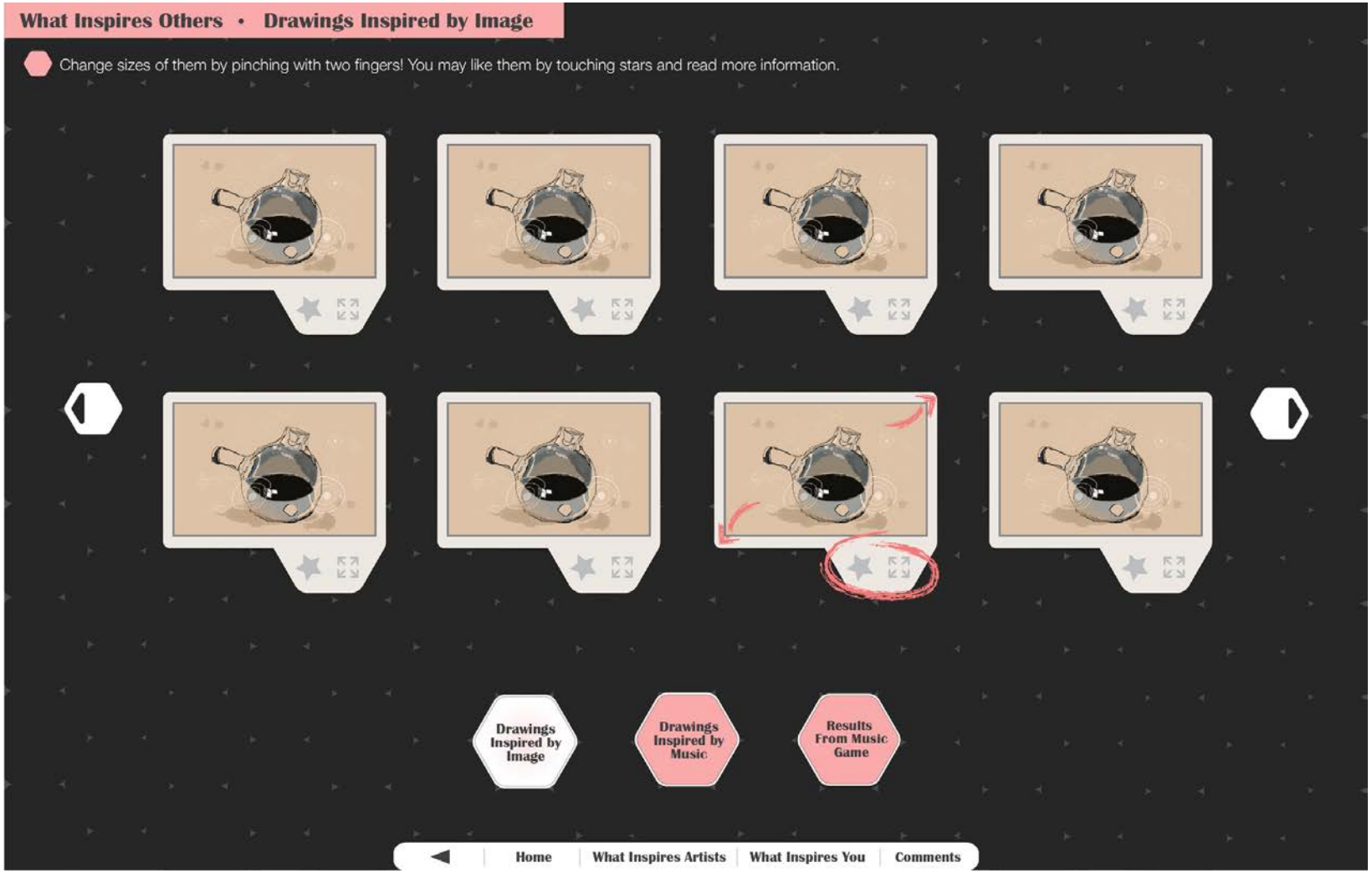


Figure 91. The *sharing* section A-1: the "Drawings inspired by Images" interface.

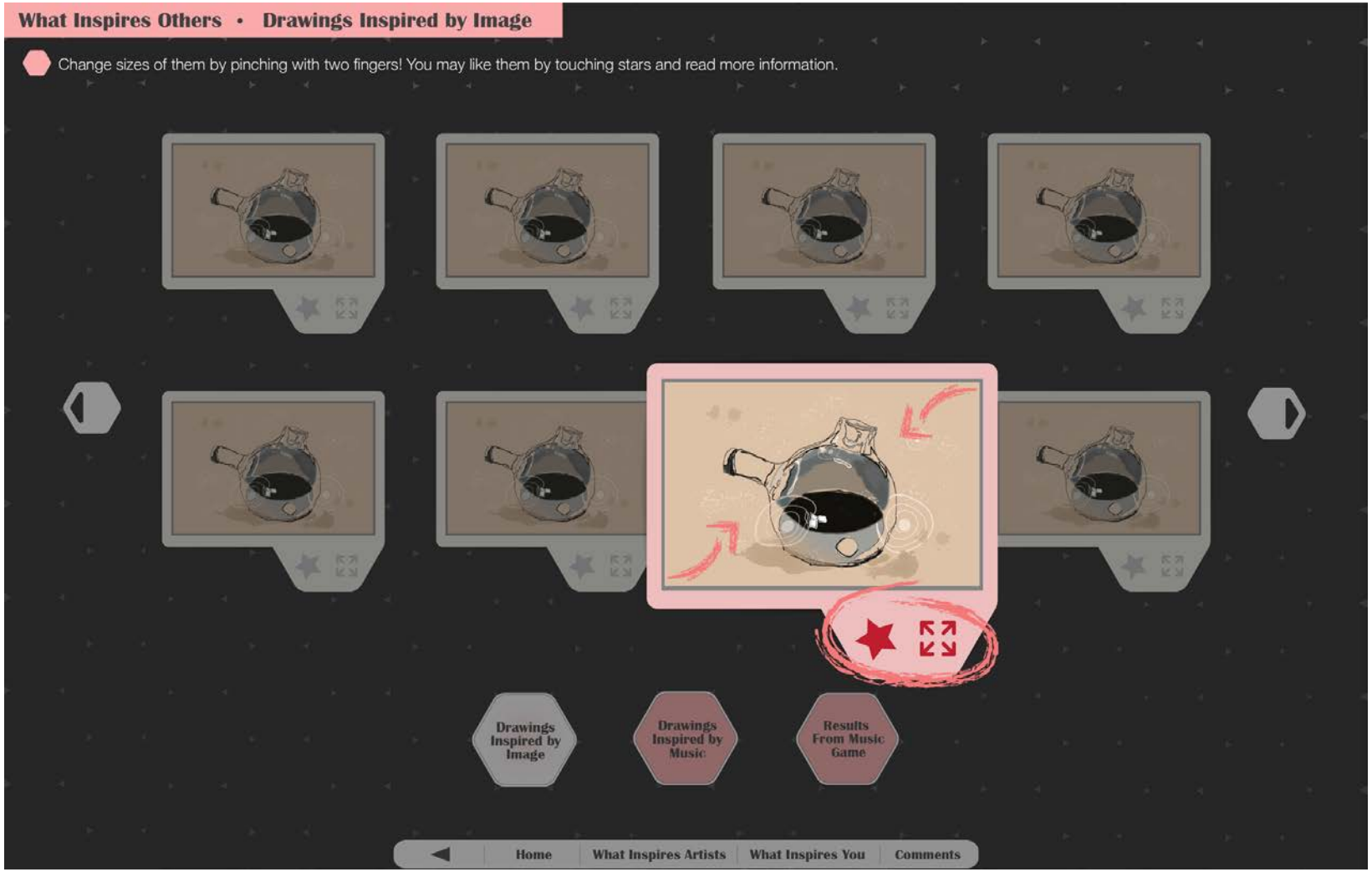


Figure 92. The *sharing* section A-2: the user can "like" previous drawing by selecting the star.

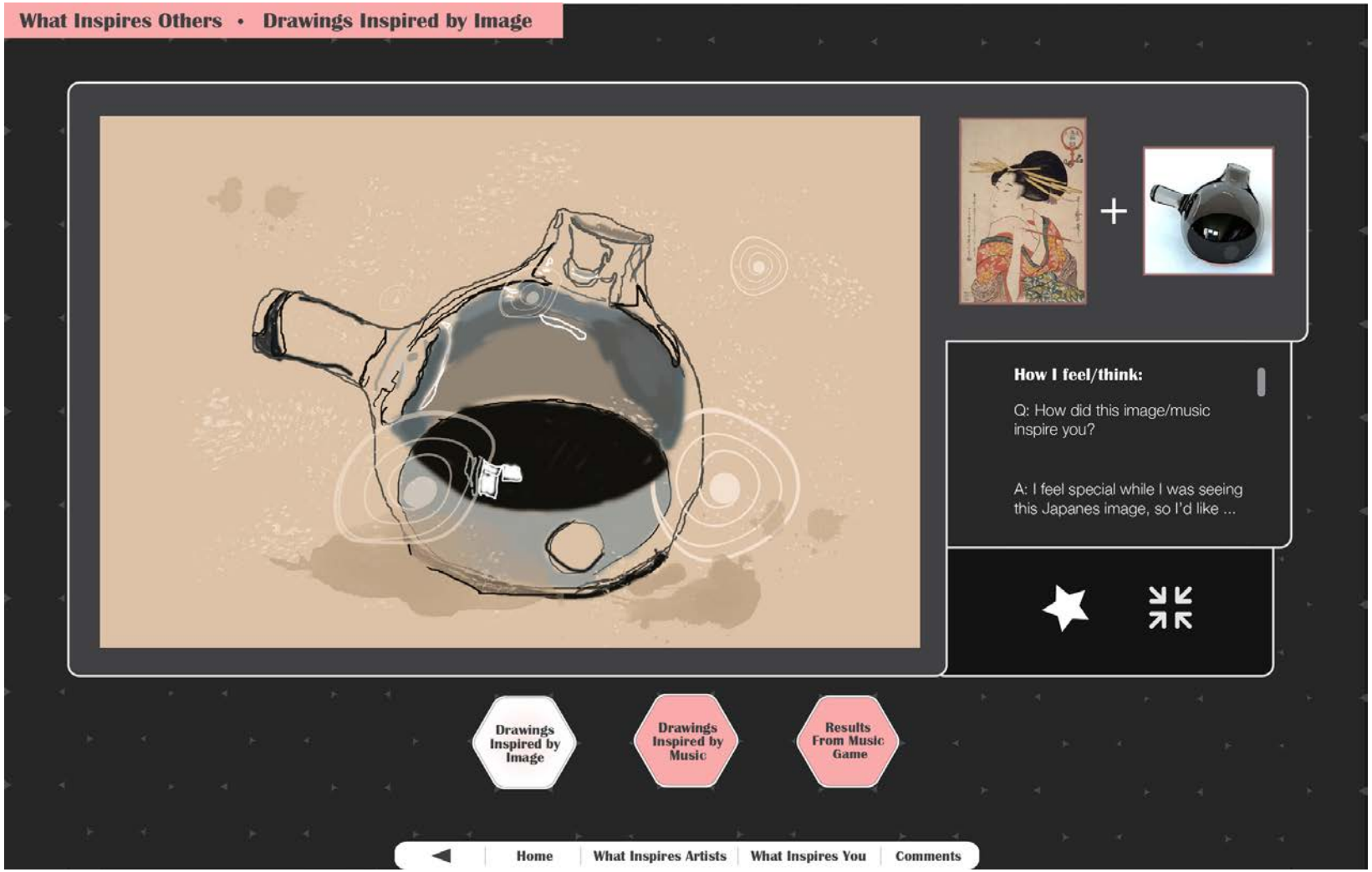


Figure 93. The *sharing* section A-3: the detailed view of a previous drawing.

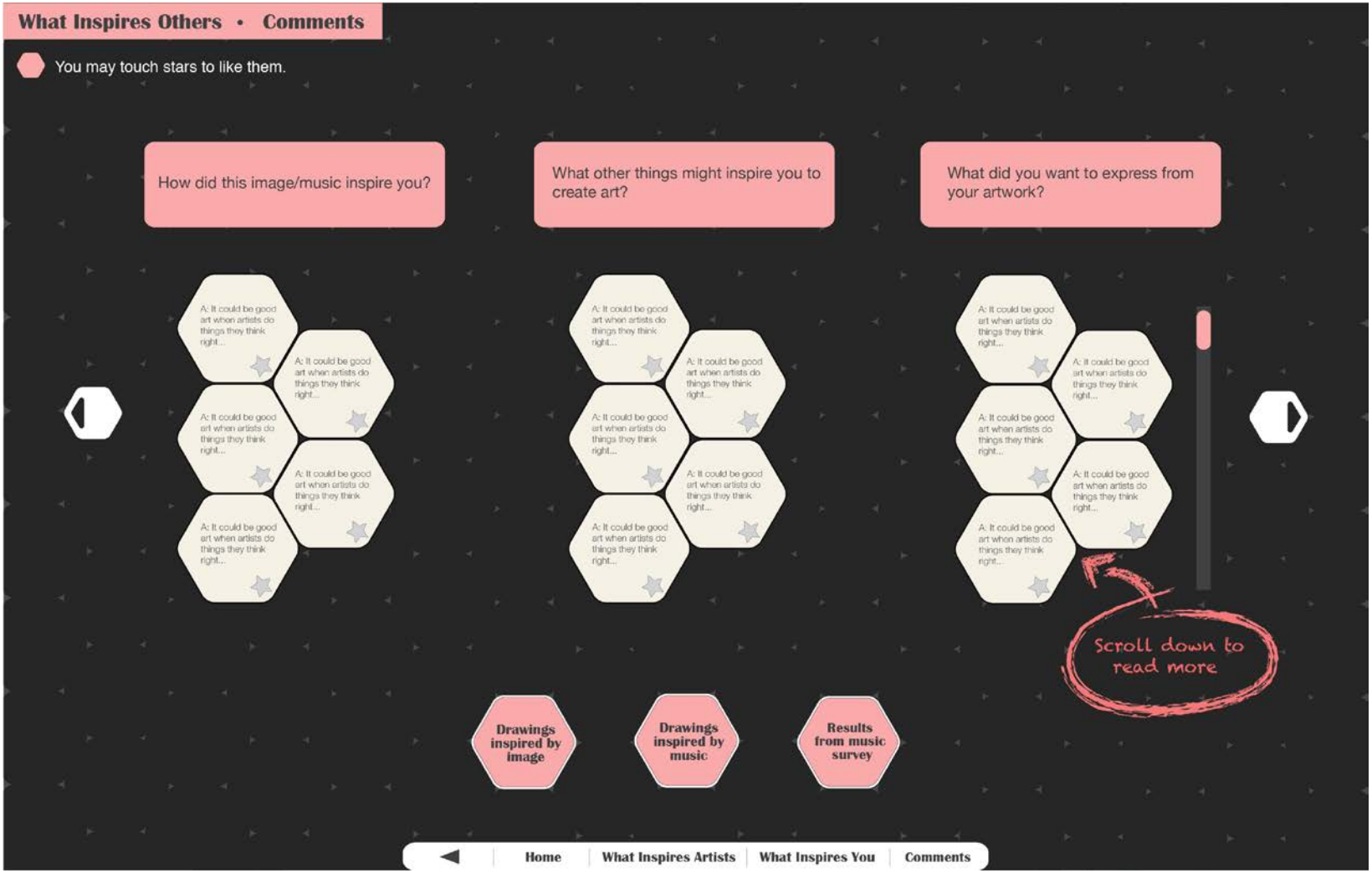


Figure 94. The *sharing* section B-1: the interface of the "Comments" section.

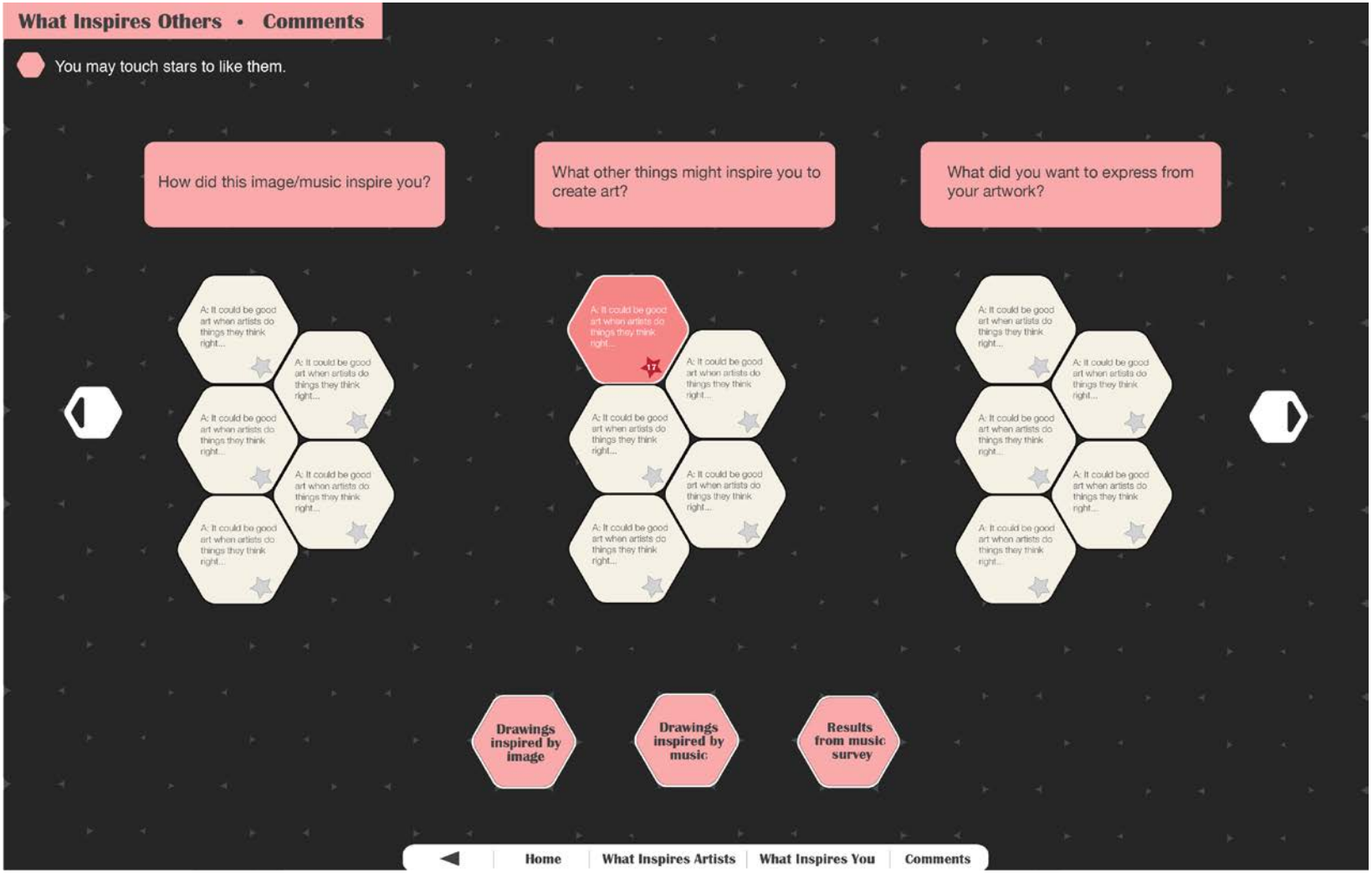


Figure 95. The *sharing* section B-2: the "Comments" interface with one comment activated and "liked."

Criteria for Effective Interaction

Significant criteria that are confluent with the key features of the prototype are presented in this chapter. They were based on the literature review and recommended by current best practices according to the field observation.

This section is composed of two criteria tables. The first table focuses on museum interactivity by comparing interactive exhibits that have been recorded and analyzed in the field observation to the conceptual prototype in this study. Criteria of the first table have been identified and summarized based on theories about museum interactivity, museum education and exhibition design from the literature review. Performances of various interactives from three types of museums based on the field observation have been recorded and analyzed in the list as well[1]. The second table focuses on the interactive design itself, and is also adapted from the sections of human computer interaction in the literature review. Because the conceptual prototype for this study works with a large-scale multi-touch tabletop, which users should be able to walk-up-and-use in a public space, NUI has been explored to be the main concept for the multi-touch interactive design.

The Criteria for Effective Museum Interactivity

Listed here are the criteria for effective museum interactivity (Table 1 and Table 4), along with the chapter and section locations in the literature review where each can be found.

- Deliver message effectively (Museum Interactivity/Museum Education)
- Attract visitor's attention (Digital Interaction in Museum Design)
- Keep visitor's attention (Museum Interactivity/ Digital Interaction in Museum Design)
- Provide information for exhibits (Digital Interaction in Museum Design)

[1] This table can also be seen in the summary section of the field observation as table 1. References of criteria will be explained in detail in the following section.

- Provide open-ended experience (Constructivism in Museum Education/Art Museum Education)
- Facilitate social interaction (Museum Interactivity/ Digital Interaction in Museum Design/Art Museum Education)
- Engage hands-on activity (Museum Interactivity/Digital Interaction in Museum Design)
- Multiple levels of content (Exhibition Design/ Museum Education)
- Effective storytelling (Exhibition Design)
- Smooth interaction (Museum Interactivity)

Table 3. Criteria for effective museum interactivity.

Criteria	Evident in Conceptual Prototype
Deliver message effectively	yes
Attract visitor's attention	yes
Keep visitor's attention	yes
Provide information for exhibits	yes
Provide open-ended experience	yes
Facilitate social interaction	yes
Engage hands-on activity	yes
Multiple levels of content	yes
Effective storytelling	yes
Smooth interaction	yes

Performance of various interactives from three types of museums based on the field observation, as well as the conceptual prototype from this study, have been documented in this table.

The Criteria for Effective Interactive Design

Brave NUI World, a book that documents complete concepts of NUI, includes design guidelines for NUI design (Wigdor & Wixon, 2011). These design guidelines were used to guide the interactive design of the conceptual prototype (Table 4). Here are the summarized criteria for Table 4:

1. When developing an application, start with the most fundamental interactions. Perfect them through careful design and testing. Then extrapolate those designs to more complex regions in an interaction domain.
2. Begin with what actions are elicited in this environment. A game can begin with the environment and actions typical of that game.
3. Consider content. Interface should focus on content. Provide minimal number of interface elements that are required for the interaction.
4. Consider how these interactions might be logically extended so that the new actions are easily learned and present the expected result.
5. Depending on your application's scenarios and context, the viewable space might be constrained. Create an environment that is optimized for touch in its layout, feedback, metaphors, and behaviors. Any item that responds to users' touch must be at least 15mm in size in all directions, and there must be at least 5mm between minimally sized touch targets.
6. In situations with large canvases, make sure that the spatial relationship of objects is clear and consistent.
7. In situations with multiple users, consider how to support different levels of coupling in the tasks, and how to support varying levels of coupling within the same application.

8. Respond to every contact immediately. The immediate feedback shows that the system is responding, which blurs the line between the real and the virtual. Make every transition fluid. Every object and visible property change must smoothly animate and transition into and out of existence, or between changes.
9. Enable single-finger drag and flick movements on movable content to make sure that users can always apply these basic manipulations to all content.
10. Enable inertia on objects and content that users can interact with.
11. Enable users to manipulate content directly, rather than through user interface controls.
12. At the appropriate time, show users affordances that guide users to access the unseen content of functionality.

Table 4. Criteria for effective interactive design.

Criteria NO.	Description of Criteria	Evident in Conceptual Prototype	Where implementation of this criteria can be seen:
1	Start fundamental interactions	yes	Figure 52, 56-60, 81-84, 91-92
2	Begin with elicited actions in evironment	yes	Figure 51, 52
3	Interface focuses on content	yes	Figure 51-70, 73-74, 77-78, 80-95
4	Logically extend interactions	yes	Figure 81-84, 91-92
5	Optimize environment for touch	yes	Every figure
6	Clear/consistent spatial relationship	yes	Figure 51-57, 59-95
7	Support levels of coupling in tasks	yes	Figure 56-68, 81-84, 88-95
8	Immediate feedback of contact	yes	Every figure
9	Drag/flick enable basic manipulations	yes	Every figure
10	Enable inertia on objects/content	yes	Figure 51-80, 85-90, 94-95
11	Enable direct manipulations on content	yes	Figure 56-60, 71-72, 75-76, 79, 82-84, 91-92, 94-95
12	Guide users to unseen content	yes	Figure 71-80

Limitation of this Methodology

This study focused on design intent and concepts, but did not include the development of a functioning prototype. For this reason, the effectiveness cannot be fully determined by a usability test, which is a significant way to improve a human-computer interactive application. Systematic usability tests allow designers to collect feedback directly from users. The feedback reveals inappropriate or ineffective design of a prototype, so that designers can modify those weaknesses in order to make the application easy and enjoyable to use. If this testing were to be done in the future, the app design could be modified based on the resulting information.

Although the conceptual prototype was analyzed as a multi-touch interactive application, it was not compared to other forms of creative engagement than an art museum might offer. This study did not intend to determine if a digital interaction was more effective than a traditional art class or workshop. This study only intended to provide another approach to enhance the visitor experience in art museums.

CHAPTER 4: CONCLUSION

Museums are being challenged by diverse sources of information and entertainment in a fast-paced era. The public has many choices as to how they spend their leisure time. Therefore, museums have to change the stereotypes about their existences and functions in the mind of the public. Modern museum design emphasizes the visitor experience to attract visitors from all ages and cultural backgrounds. Not only are one-time visitors important to the development of the museum, the visitors who regularly return to the museum are an important part of the audience. However, the passive visitor experience does little to increase numbers of visitors when museums are competing with a world full of interactive experiences. Most museum experts believe that a dynamic visitor experience, which potentially gives visitors impressive memories, needs to be incorporated into exhibits. To accomplish this, digital interaction has become a promising and important approach to improve museum interactivity; it empowers visitors through various ways of interactions. Due to content of their exhibits, it is unsurprising that science and natural history museums were the first to develop digital interactions for museum learning.

Art museums, however, have been less successful incorporating interaction into their visitor's experience. This difficulty is potentially bad for museums, because visitors may begin losing interest in spending time visiting art museums. To change this situation, some art museums have developed a few interactives on multi-touch devices to engage visitors. Most of these still provide information passively, rather than educating visitors in an empowering way.

To explore an educational interactive application for the use of art museums, this study attempts to determine a breakthrough point to achieve the combination among education, interactivity, and technology. An art museum conceptual prototype on a large-scale multi-touch

tabletop has been carefully designed. The prototype offers a potential solution for the lack of digital interactivity in art museums. The prototyping process demonstrates that an interactive application can not only provide background information, but also invite visitors to construct their personal meanings through open-ended interaction. The prototype attempts to engage visitors through hands-on activities as well as the sharing functions of social media, so visitors are able to participate in the whole learning process more actively.

In order to determine the effectiveness of existing digital interactives in the museum world, field observation was conducted. After observing the many effective interactives in science and natural history museums, and comparing these to the more limited and less effective ones, it was determined that a constructivist approach should be used for the art museum prototype. Visitors would be encouraged to find connections between art and their daily life through the conceptual prototype. The information architecture of the prototype was carefully designed in order to build an open-ended learning process based on constructivist theory of museum education. Three sections have been developed in this prototype: the *learning* section, the *doing* section and the *sharing* section. The three sections provide two warm-up games, instructional content, a drawing activity, and various kinds of visitor feedback through comments and images. More than forty interface screens have been developed to show the basic interaction of each step. After the design phase, criteria for effective interaction design and museum interactivity have been documented.

Although the usability test has not yet been conducted, it is the next step in the development of this prototype. The conceptual prototype clearly is a way to provide the dynamic experience for visitors in art museums. If implemented, it would increase open-ended learning experiences in art museum by combining museum interactivity, education, and technology.

Because art is itself an immersive, open-ended experience, it is necessary and appropriate for art museums to offer visitors an opportunity to be creative, rather than to remain passive by viewing a digital catalog of artworks.

REFERENCES

Alderman, C. (2011). I Spy: Interpreting Artworks Through Games, *Museum at Play*. Edinburgh, UK: MuseumsEtc Ltd.

American Association of Museums. (1992). *Excellence and Equity: Education and the Public Dimension of Museums*. Washington, DC: American Association of Museums.

Antle, A. N., Bevans, A., Tanenbaum, J., Seaborn, K., & Wang, S. (2011). *Futura: Design for Collaborative Learning and Game Play on a Multi-touch Digital Tabletop*, TEI'11, January 22-26, 2011, Funchal, Portugal.

Antle, A. N., Droumeva, M., & Ha, D. (2009). *Hands on What? Comparing Children's Mouse-based and Tangible-based Interaction*, IDC 2009, June 3-5, Como, Italy.

Arvanitis, K. (2005). *Museum outside walls: mobile phones and the museum in the everyday*, IADIS International Conference: Mobile Learning 2005, Qawra, Malta. Unpublished.

Beale, K. (2011). *Museums at Play*, Edinburgh, UK:MuseumsEtc Ltd.

Berkman, M., & Karahoca, A. (2012). A direct touch table-top display as a multi-user information kiosk: Comparing the usability of a single display groupware either by a single user or people cooperating as a group. *Interacting with Computers* (24.5), 423-437.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How People Learn*. Washington, DC: National Academy Press.

Bruckman, A., & Bandlow, A. (2008). *Human-Computer interaction for kids, the human-computer interaction handbook*. (2nd ed.) New York, NY: Lawrence Erlbaum Associates.

Buxton, B. (2012). *Multi-Touch systems that I have known and loved.* Retrieved from http://www.billbuxton.com/multitouchOverview.html.

Buxton, B. (2010). *"CES 2010: NUI with Bill Buxton."* Microsoft Research.

Buxton, B. (2007). *Sketching user experiences: getting the design right and the right design*. San Francisco, CA: Morgan Kaufmann.

Cutting, J. (2011). Telling Stories with Games, *Museums at Play*, Edinburgh, UK: MuseumsEtc Ltd.

Clements, R. D., & Wachowiak, F. (2010). *Emphasis art: A qualitative art program for elementary and middle schools*. Boston, MA: Pearson Education.

Derboven, J., Roeck, D. D., & Verstraete, M. (2012). Semiotic analysis of multi-touch interface design: The MuTable case study. *International Journal of Human-Computer Studies* (70), 714-728.

Dewey, J. (1938) *Experience and Education*. Terre Haute, IN: Simon and Schuster.

Dietz, P., & Leigh, D. (2001). DiamondTouch: A multi-user touch technology. *Proceedings UIST 2001*, 219-226.

Ebitz, D. (2008) Sufficient foundation: Theory in the practice of art museum education. *Visual Arts Research* (34.2), 14-24.

Falk J.H., & Dierking, L. D., (2000). *Learning from the Museum*. Walnut Creek, CA: AltaMira Press.

Froes, I., & Walker, K. (2011). The Art of Play: Exploring the Roles of Technology and Social Play in Museums, *Museums at Play*, Edinburgh, UK:MuseumsEtc Ltd.

Fyfe, G. (2006). *Sociology and the Social Aspects of Museums*: *A Companion to Museum Studies*. Malden, MA: Blackwell Publishing.

Gammon, B. (1999). Visitors' use of computer exhibits: Findings from five grueling years of watching visitors getting it wrong. *The Informal Learning Review*, 1112-a.

Gardener, H., (1983). *Frames of mind: The theory of multiple intelligences.* New York: Basic Books.

George, J., Araujo, E. D., Dorsey, D., McCrickard, D. S., & Wilson, G., (2011). Multitouch tables for collaborative objects-based learning, design, user experience, and usability: Theory, methods, tools and practice. *Lecture Notes in Computer Science* (6769), 237-246.

Glaserfeld, E. (1989). *Constructivism in education*. Oxford, England: Pergamon Press. p. 162.

Heath, C., & Lehn, D. V., (2003). Interactivity and collaboration: new forms of participation in museums, galleries and science centers. In M. Hinton (ed.), *The Proceedings of interactive learning in museums of art and design*. London: Victoria and Albert Museum.

Hein. G. E. (2006). *Museum education, a companion to museum studies*, Malden, MA: Blackwell Publishing.

Hein, G. E. (2004). John Dewey and Museum Education. *Curator: The Museum Journal* (47.4), 413-427.

Hinrichs, U., Schmidt, H., & Capendale, S. (2008). EMDialgo: bringing information visualization into the museum. *IEEE Trans Vis Computer Graph* (14.6), 1181-1188.

Hooper-Greenhill, E. (1991). *Museum and Gallery Education*. Leicester: Leicester University Press.

Hornecker, E., & Keynes, M. (2008). "I don't understand it either, but it is cool" – Visitor Interactions with Multi-Touch Table in a Museum, *Proceedings Of IEEE Tabletop 2008.*

Hubard, O. M. (2007). Productive Information: Contextual Knowledge in Art Museum Education. *Art Education* (60.4), 17-23.

Huhtamo, E. (2002). *On the Origins of the Virtual Museum*, Nobel Symposium on "Virtual Museums and public understanding of science and culture", Stockholm, Sweden, 2002.

ICOM (International Commission of Museums) (n.d.) ICOM definition of a museum Retrieved from http://icom.museum/definition.html.

Joo, E., Keehn, J., & Ham-Roberts, J. (2011). *Rethinking contemporary art and multicultural education: New museum of contemporary art*. New York: Routledge.

Keefe, D. F., Gupta, A., Feldman, D., Carlis, J.V., Keefe, S. K., & Griffin, T. J. (2012). Scaling Up Multi-touch Selection and Querying: Interfaces and Applications for Combining Mobile Multi-touch Input With Large-scale Visualization Displays. *International Journal of Human-Computer Studies* (70.10), 703–713.

Kidd, J., Ntalla, I., & Lyons, W. (2011). Multi-touch Interfaces in Museum Spaces: Reporting Preliminary Findings on the Nature of Interaction, *Re-thinking Technology in Museums 2011*.

Lee, S. (1978). Art museums and education. In B. Y. Newsom & A. Z. Silver (Eds.), *The art museum as educator* (21-26). Berkeley: University of California Press.

Lorenc, J., Skolnick, L. H., & Berger, C. (2008). *What Is Exhibition Design*? UK: RotoVision.

Liu, Y & L. J. Shrum (2002). What is interactivity and is it always such a good thing? Implications of definition, person, and situation for the influence of interactivity on advertising effectiveness. *Journal of Advertising* (31.4), 53-64.

MacDonald, G. F., & Alsford, S. (1991). The Museum as information utility. *Museum Management and Curatorship* (10), 305-311.

Marcus, A. (2008). *Global and Intercultural User-Interface Design, The Human-Computer Interaction Handbook* (2nd ed). New York, NY: Lawrence Erlbaum Associates.

Marshall, P., Morris, R., Rogers, Y., Kreitmayer, S., & Davies, M. (2011). *Rethinking 'multi-user': An in-the-wild study of how groups approach a walk-up-and-use tabletop interface*. New York, NY: ACM.

Mayer, M.M. (2005). A Postmodern Puzzle: Rewriting the Place of the Visitor in Art Museum Education. *Studies in Art Education* (46.4), 356-368.

Morrison, G. R., Ross, S. M., Kemp, J. E., & Kalman, H. K. (2007). *Designing Effective Instruction* (5th ed). John Wiley & Sons, Inc.

Nashashibi, S. (2002). *Visitor-written labels in US art museums*. Orinda: JFK University Press.

Norman, D., & Nielsen, J. (2010). Gestural interfaces: A step backward in usability. *Interactions* (17.5), 46-49.

Norman, D. (2011). *Living with complexity*. Cambridge, Massachusetts: MIT Press.

Peltonen, P., Kurvinen, E., Salovaara, A., Jacucci, G., Ilmonen, T., Evans, J., Oulasvirta, A., & Saarikko, O. (2008). It's mine, don't touch!: Interactions at a large multi-touch display in a city center. *Proceedings Of CHI 2008*, 1285-1294.

Perble, D., & Perble, S. (1994). *Artforms: an introduction to the visual arts* (*5th ed)*. Harper Collins College Publisher.

Piaget, J. (1970). *Science of education and the psychology of the child*. New York: Orion Press.

Rice, D. (1995). Museum education embracing uncertainty. *Art Bulletin* (77.1), 15-20.

Roccetti, M., Marfia, G., & Semeraro, A. (2011). Playing into the wild: A gesture-based interface for gaming in public spaces. *Journal of visual communication and image representation* (23.3), 436-440.

Rogers, Y., & Lindley, S. (2004). Collaborating Around Large Interactive Displays: Which Way Is Best To Meet? *Interacting With Computers* (16.6), 1133-1152.

Ryall, K., Forlines, C., Shen, C., & Morris, M. R. (2004). *Exploring the effects of group size and table size on interaction with tabletop shared-display groupware,* CSCW'04, November 6-10, 2004, Chicago, Illinois, USA.

Seefeldt, C. (1995), Art – A Serious Work. *Young Children* (50.3), 39-54.

Shneiderman, B. (2003). *Designing the User Interface* (3rd edition), Person Education.

Simpson, M. (2002). *Interactive Art Exhibits: An Overview of Developments in the USA,* Journal of Museum Education.

Simon, N. (2010). *The Participatory Museum*, Museum 2.0.

Sternberg. S. (1989). The art of participation. In N. Berry & S. Mayer (Eds.), *Museum education: History, theory, and practice* (154-171). Reston, VA: The National Art Education Association.

Tallon, L., & Walker, K. (2008). *Digital Technologies and the Museum Experience: Handheld Guides and Other Media*, Lanham, MD: Altamira Press.

Tapia, J. M. (2008). Poking holes in the oil paintings: The case for critical theory in postmodern art museum education. *Visual Arts Research* (34.2), 14-24.

Watzman, S. (2008). Visual Design Principles for Usable Interfaces. In *The Human-Computer Interaction Handbook* (2nd ed.). New York, NY: Lawrence Erlbaum.

Weaver, S. (2007). *Creating Great Visitor Experiences*. Walnut Creek, CA: Left Coast Press.

Westerman, W. (1999). *Hand tracking, finger identification, and chordic manipulation on a multi-touch surface*. (Doctoral dissertation). University of Delaware.

Wigdor, D., & Wixon, D. (2011). *Brave NUI World: Designing Natural User Interfaces for Touch and Gesture.* Burlington, VT: Elsevier.

Witcomb, A. (2006). Interactivity: Thinking Beyond. In Macdonald, S. *A Companion to Museum Studies*. Malden, MA: Blackwell Publishing.

Witcomb, A. (2003). *Reimagining the Museum: Beyond the Mausoleum*. London, UK: Routledge.