Skyline: Scaffolding Education Through a Digital Augmentation

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ABSTRACT

UPDATED—6 June 2017. Museum exhibits that employ physical-digital interfaces to encourage engagement result in more interesting experiences with better learning outcomes for visitors. Such learning tools are occasionally integrated well into the interactive portion of the exhibit, such as New York Hall of Science's *Oztoc Game Design*, but more often the educational tools are isolated from the interactive portion of the exhibit such as Chicago Children's Museum *Skyline* exhibit.

In this paper we present a digital augmentation that adds educational scaffolding to the *Skyline* exhibit using computer vision blog technology.

INTRODUCTION

Skyline, an experience presently on display at the Children's Museum of Chicago, provides children with straight wooden beams, small nuts and bolts, and simple tools (ref. Figure 1) and encourages them to explore the strengths and weakness of different approaches to constructing simple structures. The exhibit stresses creativity and open-ended exploration – there are very few instructions or outside information given and the impetus is on the museum-goer to learn through tinkering and testing. There is educational material in the entrance of the exhibit highlighting what shapes lead to stable structures, and what the wireframe of famous buildings around the world look like. However, that educational material is largely skipped by the children visiting due to how compelling the interactive building environment is.

Figure 1 Child in the interactive building portion of Skyline

We propose an augmentation of the Skyline that will add a digital interface that provides live, educational feedback as visitors build the structure. The educational interface will utilize the camera/screen system the exhibit already employs so as to not significantly deviate from workflow of this already successful exhibit. The feedback system is accomplished through computer vision blob detection technology.

Figure 2 Camera/Screen Area of Skyline Exhibit

MOTIVATION

Skyline, as presently constructed, is certainly a good, if not great, exhibit. It encompasses the idea of tinkering in learning well - specifically the idea of open ended learning. However, that same open ended learning environment makes it difficult for learners to fail forward. Klopfer, Osterweil, and Salen assert that "freedom to fail" - the idea that if children are not afraid of failure, they "are free to learn from failure and move ever closer to mastery of their world" [1]. *Skyline* visitors certainly fail in their construction of buildings, but due to lack of educational scaffolding they are not failing in a productive manner.

Leilah Lyons's in, *Designing Visible Engineers*, asserts children "playfully [exploring] a problem space by iteratively adjusting and testing an artifact they are constructing"[1] increases learning about engineering [2]. Similarly, by putting learners in charge of their exhibits, Skyline currently provides users the opportunity to tinker with the building materials to construct a framework according to their liking and judgment. This open ended learning environment allows users to learn and explore their curiosities, albeit only to a certain extent.

Open ended learning is not sufficient to create successful learning through tinkering. Secondary facilitation of that learning, specifically sparking initial interest, sustain participation through introduction of new information, and deepening understanding by connection to learners is a crucial part of a successful tinkering, learning environment. While the interactive environment of *Skyline* does an excellent job of sparking the initial interest, the separated learning/interactive environments make it difficult for visitors to sustain that learning through roadblocks and make personal connections to the learners.

RELATED WORK

Related Work (Learning)

Several currently-existing children's museum exhibits employ technological and design principles that we will use in the augmentation of *Skyline*.

Seattle's Imagine Children's Museum takes a similar approach in the construction studio they call *Thinker Linkers*. The exhibit uses curved and straight notched pieces of wood of different sizes and shapes that fit together in a limitless number of ways and can be assembled into vehicles, animals, or any type of abstract shape that the child desires. The exhibit's learning goals are similar to those of *Skyline* -"engineering principles like balance and gravity, and learn mathematical concepts such as size, shape and quantity". The exhibit additionally enforces the more abstract values of planning, problem solving, and cooperation.

With *Oztoc*, exhibit designers combined physical interactive technologies with visual digital feedback to link the children's engagement with the learning experience itself. Using a set of wooden blocks that represent electrical components (LEDs, resistors, batteries, etc.) placed on a tabletop screen, museum-goers create simple circuits that are used to 'lure' digitally-rendered fish. Different circuit designs allow the capture of different digital fish, challenging the children to build different and more complex systems in order to beat the game. In this exhibit, physical interaction on the behalf of the user creates digital feedback that informs them of the success of their design and gives feedback about potential solutions to errors in their circuits.

The San Jose Tech Museum's *Shake Platform* teaches visitors about the earthquake experience by simulating the magnitude of one of eight historical on a shake table [3]. The earthquakes happen at 5 minute intervals and in the time between earthquakes visitors construct structures out of foam blocks with the goal of them withstanding the upcoming earthquake. While this exhibit does not employ other learning methods that successful exhibits do, specifically Active Prolonged Engage, it explicitly links the learnings about earthquakes to real-life examples. This often can spark child-parent interactions as children enquire about the earthquakes, furthering the learning experience.

Related Work (Technical)

Computer vision technologies form the backbone of the interaction behind our augmentation of the *Skyline* exhibit. More specifically, our implementation relies on the use of TopCodes, a computer vision library that allows for the rapid detection of objects on a two-dimensional plane [4]. In our implementation we place codes on the face of each bolt used to link the wooden beams such that every joint in the structure can be identified in the reactive interface.

THEORTICAL BACKGROUND

Our main learning objective of *Skyline* is to provide an opportunity for curious visitors to assert authority over their exhibits in a museum setting in order to foster their creativity, explorative qualities and social skills. We will discuss briefly about four important styles of learning that empower our learning objective - tinkering, active prolonged engagement (APE), parent-student learning, and relation to personal experience. We will begin by defining the properties and role of tinkering in our learning objective.

Tinkering serves as a style of learning that focuses on playful, exploratory engagement with the exhibit/project t[5]. Users employing this work method constantly develop new ideas, create adjustments and refinements, experiment new possibilities, and all of this under their jurisdiction. This informal style embraces a bottom-up approach of traditional planning by finding a solution through materialistic experimentation rather than relying on a structured, thought-out plan or blueprint [6]. By supporting autonomy and control of their works, tinkering environments increase users' engagement and persistence, develop confidence and identity, and foster resourcefulness [7]. Some argue that performing through tinkering leads to nowhere due to its messy, unorganized nature, but the design of high APE (Active Prolonging Engagement) exhibits require longer engagement than low APE exhibits, thus involving users in the process of inquiry better.

This style of learning emerged from the recent Maker Movement that embraces inquiry-based educational activity in order to introduce and promote STEM activities and devices to interested youth [8]. The movement reimagines the structure of pedagogy by promoting “making settings” that encourages students outside of school settings like museums to collaboratively produce a range of artifacts and draw on interdisciplinary tools in order to foster interest and increase engagement with the exhibits.

Tinkering is important in the constantly-changing world today because it improves adaptability, evolution and improvisation, hence never staying put on one set of procedure [9]. This, however, leads to a tradeoff of creativity and agility over efficiency and optimization, leading to its constant undervalue in school settings, where teachers tend to value formal planning over free-thinking in their curriculums. This struggle between strict procedures and tinkering is especially prevalent in STEM classes where classes often stifle student creativity. However our learning objective for Skylines is to introduce a museum-owned, STEM-related exhibit to young visitors, so we want to focus our attention more to producing fun and freedom for the users while teaching them the basic principles of construction. For this, we will redirect our attention of tinkering to museum exhibits designed for youngsters and families.

In a museum setting, tinkering exhibits provide not just satisfaction for curious users, but also create a social ground that fosters social, interactive skills with other users. Gutwill (2014) identified three types of social interactions among users in a museum tinkering setting: direct requesting, offering of help, inspiring new ideas, teaching new approaches, receiving peer feedback and physically connecting with others and their works [10]. This environment provides a space of sharing, collaboration and authenticity, hence deepening user engagement and learning. Compared to a hypercompetitive and repetitive setting like the school classroom, tinkering environments promote collaboration, teamwork and endless experimentation between users [11].

We hope that our exhibit Skylines will encourage the same collaborative behavior as described by Gutwill. The lack of formal authority and the numerous resources in Skylines will give plenty of room for the users to build on their creativity and imagination in order to build indefinitely and make adjustments in their discretion.

Besides exhibiting tinkering behavior in users, Skylines also promotes parent-student learning and relation to personal experience in order to connect and engage both parents and students in our learning objective. Parents in these types of exhibits tend to employ informal, simple and prior information to explain concepts to their children [12]. Already having a trustworthy relationship upon arrival, parents and teachers can utilize the listed information to personalize meanings and concepts to improve their children's' understanding. This is important because children can learn to access prior information from real life experiences to tackle a problem, while parents can actively engage in their children’s development. Skylines invites this type of parent engagement into their children’s quest to explore and build whatever house they want.

DESIGN

Our re-design of the Chicago Children’s Museum *Skyline* exhibit augments the current exhibit with a camera/screen interface that provides instructional feedback to visitors as they build structures.

The *Skyline* exhibit is already largely successful in its utilization of Active Prolonged Engagement (APE) design principles [13]. Additionally, it fosters the parent-child interaction that is crucial to learning. Consequently, any re-design of the exhibit cannot detract from *Skyline’s* current success.

The feedback camera/screen will be in the place of what is currently a screen that records the building process. By placing the digital interface in a location that is easily visually accessible from where visitors physically access the exhibit, Active Prolonged Engagement is maintained. The blobs used in the computer vision technology will be attached to the bolts. This ensures the detection blobs are at the joints without disturbing the original workflow of *Skyline* (ref. Figure 3, Figure 4).

Figure 3 Materials Provided to "visitors" in our Redesign

Figure 4 Sample Construction with Topcodes at Joints

Additionally, exhibit studies have shown parents gravitate toward educational information while children go toward interactive information. Marrying the interactive and educational environment can help further the parent-children learning.

Tinkering is key for developing exploratory problem solving in children, however the same unguided process that is key for that development, can leave tinkerers without the tools to overcome obstacles. The proposed UI would force users to think critically about their designs by pointing out structural shortcomings and also provide real life examples to help users overcome those structural problems (ref. Figure 5).

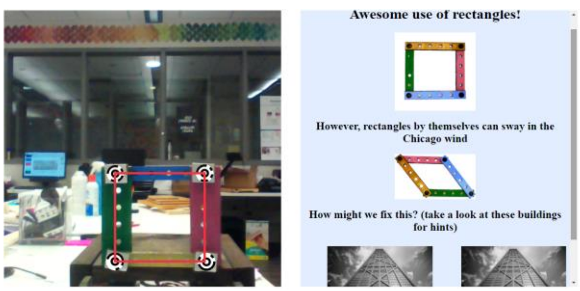

Figure 5 Educational Interface

Through the design considerations described above, we believe that the proposed augmentation of the *Skyline* exhibit will further the learning goals of the exhibit without taking away what makes the design successful. A video demo of the design can be found here [14]**.**

CONCLUSION AND FUTURE WORK

In this paper we present a redesign of Skylines, an exhibit currently on display at the Chicago Children's Museum, in which we attempt to address what we identify as the exhibit's major design flaw: a disconnect between the highly-engaging, open-ended experience of building physical structures and the dense, isolated panels of information and non-interactive demonstrations that line the walls around the exhibit space. We present a design that seeks to link these two currently disparate areas of information by employing a system that uses computer vision to identify the structures that the children build, give them feedback about possible ways of improving their designs, and provide background information that educates them on basic principles of structural engineering and connects strategies used in their own building to those of real world examples that can be seen on the real Chicago skyline through the windows of the Children's Museum.

Our system, however, is as of yet only a prototype. In future work we hope to expand the physical scale of the system, its capacity to algorithmically identify the underlying shapes in three-dimensional structures, and increase the volume and diversity of feedback that it provides. First, the size of the system, specifically its physical components, must be increased to replicate that of the existing exhibit. Our prototype currently functions on a desktop scale and as such would not provide children the wonder of building a structure as tall or taller than themselves, which is a major draw in the current exhibit. Doing this will undoubtedly be challenging – there are limits to the size and distance at which TopCodes can be detected. Following the example of the exhibit section that has visitors building in front of cameras so that they can 'take their building home' (view it in an online interface) we believe it to be very much within the realm of possibility.

Second, we look to increase the system's ability to recognize arbitrary shapes created in the tinkering process. The current implementation can only identify TopCode-bounded squares, rectangles, triangles, and cross-beam supports. In an effort to both make the system as useful as possible and not affect the more successful aspects of the existing exhibit, we will need to greatly increase this list.

Any improvement in shape recognition will only be as useful to museum-goers if the associated feedback is improved as well. In the current iteration, the feedback is limited and comes with recommendations that, if implemented by users, would have building designs will be convergent rather than the unique creative structures that populate the exhibit today. Future work must include a large body of feedback that can provide meaningful information and guidance in all possible situations in a way that does not hamper the creativity that makes the building process so engaging. We envision accomplishing this by softening the tone of our suggestions and placing an emphasis on the engineering content with many examples of buildings.

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