Educational Connections and Evident Learning using Interactive Display Objects in the Museum of Science Fiction

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The display objects proposed for the Museum of Science Fiction's Preview Museum site represent a range of culturally and technologically relevant interactive replica display objects from a variety of genre works. The collection exhibitions opportunities for links grouping items thematically, situationally, and/or educationally in the context of the interactive smartphone app, planned for incorporation with them.

The 'situational' analysis will draw on the Museum's narrative structure: that visitors will be presented with a 'dilemma' they must resolve during their exploration of the museum's artifacts and display objects. It is presented only hypothetically, as that narrative is being developed by a visitor experience team.

This document will explore some of those links and how they may be used to support formal learning and satisfy informal learning objectives, including ideas for the informal learning objectives themselves. It will expand upon the idea of involving a series of display objects to build upon learning concepts to achieve informal learning objectives, while also representing the challenge of connecting the components within that structure.

Educational Connections Informing Interactivity

Referencing the Museum's planning matrix, the following display objects were evaluated for their educational potential per the core ideas laid out in the Next Generation Science Standards. A range of visitor ages were considered for this formal/informal educational analysis: grades 3-5, middle school, and high school.

The Next Generation Science Standards differ from previous iterations of educational science standards in their use of performance expectations as qualifiable demonstrations of learning. These expectations do not involve the recitation of facts or figures, but the formulation of arguments, interpretation of data, and observation of scientific phenomena. By the design of these standards, a learner who meets performance expectations demonstrates their understanding of a core idea.

The clearest possible connections to the Next Generation Science Standards performance expectations are listed here for reference.

Museum Display Object	NGSS Lesson Plan
Dune Stillsuit	MS LS2 1, MS LS2 5 HS ESS3 1, HS ESS3 4
Flux Capacitor	3 ESS2 1, 4 PS3 2, 4 ESS3 1 MS ESS2 5, HS PS1 1, HS PS2 6
Iron Man Suit	3 PS2 2, 4 PS3 2, 4 PS4 1, 4 ESS3 1, 5 PS1 1, 5 PS2 1 MS PS2 1, MS LS1 3 HS PS2 6
Nautilus	3 PS2 2, 4 ESS3 1 MS PS3 1, MS ESS2 4 HS ESS3 4
Orion III	5 PS2 1 HS PS1 5
Photon Probe	4 PS3 2, 5 PS1 1, 5 ESS1 1 MS PS4 1 HS PS4 1, HS ESS1 3
R2 D2/C 3PO	3 PS2 2 MS PS4 3 HS PS4 2
Shuttlecraft	3 PS2 2, 5 PS2 1 MS PS3 1
Tricorder	PS1 1, 5 PS1 3, 5 PS1 4 MS PS1 1, MS PS4 3 HS PS1 7, HS PS4 2, HS PS1 5

The Gort/Maria robotic model and Portal Gun, while planned to be interactive, present only loose opportunities to connect to standards' performance objectives and so were removed from the above list.

Achieving the Standards' performance goals in the museum setting will be limited by the scope and digital nature of the interactive mobile app, but its simulations, models, and media may support users in gathering and understanding knowledge required to meet those objectives. At the Museum's end, recognizing potential connections to the core ideas reflected in the Standards may inform some of the interactivity possible to a user of the app. For example, drawing upon a connection to Earth System science, an elementary aged visitor could interact with the Flux Capacitor in this way: The Flux Capacitor needs a lightning strike to power it up to make the return trip from a time travel destination. An animated weather map could appear in the app to show local conditions and the potential for storms in the area (fictional). An audio recording of 'Doc' accompanying the visual could explain what causes lightning to occur and inform the user that this data is historical, recorded by scientists of that year for the study of changing weather and climate patterns. Lightning could 'strike' whenever a user determined that conditions or timing were right based on a graphical read-out and send a 'charge' down an illuminated wire 'telephone line' to light up the Flux Capacitor in its case. This action would connect real-world science and technology to a fictional display object and in doing so, also relay a disciplinary core idea for grade 3 Earth's Systems Science which states: Scientists record patterns of the weather across different times and areas so that they can make predictions about what kind of weather might happen next. (3-ESS2-1)

While acknowledging that formal disciplinary core ideas and their connections will make the museum a resource for educators and their students and provide fodder for potential interactive development, the list above reveals that few display objects express relationships with each other through the same disciplinary core ideas or performance goals. Though the Nautilus submarine, Iron Man suit, and Flux Capacitor each can relate information about their sources of power and renewing energy, they may not resonate to a visitor in that grouping (or order), nor be appropriately relevant to the age group that educational idea may target. A broader approach to deciding the informal learning objectives is required.

Appendix J and Informal Learning Objectives

Appendix J of the Next Generation Science Standards articulates a core idea that cuts across the standards; that is the interdependence between science, engineering, and technology. This core idea is not explicitly laid down in performance goals, but reflexively connects to many. Its core ideas may inform a framework for the development of possible museum-wide informal learning objectives. The core ideas of Appendix J, as they appear in the standards, are presented below.

Interdependence of Science, Engineering, and Technology			
K-2 Connections Statements	**3-5 Connections Statements**	**6-8 Connections Statements**	**9-12 Connections Statements**
· Science and engineering involve the use of tools to observe and measure things.	· Science and technology support each other. · Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies.	· Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems. · Science and technology drive each other forward.	· Science and engineering complement each other in the cycle known as research and development (R&D). · Many R&D projects may involve scientists, engineers, and others with

Influence of Engineering, Technology, and Science on Society and the Natural World			
K-2 Connections Statements	**3-5 Connections Statements**	**6-8 Connections Statements**	**9-12 Connections Statements**
· Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials. · Taking natural materials to make things impacts the environment.	· People's needs and wants change over time, as do their demands for new and improved technologies. · Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands. · When new technologies become available, they can bring about changes in the way people live and interact with one another.	· All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. · The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. · Technology use varies over time and from region to region.	· Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. · Engineers continuously modify these systems to increase benefits while decreasing costs and risks. · New technologies can have deep impacts on society and the environment, including some that were not anticipated. · Analysis of costs and benefits is a critical aspect of decisions about technology.

Based on the core ideas (here termed connection statements) above, another type of app-enabled interactive prompt could be developed, linking previously unrelated display objects.

For example, a high school-level user may be assigned the role of a scientist and undertake the task of exploring possible applications of the display objects as real-world technology. The mobile app's interactivity in this regard may be to simulate the use of the objects in a virtual real-world environment, where the known laws of physics apply. Users would apply their understanding of the world and determine through a simulated testing procedure which object has the most potential for real-world development. A possible sequence for this may be:

Portal Gun > Flux Capacitor > Iron Man Suit > Tricorder

At the end of the app, when they've resolved the problem, a video could be loaded to share with them the latest developments in the pursuit for a working medical Tricorder-like device, with special attention paid to the process of research and design (and acknowledgement of their role in a simplified simulation of that process as a tester). This would connect to the core idea described in the connection statements under section 1, grades 9-12. This is considered by the National Research Council of the National Academies in their publication of Surrounded by Science as an embedded assessment, wherein a learner uses their knowledge to advance their interactions in the exhibit setting.

The theme of science and technology supporting each other recurs throughout the museum's collection, and also alludes to the idea of innovation presented in the museum's interpretative framework. A less involved (or sequential) interactive might include a prompt for students at the grade 3-5 level to examine why a population would develop technology for water collection and purification, directed towards the Stillsuit display, to reinforce the idea of a population's needs changing and technology responding to those needs.

It would be challenging to evaluate knowledge transmitted if informal learning objectives are too specific. Requiring visitors to recite or reference facts presented moments earlier in another interactive won't demonstrate learning; the Next Generation Science Standards are revising thought patterns to encourage learning and the expression of knowledge in different ways. The broader the informal learning goals of the museum, the more achievable and measurable they will be. Simply acknowledging the role the supportive role of technology and science within science fiction, as well as their relationships with each other, may form a key informal learning objective for museum visitors across the age range.

Thematic Connections

There are also rich opportunities available to tie a series of display objects together thematically.

Wearable technology, communicators, transport devices, real-world potential, scanners and sensors, robotics, biomimicry, even changing perspectives on nuclear technology are all inherent aspects in the display objects as they are and form some of the possible thematic connections among them. Before app-enabled interactivity is considered, the education team could draw from these thematic connections to link display objects to educational objectives.

In a sequence, Gort (or Maria) could link to R2-D2 and C-3PO to express changing perceptions of technology as benign and service oriented, rather than an instrument of fear and the current climate of technological development as a change in attitude towards technological advances.

Problem Solving / Situational Connections

Dependent upon the 'dilemma' selected to form the Museum's narrative, additional connections between display objects may be possible. A user of the mobile app may be prompted to 'gather tools' for a fictional space transit or quick escape, and be required to determine and visit those display objects in the Museum that will aid in their exit from Earth and subsequent survival.

In another situation, a user may be prompted to use the scanning system of a Tricorder to determine which of the technological components has become self aware and assessing the risk to other visitors. This could introduce users to the idea of self-awareness, what constitutes living and non-living organisms, and Asimov's laws of robotics, as well as begin a dialogue about the future of technology as foreseen by science fiction.

Generic Learning Outcomes

Generic learning outcomes do not connect to the Next Generation Science Standards, but they have been adopted by other museums and information centers. The Museum of Science Fiction may connect in content to STEAM learning, but possible learning outcomes may not be scientific alone, but also cultural and historical. A link to these generic learning outcomes and a discussion of their application is being included here to represent another tactic for developing measurable learning objectives: https://www2.le.ac.uk/departments/museumstudies/rcmg/projects/lirp-1-2/LIRP%20end%20of%20project%20paper.pdf

Evaluating Impacts

In the *Framework for Evaluating Impacts of Informal Science Education Projects* (NSF, 2008, available online here: http://informalscience.org/documents/Eval_Framework.pdf) the following categories of measurable broad impacts of a museum exhibition are outlined: knowledge, engagement, attitude, behavior, and skills. Few of these impacts will relate to the interactive smartphone app alone; most could be applied to the preview museum as a whole. However, as they are regularly referenced by science-technology museums in planning exhibitions, they are worth considering.

To some extent knowledge has been covered in earlier suggestions. The museum's interactives will seek to increase knowledge and understanding in line with the museum's informal learning objectives, in development. It is difficult to hypothesize which of the display objects a single visitor will interact with within the space; their interactions may be informed by the crowd level, operating capacity, or personal interest and schedule. Developing museum-wide informal learning objectives supported by all (or most) display objects will ensure visitors are provided ample opportunity for achieving the learning objective, no matter the conditions of their visit. The National Research Council reminds planners that museum learning is free-choice for all these reasons, and advises developing learning outcomes as a reflection of a whole exhibition.

In the Museum of Science Fiction, engagement with the display objects could be measured by 'tracking and timing' of a visitor's movements (as recommended by an NSF EAGER Study), and interaction with the mobile app by time stamps, usage, and/or other metrics that Google Analytics is capable of analyzing. Most fitting for these would be the robotic components, R2-D2 and C-3P0, or the model of Gort or Maria. These analyses, though complicated to engineer, could produce qualifiable results to show evidence of sequential progressive learning and cognition.

It is unlikely that a visitor's behavior will be changed by any of the display objects or their accompanying interactive capabilities; the museum is not actively seeking to change any behavior, other than to perhaps inspire visitors to seek out more examples of science-fiction available (and drives sales at the museum store).

However, it is possible that the display objects, viewed as a whole exhibition, could change attitudes about the role of science fiction in the development of technological advances, and vice-versa. This could be described as what a visitor considers the 'value' of science fiction and its place in education. Measurement of this impact could be achieved through a staff-prompted exit interview or quick app exit survey and connects back to the informal objectives posed in the Appendix J section of this document.

Possible skill development is dependent on what interactive capabilities are put into the mobile app, however scientific inquiry skills such as observation, prediction, and interpretation could be reinforced by the app. Reinforcing scientific reasoning is a reasonable skill to make inherent in all of the app-enabled interactivity.

Sequential Progressive Cognition

To measure evident transformative informal learning, the Museum will implement a sequence of wifi-enabled exhibits with specific learning objectives associated with individual display objects. Each display object is enabled for interactive visitor control via a Bluetooth-connected mobile device. The mobile software will require the visitor to learn how adjust interface settings for each display object to achieve a desired outcome. Each display object will have a unique learning component needed to successfully adjust the settings of other display objects.

To use a simplified example, a sequence of three display objects (the sequence of the display objects is at the visitor's discretion) will illustrate the sequential progressive cognition concept: Frankenstein's creature, a trilithium heliophysics photon probe, and a terminator.

Creature > Probe > Terminator

In the Frankenstein exhibit, visitors will learn about science fiction's very early beginnings and how Mary Shelley was inspired to write the seminal story. The science areas in this story are rich for informal learning about anatomy, physiology, microbiology, surgical procedures, and electrical reanimation (think: modern day defibrillators), to name a few. The desired outcome for this display object is to learn what is needed to reanimate the seven-foot creature lying on the operating table in front of you.

The visitor reads on their mobile device about the correct procedure to generate the energy needed to "spark" the creature to life. By correctly adjusting the settings (wattage, volts, power curve, time duration, body temperature, and biofeedback), a brightly visible Tesla arc would arc-across two electrodes from table-side to the Creature's neck. The arc would continue across the electrodes and activate the animatronics underneath the Creature's face and hands. Beginning with hand and facial twitches, the Creature's lifelike eyes open after a few more seconds and then smiles to end the program before resetting for the next visitor.

Moving over to the trilithium heliophysics photon probe, this exhibit shows visitors about other science areas: solar weather, astrophysics, astronomy, nanotechnology, and celestial cartography. The desired visitor experience outcome from this exhibit is to “hover” the probe to test its propulsion system and on board multi-sensory instrument package.

In order to hover the probe from its maintenance bay (via high capacity magnetic levitation, or maglev – as also demonstrated in the Future of Rail Transportation exhibit), the visitor reads (on their mobile device) about how to download and analyze the probe’s heliophysics data and run diagnostics on the probe’s internal systems. By correctly adjusting the power settings (as learned from the Frankenstein exhibit) to “test” the sub-light propulsion system, the probe lifts off of its cradle and hovers for ten seconds before resetting for the next visitor.

The last exhibit in the sequence uses a robot from the film, *Terminator.* This exhibit introduces the visitor to engineering, nanotechnology, robotics, and computer science academic areas. The desired learning outcome is to re-program the Terminator to be a Museum docent. To accomplish this task and activate or “wake up” the Terminator, the visitor must test/actuate the robot’s arm and learn how to correct the robotic operating system (ROS) by downloading and removing “dangerous” code and uploading the repurposed, “safe” docent ROS code (downloading and analysis were introduced in probe exhibit). Upon successfully uploading the new code, the Terminator is activated, red eyes illuminated, it sits up, and greets the visitor by name . . . “Hello [Patrick], may I assist you,” (perhaps in an Austrian accent) using the Museum’s *amb-i* technology (ambient intelligence) as described by David Brin in a related article.

As visitors interact with the exhibits and play with the display objects using their mobile devices, learning measurement can be recorded and analyzed for performance evaluation. Measurement parameters could include: basic demographic data, time on task, percentage of correct choices, level of difficulty, exhibit progression sequence, relational progression sequence, cognition progression sequence to begin demonstrating degrees of evident learning in an informal museum environment.

The Museum of Science Fiction presents a unique informal learning opportunity to experiment with bringing sophisticated educational concepts to the general public in a very entertaining and exciting way. This approach also allows an opportunity to deliver challenging, more complex academic topics to students in a less intimidating environment, possibly inspiring them to learn more about these areas. Admittedly, high school calculus will never be easy for everyone, but if we can sneak it into a few exhibits where the visitor needs a basic understanding to activate the Museum’s Stargate, then perhaps we have made some tangible progress worth measuring.

Recommended Action

The recommended course of action is to use Next Generation Science Standards to inform some of the app's interactivity and develop museum-wide informal learning goals that reflect the broad understanding of the interdependence of science and technology, and their role in the real and fictional worlds. Using the NSF's Framework for Evaluating... the Museum of Science Fiction will be best positioned to develop and evaluate potential learning outcomes.