Stem Promotion through Museum Exhibits on Cardiac Monitoring & Cardiac Rhythm Management

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***Abstract*—Formal education in science, technology, engineering and math (STEM) does not successfully engage all of the students who have potential to become skilled in STEM activities and careers. Museum exhibits may be able to reach and engage a broader range of the public. STEM Exhibits that are both understandable and capture the imagination of viewers may contribute toward increased interest in STEM activities. One such topic for such an exhibit could be cardiac pacemakers and cardioverter defibrillators that sustain life.**

Although museums have existed for centuries, the available types of exhibit designs has dramatically increased in recent decades due to innovations in technology. Science and technology museums have especially taken advantage of the progression of exhibit design to developed new ways to communicate to their viewers. These novel presentation tools allow museums to more effectively convey to and engage viewers. This paper examines the techniques employed by museums in exhibits and considers the practices of several museums with exhibits related to cardiac monitoring (CM) and cardiac rhythm management (CRM).

I. Introduction

Society has problems that can be alleviated by those trained in the fields of science, technology, engineering and math (STEM). Many people are not prepared for STEM careers because earlier in their life they decided that they were neither interested in nor good at STEM activities. A subset of these people would have become interested in and good at STEM if earlier experiences had sparked their curiosity and affirmed their potential ability. Museum exhibits could facilitate such experiences for a wide spectrum of society, including many of those who would otherwise have a low probability of engaging in STEM activities and careers.

An example of an attraction that can bring in viewers, engage their minds and emotions, spark their curiosity and increase their interest in STEM is Frankenstein. In the early nineteenth century, Mary Shelley composed perhaps the first modern science fiction novel about a scientist and his monster. Two hundred years later, this intriguing story still has the ability to apprehend the attention and interest of people today, particularly children. The Bakken Museum (Minneapolis, MN, USA) uses this aura of Frankenstein to attract viewers to all of the exhibits related to electricity and life [1]. The U.S. National Library of Medicine also made a long running exhibit (2002-2012), *Frankenstein: Penetrating the Secrets of Nature* [2]. This exhibit explored the historical evolution of how the story was perceived by society in different time periods, and how the story seems to bring insight into whatever the contemporary ethical struggles with science, life and biology are right up to the present day [2].

Although the Bakken Museum and the National Library of Medicine both used the Frankenstein story to inspire their exhibitions, they developed different themes, illustrating the creative potential for relevant societal impact. By drawing in viewers through the story of Frankenstein, both children and adults learn about history, society, complex ethical issues, electricity and life. Some of these viewers may have a long-term increase in STEM involvement.

An extreme example of such an impact is Earl Bakken. As a young boy he watched the movie Frankenstein (an early multimedia experience), became fascinated with the relation between science, electricity and life. His fascination led to playing with educational toys (related to electricity, chemistry and building), pursuing educational pathways toward electrical engineering, starting a company repairing medical devices, and developing electrical circuits and devices to help a physician sustain life with battery powered cardiac pacemakers. Not all interactions between museum exhibit and viewer will result in such a STEM directing impact, but some may constitute one of many steps guiding a person toward increased STEM interest and activities.

Museums are intended to hold history and knowledge, and present that to others. Without effective presentation, viewers will not come, experience or have a memorable impact. Besides a focus on a compelling science fiction story like Frankenstein, another theme could be concepts and devices at the core of life, monitoring and sustaining life in ways that much of the public would find both familiar and attractive to explore further. Such would be a theme around the function and rhythms of the heart, methods to monitor the rhythms, and artificially generated electrical pulses to help the heart function better. This theme could be termed Cardiac Monitoring & Cardiac Rhythm Management (CM&CRM). CM&CRM includes cardiac pacemakers, Cardiac Resynchronization Therapy (CRT), Electro-cardiogram (ECG), Implantable Cardioverter Defibrillator (ICD), and Automated External Defibrillator (AED). Exhibits related to this theme of CM&CRM have well known concepts like heart contractions, ECG traces and pacemaker devices, and yet have much depth that optionally could be explored in numerous related areas including cardiovascular physiology, electrical signals and circuits, signal processing, mathematical algorithms, computer programing, surgery, implantable devices, embedded processing, batteries, and health and fitness.

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This paper explores the historical development of effective museum exhibits, ways to present engaging exhibits, and considers examples of exhibits related to CM&CRM.

II. HISTORY OF MUSEUMS: ENTERTAINMENT VS. EDUCATION

For millennia, humans have been keeping objects as reminders of the past. The root of the word "museum" may be expressed as the "place of the muses." Muses were considered the inspiration of the arts and sciences in Greek mythology. Likewise, museums attempt to inspire viewers to learn from the past and build for the future. People not only feel connected to objects of their personal past, artifacts or places associated with a community's past are also treasured. This sense of collective memory continues to motivate preserving the past.

Perhaps the earliest museum was discovered in the ruins of Ur in a room that contained a variety of labeled artifacts. In the 17th century, Elias Ashmole assembled and donated a collection of curiosities to Oxford in what is considered the first modern attempt at a museum [3]. Such early exhibits were venues for collectors to show curious and fascinating objects, and many people were willing to pay to see.

Thus, early museums had a primary purpose in entertainment. This element of entertainment remains as an integral part of museums. In recent decades, however, museums have shifted towards education as a primary purpose [3]. For any learning to take place, a museum exhibit needs to attract and capture the attention of viewers. Thus, museums strive to balance roles of holding history and knowledge, entertaining and educating.

Museums of recent years have benefited from research regarding human learning capabilities and tendencies [3]. Great interest has been generated by museums into how people learn and how to effectively instruct different types of people. Learning of history and even of science, encompasses more than just objective facts. Memorable learning often involves positive and negative emotions produced when viewing the exhibit.

Learning at a museum is different from learning in conventional venues of education. Museums have a wider spectrum of the public, but these potential learners are free to determine both the pace and direction of learning. Research has characterized several types of learning tendencies [3]. The "behaviorist" approach is where people are governed by their previous experiences and will learn based on the stimulus provided by museum exhibits. The "cognitive-developmental" approach considers learning to be conducted by action of the learner with the exhibit.

III. SHAPING EXHIBITS TO BE ACCESSIBLE YET HAVE DEPTH

A principle purpose of museums is to educate. Unfortunately, the difference in the knowledge of "the experts" and of museum visitors is often wide, especially in science museums. The goal of a museum should not be to transform the museum visitors into experts [4]. Expertise takes more than a day to obtain in any field. Instead, museums should try to guide viewers through small steps. Most museums build exhibits that aimed at an appropriate level of understanding for their viewers. Exhibits may even have a tendency to oversimplify. Not all simplifications are inherently wrong, yet exhibit designers must walk a fine line between oversimplification and complexity.

Schools and museums often have partnered together in order to educate students. The dialogue between museum staff and teachers is of upmost importance to present the exhibit concepts in the most accessible way for the students to understand and learn.

Different museum visitors learn differently. An exhibit that reaches one visitor effectively may struggle to reach others. Museums should endeavor to reach a variety of learners, such as by designing exhibits based on multiple perspectives. Conveying a science concept in an all-encompassing way in a short period of time is essentially unachievable. Instead, a museum should try to take small steps in building upon the existing knowledge of the viewers.

Over the years, science and technology museums have produced fascinating and creative ways of educating their visitors [5]. Exhibits have incorporated various interactive exhibits. These exhibits have the ability to instruct in ways that traditional displays are unable to communicate. These exhibits appeal to an assortment of visitor groups that may otherwise be put off by conventional exhibits. Children in particular appreciate hands-on displays. Although interactive exhibits have merit, artifacts still have an important place in exhibits. Artifacts can exist as symbols of innovation and serve as educational tools.

A general purpose of museums is to preserve artifacts and to make them available to the public [6]. Unfortunately, these two functions are in conflict. By making an object accessible to the public, artifacts can be put at risk. Displays expose artifacts to various threats that would otherwise be avoided. Even elements such as light have the potential to cause great harm to historical items. One way to preserve artifacts is to display replicas [7]. Replicas allow viewers to see important artifacts, but also have the original one preserved in the most optimal way.

Not only do museums vary in size and collection, museum visitors exhibit a wide range of diversity [3]. Museums must learn to meet to the needs and qualities of its visitors. In this way, a museum is akin to businesses seeking customers. Although museums must ultimately respect the essence of their collection, viewing their visitors as customers aids exhibit designers to make the best exhibit designs.

Sometimes, museums can become overly content with a certain set of viewer types. In this way, museums may reflect societal divisions and may unknowingly cater to a certain category of people to the educational or social detriment of others. Such a division may reinforce the erroneous self-expectation in some of the viewers that they are not interested in nor capable of STEM activities. Thus, a museum should continually strive to attract new visitors through possibly new types of exhibits. This research should be conducted on a regular basis in order to re-evaluate and constantly adapt to provide the best educational experience.

IV. TYPES OF EXHIBITS

Education, balanced with entertainment to attract and maintain attention of viewers, has become a primary purpose of museums [3]. Interpretation is of foremost significance in the museum world. Some objects need relatively little explanation, but interpretation is often necessary in order to wholly appreciate an artifact. Interpretation includes the placement of objects, surrounding environment, grouping with other objects and explanations. Just as a successful presenter has considered the audience, so a museum should consider the viewer's point of view when setting up the interpretation of the exhibits. Visitors approach a display with certain assumptions or knowledge that has already been acquired. Museums can adapt their interpretation to best suit the needs of their audiences. Part of the interpretation is what goal or message the exhibit is to convey to the viewer. In order to effectively communicate the essence of its exhibits, a museum must select the best interpretation techniques.

In modern times, a variety of exhibit designs are available for use. From audiovisual exhibits to models, interpretation can employ a great number of techniques. Simple graphics are a common tool used to convey an interpretation to the public. Graphics can include blocks of text, illustrations, and photographs. This method is straightforward and easy for visitors to read and enjoy. A three-dimensional approach employs a variety of objects to communicate a point to the museum-goers. This technique avails an exhibit to models, furnishings, dioramas, and replicas. This method, like graphics, uses visual stimuli to explain an interpretation. 3D printing can be used to make a replica or render a 3D computer model to enhance viewer understanding.

Audio-visual and multimedia may also be utilized in exhibits. These tools ought to be carefully planned and considered to attract and deepen viewer understanding. Audio-visual and multimedia designs offer opportunities of learning for viewers. Technology has offered museums numerous choices in this category. An exhibit design can even use such technologies as holograms [8]. Holograms are constructed using complete optical wavefronts. These wavefronts capture images that manifest in a 3D appearance that can be observed from multiple perspectives. By combining holograms with a 3D computer graphical interface, the exhibit can become interactive.

Interactive exhibits are a relatively recent phenomenon in museums. Interactives engage the sense of touch and kinematic motion as experiences to enhance memory and learning. Interactives are used more and more in science and technology museums. This approach employs a variety of types of exhibits, such as computer games, touchscreens, and movable models. Virtual Reality is another novel technology that museums have grasped as a powerful mode of communication. Virtual Reality technologies have also been used as an efficacious tool to teach medical students and healthcare workers for 3D procedures and general instruction [9]. Well thought out and designed interactive exhibits can enhance viewer learning. The use of each type of exhibit should be based both on the types of viewers a museum wishes to reach and on the message of interpretation the museum desires to convey.

V. CM & CRM EXHIBITS

A. Examples of CM&CRM Exhibits

Cardiac Monitoring & Cardiac Rhythm Management (CM&CRM) related history, concepts and devices can function as the theme of museum exhibits that attract and educate viewers in ways that encourage understanding, curiosity and interest in STEM activities. As already mentioned, the Bakken Museum has a Frankenstein related exhibit. As electricity was employed to bring life in Frankenstein's monster, so Bakken created a pacemaker to preserve life. Through these exhibits, including Frankenstein's Laboratory, The Bakken Museum wishes to inspire the next generation. The museum utilizes creative exhibit designs in an effort to both entertain and educate. Other exhibits in the museum, such as Ben Franklin's Electricity Party and Electrifying Minnesota, employ imaginative displays capture the attention and deepen the understanding of viewers.

Pacemakers have experienced many further developments, incorporating cardiac monitoring and other interventions. Electrocardiogram (ECG) is a way to observe the electrical activity and timing of the muscle contractions in the chambers of the heart. ECG is used to diagnose heart rate, irregularities, conduction blockages and other problems related to the timing of contractions. The history, science and engineering of ECGs is presented at museums across the world. The Dittrick Medical History Center is a museum related to Case Western Reserve University (Cleveland, OH, USA).

The museum exhibits artifacts and displays many of the historical developments of ECG. Many of these artifacts and key concepts were developed at this university. Around the turn of the twentieth century, biomedical technology developed and became able to measure the electrical impulses of the heart. In the late nineteenth century, the capillary electrometer was the first machine that could record the electrical impulses of the heart [10]. Eventually, physician Willem Einthoven developed a system of recording the electrocardiography using labels P, Q, R, S, and T that has survived to modern times. He also employed a string galvanometer to directly document ECGs. Einthoven is credited with developing the ECG and, in 1924, he received the Nobel Prize. Eventually, the leads Einthoven used to monitor the heart were replaced by electrodes. In present day, the leads can be implanted along with a pacemaker to better function.

The Dittrick Medical History Center includes a Williams-Hindle Model 2, circa 1920, in its collection. This ECG device was first operated in a medical research laboratory, but, after its use had terminated, the machine was donated to the museum in 1958. The ECG, as a concept and machine, encouraged new cardiac research. As a result of the capabilities of the ECG, hospitals produced new methods to document patient cardiac health based on ECG charts. This technology also accelerated the trend toward greater physician specialization.

The ECG was and is significant to cardiac care and healthcare overall [11]. Museums can produce exhibits to convey the history of the ECG. The Nagoya City Science Museum (Nagoya, Japan) highlights the history of ECG. The exhibits show various views of the heart in cross-sections. The display reveals the path of the electrical impulses through the atria and then the ventricles before it returns through the atria.

Although the ECG can detect irregularities in a heartbeat, it cannot remedy any detected problem. Sudden cardiac arrest is a condition in which the heart discontinues functional beating. Arrhythmias may also result in a lack of functional heart contractions. Ventricular Fibrillation is an arrhythmia in which the lower chambers of the heart beat at a fast and irregular beat. Ventricular Tachycardia (another arrhythmia) occurs when the heart continues to beat an overly speedy and regular pace. If not treated such conditions may lead to death, possibly within minutes. Each minute that passes results in a ten percent reduction of the probability of recovery. An Automated External Defibrillator (AED), can supply an electrical shock to the heart that allows resumption of rhythmic and coordinated heart beats. An AED directly may sustain life.

"A Hands-On Adventure" (AHA!) children's museum (Lancaster, OH, USA) has utilized an AED in their exhibits [12]. By the combining a trainer and the AED, the museum has made an exhibit to educate visitors on the use and life-saving significance of AEDs. "AHA!" employs a visual representation of an AED to demonstrate its purpose.

B. Exhibits on CM&CRM may improve STEM

The museums containing exhibits concerning the progression of CM&CRM, can engage viewers through creative and thought provoking exhibits. Viewers may become more interested in and desire to undertake more STEM activities. Advancements in exhibit technology have granted museums a variety of designs. These varieties allow for an exhibit designer to best convey a message and an interpretation. Although the Bakken Museum and other science and technology museums have utilized these developments, available technology is ever-changing and require even greater diligence of museums in the modern era. Museums should consider the implementation of exhibit designs and strive to continually improve exhibits to reach more people.

Many individuals can learn to appreciate STEM and be inspired through basic museum text block descriptions. Although this still appeals to some, today's generation seems to need greater audio-visual stimulation to spark interest and keep attention. Fortunately, museum technology has greatly progressed. Enhanced visual imagery, such as high definition screens, can bring cardiac pathways and technology to life in the viewpoints of the next generation. Touchscreens have been successfully employed to engage science museum visitors. The current advances in 3D technology can be utilized in exhibits to bring captured images of STEM right to a viewer and ignite curiosity that can last. It is up to STEM focused museums to discover new and effective ways to educate and interest its audience in STEM.

The purpose of museums, regardless of type, is to preserve their historical collections and to make them available to the public. Presentation is a critical component of any museum. Their exhibits and displays are the outward expression of the contents of the museum's collections. A museum's staff must take care to accurately portray history through its exhibits. Not only are museums responsible to faithfully represent the past through artifacts and displays, museum staff must strive to fashion exhibits in a creative manner. The study of history intended as both an educational and motivational tool. By preparing suitable exhibits, an audience can learn from the past and be inspired to improve their future.

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