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Engineering an Electric Eel Exhibit for Effective Engagement, Entertainment, and Education

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Abstract

Science museums, zoos, and aquariums are informal learning environments in which interactive technologies can be used to engage, entertain, and educate people about science. Hands-on electronics and graphic displays were created for the electric eel exhibit at a public aquarium in Detroit, Michigan. Electric pulses from the eels were converted to sound and light flashes, pulse frequency and text about the eels were displayed on a monitor; and a button was provided to enable the sound effects to be heard. Surveys conducted before entering and after exiting the aquarium showed that the interactive electronic enhancements of the exhibit were associated with significant increases in knowledge, enjoyment, and time spent at the electric eel exhibit. Patrons who did the survey prior to encountering the exhibit gained more than those who did not, suggesting that a combination of social and technical enhancements may be the most effective way to achieve an impact on the knowledge and enjoyment of the general public.

Keywords: *Bioelectricity, Devices for Learning, Electric Eel, Learning Environments*

1. Introduction

INSTITUTIONS such as science museums, zoos and aquariums serve important educational roles in our society. These public educational "commons" offer programs that educate and influence attitudes and enthusiasm for their focus areas. Aquariums have been known for centuries as a way to not only entertain the community, but also to educate them about species from around the world. Zoos and aquariums present materials that can educate people about basic biological concepts, biodiversity, evolution, ecology, and conservation. A recent strategic planning report noted "For most Americans, STEM [science, technology, engineering, and mathematics] learning occurs outside formal classrooms in informal settings, such as parks, zoos, science centers, aquariums, and museums"[1]. Visits to a public aquarium have been shown to be associated with significant positive persistent increases in conservation-related awareness and knowledge [2]. Therefore, technologies that can augment the experience of visitors to such institutions and engage them in educational activities are likely to have beneficial effects on their knowledge and attitudes towards science.

The goal of the present project was to develop electronic enhancements to the electric eel exhibit at the Belle Isle Aquarium (BIA) in Detroit, MI and to determine whether these enhancements improve the enjoyment and knowledge of visitors to the Aquarium. Built in 1904, the BIA is the oldest operating public aquarium structure in the United States. Its green-glass tile arched ceiling was designed by architect Albert Kahn to evoke an underwater feeling, and its 10,000 ft^2 45-tank gallery houses more than 125 species of fish. The BIA is visited by more than 100,000 people per year. Besides having a diverse collection of species from both freshwater and marine environments, the BIA emphasizes several themes illustrated by unique aspects of its collections, including a large number of species of air breathing fish (e.g., lung fish, gourami, gars, electric eels, arowana, etc.), invasive species (sea lamprey, zebra mussels, round gobies, and models of northern snakehead, Asian carp, and others), rare African species (e.g., *Polypterus* spp.), and more species of gars than any other public aquarium in the world (Longnose, Shortnose, Spotted, Tropical, Alligator, Florida, and Cuban gars).

The BIA collections are meant to entertain the public with a variety of organisms and to educate the public about biodiversity and the unique adaptations by which fish interact with their environment and other organisms. A planned enlargement of the BIA exhibits of electric fish gave impetus to developing electronic enhancements to its electric eel exhibit both to illustrate the large electrical shocks that fish are capable of producing and to educate the public about the variety and sources of electrical activity in fish and, by extension, in the visitors' own bodies.

With drab color and often languid behavior, electric eels, *Electrophorus electricus*, may not at first seem attractive to the public; however, the eels' unusual respiratory behavior and their potent electrical discharges provide great opportunities for engaging the public's attention. Electric eels are found in South America in the Amazon basin, and their aquatic environment is often shallow, muddy, and low in oxygen. Therefore, unlike most other fish, which extract oxygen directly from water through gills, electric eels are obligate air breathers. Electric eels have evolved to obtain their oxygen from the air by surfacing at intervals to swallow air and absorb it through specialized capillary-rich tissues that line their oral cavity. Electric eels must surface every few minutes to obtain air or they would drown [3, 4].

Electric eels have poor vision, as befitting a fish that lives in muddy water, but can use low voltage electric pulses and their lateral line electroreception organs to locate the water surface for breathing. Electric eels can also generate high frequency, high voltage pulses for stunning prey [5-7], or for defense. These electric discharges are generated by three electric organs. The first to be developed, Sachs' organ, is located at the tail of the eel, produces low voltage pulses, and is used mainly for communication and navigation. The main organ, located on the top front of the eel, develops next, followed by the Hunter's organ, located on the bottom front of the eel. These two organs produce high voltage pulses of approximately 500 V that are used for protection from predators, for mediating fright reflexes, and for stunning prey.

While few electric pulses are observed when the eels lay motionless at the bottom of their tank, the public can frequently observe the navigation pulses that are produced every few minutes as the eels stir themselves up to the surface of the water to take a breath. More dramatically, when the eels are fed with a small piece of fish dropped into their tank, the eels respond immediately with rapid swimming and producing high frequency, high voltage pulses, and often stay aroused after the feeding event for a half hour or more. Similarly, when the eels are startled, they also respond with high frequency, high voltage pulses, possibly as a defensive response.

The reliable and frequent electrical discharges produced by electric eels provide an opportunity to engage the interest of the public. Many other behaviors are complex and difficult to quantify and analyze; however, electric pulses produced by electric eels are easy to detect and quantify. Both the low frequency, low voltage pulses and the high frequency, high voltage pulses are readily amplified and, as will be shown, can be used to produce real-time multi-media and analytical displays that can educate, entertain, and engage the public about bioelectricity.

2. Related Work

Various technologies have been developed to enhance the educational value of visits to science museums, zoos, and aquariums. A number of studies have investigated mobile devices to assist information gathering and to promote concept generation for specific museum displays. Kali et al., [8] provided students with a mobile app to activate location-aware display-specific multimedia presentations on their mobile devices. Although the apps were viewed by users as poor, they also conceded that they helped in the learning process. Context-aware devices that optionally guided the learning path of students in a geology exhibit about rocks and fossils yielded greater learning with guidance invoked than without it [9].

However, mobile devices are a step removed from the displays for which learning is facilitated and may lack the impact on visitors that direct interaction with the displays themselves might yield. An interesting technology that enables virtual interaction with a museum display is "augmented reality" using a laser drawing tool that enables patrons to make virtual drawings on real objects and to simulate interactions of virtual creatures with one another. Using such a system to stimulate museum visitors to speculate about mouth parts used for feeding in a fossil baleen whale, Takahashi et al. [10] report that although the laser system attracted the interest of visitors, no significant increase in knowledge was demonstrated as pre-tests showed that most visitors already knew the facts that the hands-on display was designed to teach. Nevertheless, the researchers concluded that the augmented reality hands-on system can help learning because the system generates interest and creates the conditions for learners to test their imagination against reality.

Similarly, digital mixed reality (MR) media have been used to educate the public at the Singapore Science Center about evolution [11]. The MR Evolution Table has a table-like screen that can display interactive icons (such as virtual paddles, knobs, or imaginary creatures) that a person, visualized by a camera above the screen, can interact with. Despite the enthusiastic description of the Evolution Table and other MR applications by the authors, the actual benefits of the system in terms of educational efficacy have not been analyzed.

While no previous peer-reviewed literature appears to have been published about museum displays exhibiting electric eels, these fish are found in many public aquariums and the electric pulses have sometimes been used to activate devices that draw attention to the display and may also serve an educational purpose. A conference presentation that reported on post-interaction open-ended interviews of fourteen families indicated that among three interactive exhibits at the New Orleans Aquarium of the Americas the electric eel exhibit was the most memorable both short term and weeks later [12]. The New Orleans exhibit included a “finger tickler shock device” that gave small electrical shocks when visitors turned a knob; however, the shocks were not directly related to the behavior of the eel. A master’s thesis by Hooley [13] describes a device at the Shedd Aquarium that can measure bioelectricity in the human hand for visitors to compare with text and graphic descriptions of electric eel pulse voltages; however, this study reports only the opinions of the designers of such displays and not the visitor experiences. Other aquariums also have displays in which the electric pulses of the eels light up LEDs and produce clicking sounds [14] or other computer-generated sound effects [15, 16]. Other “hands-on” exhibits in which the aquarium visitor can touch two electrodes and feel shocks produced by an electric eel (the available information about the displays is unclear about whether these are direct or computer-mediated and controlled shocks) are described at the Cal Academy and Ripley’s Aquarium of Canada [17, 18].

Some electric eel exhibits have used these displays to activate inquiries about whether humans also produce bioelectricity, through a light and text display in a human heart cartoon [16]. Visitors to the Blue Planet Aquarium located in the United Kingdom are able to touch a large “voltmeter”, which displays a reading of how much electricity their body generates, possibly a response to the human electrocardiogram. Despite these varied and innovative displays, no peer-reviewed study appears to have examined their effectiveness at actually engaging, entertaining and educating visitors. We hypothesized that the electric eel display at the Belle Isle Aquarium is able to achieve significant effects in all three aspects for the audience.

3. Implementation of Interactive and Educational Electric Eel Exhibit Components

This exhibit was implemented at the Belle Isle Aquarium for two electric eels housed together in a 650-gallon tank equipped with a heater to maintain 24.5 $\pm$ 1.5 ^{O}C. Signs above and to the right of the tank describe some of the life history characteristics of these animals. For this project, lights, loud-speakers, and an electric eel model with a button for interaction were added at the right of the tank and an all-in-one computer display was added on the left (Figure 1). A video illustrating the interactions of several visitors with the exhibit is provided in a supplement. The electronic and software designs for this equipment are described below.

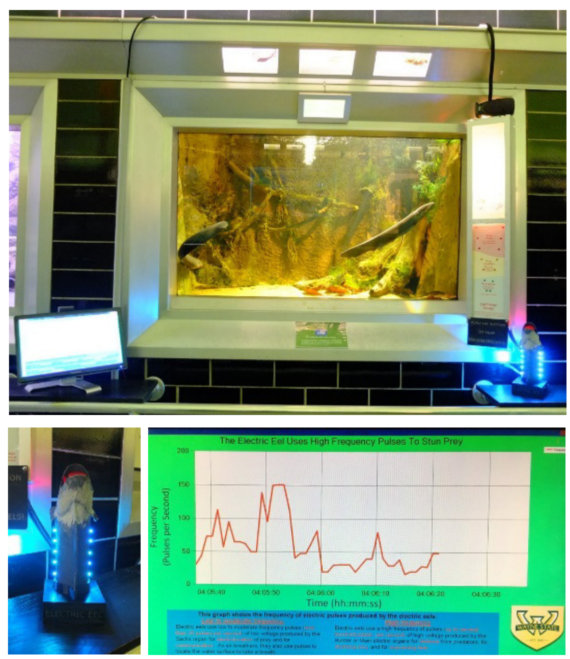

Fig. 1. Electric eel display at the Belle Isle Aquarium. Top: Overall view. Bottom left: Electric eel model with button (red, in mouth). Bottom, right: Real-time frequency monitor display.

3.1 Interactive Control of Sound Effects

In the original design of the display, dating back many years and similar to other aquariums of the time, wires were placed in the tank to pick up the electrical activity, the activity was amplified by an audio amplifier, and the output was used to light up a bank of lights such that the larger the pulse the more lights would turn on. The output of the audio amplifier also went to speakers to produce a clicking sound every time the eels produced an electric pulse, also a common feature of electric eel exhibits. The innovative feature of the present embodiment is that the output of the speakers is wired through an interactive electric eel button display that enables viewers of the eels to push a button to temporarily (33 seconds) activate the sound effects; the button can be pushed again to reactivate the sound system after it times out.

The button device is housed in a robust model of an eel's head (Figure 1, bottom left) that is equipped with light emitting diodes (LEDs) at the locations of sensory features of the eels (their eyes and lateral line sense organs) that light up according to how recently the button was pushed and whether the sound system is active. The model is constructed of a metal cylinder, cut to the desired shape, fins added with a heavy cardboard substructure, and then covered with paper mache and paint to simulate the appearance of the anterior portion of an electric eel.

The interactive circuit that activates the sound and controls the lights on the model eel is contained inside the button display and shown schematically in Figure 2. The circuit consists of LEDs, an Arduino microcontroller board (Interaction Design Institute Ivrea; Ivrea, Italy), relays (Songle SRD-05VDC-SL-C, SunFounder, London, UK), resistors, switches, and a large red push button (Uxcell; Kwai Chung, Hong Kong, China). Figure 3A shows a flow chart of the software that turns on the sound system and changes the color of the LED lights during 33 seconds. Both the duration of turning the sound system on and the colors of the LEDs are programmable (see flowchart and spectral characteristics in Figure 3) and could be changed in both intensity and color if desired.

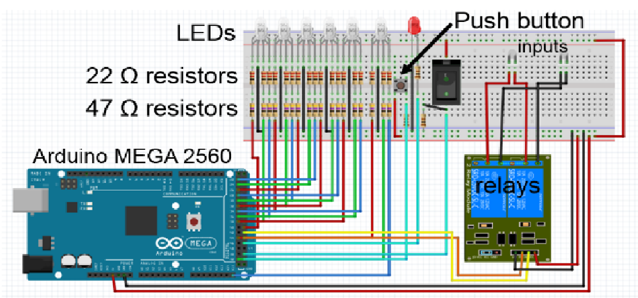

Fig. 2. Diagram of the button display circuits and controller hardware.

3.2 Frequency Monitor and Information Display

The pulse outputs of the audio amplifier are simultaneously wired into an Mccdaq A-D converter (USB-1208FS-Plus, Measurement Computing Corporation; Norton, MA), the output of which goes to a Dell All-in-One Computer (Inspiron 20 Model 3043, Dell, Round Rock, TX) for display of the frequency of the electric eel activity. The software that detects and displays electrical eel pulse frequency, E2FREQ, is written in C# coding language (Visual Studio, Microsoft, Redmond, WA). As outlined in the flowchart in Figure 4, E2FREQ filters out low levels of electrical noise, analyzes the voltage signals for duration and intensity of pulses, counts the numbers of pulses per second, and then displays the frequency (pulses per second) on the screen.

The E2FREQ program samples the electrical activity at 10 kHz, so that it can graph voltage pulses of durations as short as one millisecond, which is necessary due to the brief duration of each pulse produced by the electrical activity of the electric eels. The resultant graph, shown in a screen-shot in Figure 5, constantly scrolls from right to left as the pulses are detected in real time with each passing second.

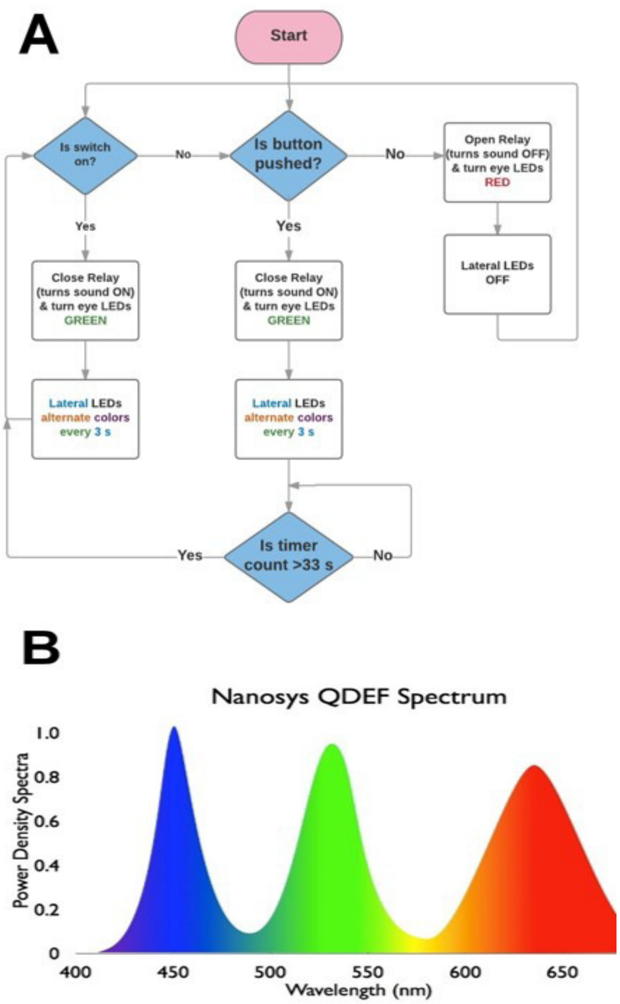

Fig. 3. Software control of the electric eel button display. A: Flowchart for control of the display lights. B: Spectral characteristics of the display LEDs, based on [19]. The red, green and blue peaks can have 8-bit integer intensity values from 0 to 255, enabling the LED to have 16,777,216 possible colors.

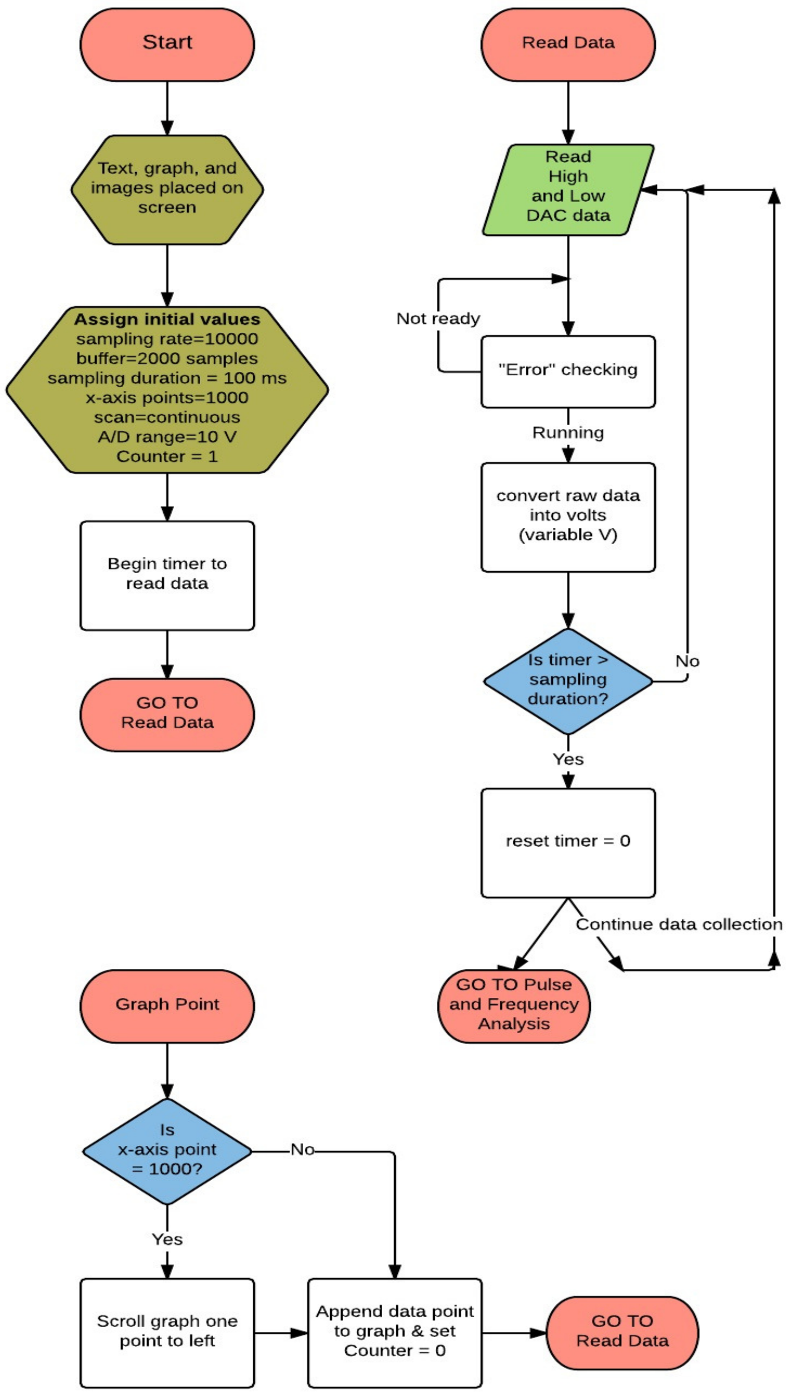

Fig. 4. Flowchart showing the logic flow of the E2FREQ electric eel pulse detection and frequency display software. Initiation of the program begins at the upper left (Start flow) to set up parameters, and then is followed by a loop that first inputs the electric eel pulses (Read the Data flow) digitized by the analog to digital converter (DAC), then analyses the voltages to identify and count pulses per second (Pulse and Frequency Analysis flow), and plots the values on the computer monitor screen (Graph Point flow).

The display illustrated in Figure 5 also adjusts the frequency scale according to the highest frequency of pulses detected during the approximately 45 seconds of the most recent activity displayed on the monitor at all times, as can be seen by comparing the scales on the two graphs in Figure 5. The screen also includes educational text relating the different frequencies of activity that are seen to the likely function of the activity.

4. Survey Design

The purposes of the button display user-interface and E2FREQ monitor display were to engage visitors and to improve the entertainment value and educational aspects for visitors to the electric eel exhibit at the BIA. The button display was designed to get visitors to pause at the exhibit, stand in front of the textual display while the sound effects that they activated were turned on, and then hopefully read the textual material more than they would have otherwise, and then also to notice the frequency monitor display.

Fig. 5. The electric eel pulse frequency display, showing informational text and real-time moving graph of pulses per second during (Upper) low-level "navigational" activity, and (Lower) "stun" and "attack" activity in response to food. The Y axis automatically autoscales to the largest activity on the screen, so even though the graphs look similar, the scale on the upper graph has autoscaled to 12 while the scale on the lower graph has autoscaled to 160.

Two versions of an anonymous survey were handed to willing visitors as they entered (version: "pre-") or exited (version: "post-") the BIA. These surveys consist-ed of questions relating to previous visits to the BIA, knowledge of electric eels, and observations about the exhibit and the devices installed. The surveys measured the effectiveness of the electronic devices in three aspects: entertainment, engagement and education. The surveys were conducted during visiting hours of the Belle Isle Aquarium in the spring and summer of 2015, on Saturdays from 11:00 am to 4:00 pm. To facilitate ad-ministration of the surveys and approval by the Wayne State University institutional review board, the surveys were administered only to adults (the first question asked about age, and subjects who answered "under the age of 18" were told not to complete it further).

The hypothesized result of the pre-survey was that visitors knew relatively little about electric eels before entering the BIA if they had not previously visited. The post-survey also asked questions that probed the visi-tor's encounter, engagement and enjoyment of the electric eel exhibit, as well as if they had taken a pre-survey, and if they had any comments, questions, suggestions or concerns. The hypothesized result of the post-survey was that visitors who encountered and engaged with the electric eel exhibit (e.g., pushing the button or accompanying a person who did) would report greater enjoyment and have more knowledge about electric eels than visitors had before they entered the BIA. This was deter-mined by comparing knowledge and enjoyment levels of those who took the pre-survey versus those who took the post-survey.

No explicit or systematic effort was made in administering the post-survey to survey the same people who had taken the pre-surveys; however, a question in the post-survey asked if the participant had also completed a pre-survey. The goal was to compare independent populations of people before and after they had visited the BIA and to be aware of any who were included in both groups, for which the influence could be examined in the analysis. The post-survey also asked whether visitors interacted with the hands-on and graphic display electronics.

Data were analyzed statistically with chi-square statistics and, where appropriate, post-hoc analyses with Fisher exact tests (FET) to determine which pairwise comparisons among the data analyzed by the chi-square tests had probabilities <0.05. Graphics and statistical data in the illustrations in this paper show data from a single survey day on which 119 pre-surveys and 105 post-surveys were conducted. The statistical results that are stated are representative of results obtained on all survey days (e.g., if the chi-square result is $p<0.00001$ on the illustrated survey day and $p<0.001$ on other days, the representative value is given as $p<0.001$ for all). Altogether, more than 800 surveys were conducted including pilot tests and >400 surveys for the data collections illustrated in this paper.

5. Results

5.1 Operation of the Interactive and Educational Electric Eel Exhibit Components

The display worked well and has been continuously active for months with minimal needs for adjustments. Anecdotally, we have noticed that children who accompany many adults who visit the BIA initiate the button pushing, causing adults to notice more about the display. Children also sometimes unnecessarily push the button many times even when the sound is on. Nevertheless, the electronic displays have withstood this frequent attention. A video showing the display and visitors viewing it can be seen at https://youtu.be/QKe9yPMvph0.

5.2 Results of Visitor Surveys

5.2.1 Education

Responses to a question about the voltage that electric eels are capable of producing are illustrated in Figure 6. More than 60% of the visitors who took the pre-survey chose 1100 volts, overestimating the voltage that electric eels were capable of producing. In contrast, in the post-survey, the percentage of people who chose 1100 volts decreased to 15%, while the percentage giving the correct answer (500 volts) in the post-survey was 77%, more than double the pre-survey result. Comparing the data from both pre- and post-surveys using the chi-square test, these values are significantly different at $p < 0.001$. The answer to this question was given in informational signs at the electric eel exhibit.

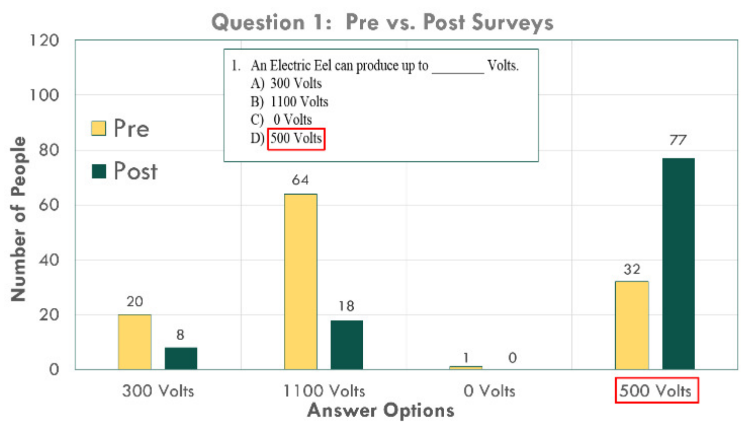

Fig. 6. Representative result for a knowledge question (inset; correct answer was "500 Volts"), comparing before entering the BIA ("Pre-") versus after exiting ("Post-") surveys. The change in proportions between and pre- and post- is statistically significant (chi-square, $p<0.001$; post-hoc FET correct v. incorrect on pre- and post-surveys, $p<0.001$, N = 220; does not include people who did not answer the question).

Similarly, a significant difference between pre-survey and post-survey was obtained for a question about the fact that electric eels are air-breathers on two out of three survey days (on the least significant day $p < 0.06$, close to the usually accepted 0.05 criterion). The third educational question was about the function of moderate frequencies of pulses. Although, overall no significant difference between pre-and post-surveys was obtained for all people who answered this question, when the data were stratified by whether people said they had noticed the frequency monitor (where the answer was displayed) the results showed 15 out of the 18 people who noticed the frequency monitor answered the question correctly. The 3 people who answered incorrectly either did not notice any of the other hands-on and user interface electronics or the electric eels were inactive during the time the visitor spent at the exhibit.

The final education question surveyed visitors' knowledge that the frequency of electric pulses used by electric eels to stun prey is in the range of about 50 to 500 pulses per second, for which significant increases between pre- and post-survey results occurred (chi-square test, p < 0.05).

5.2.2. Entertainment

To examine whether visitors found the electric eel exhibit entertaining, the post-survey asked how much time the visitor had spent at the exhibit and on a Likert scale of 1 (disliked) to 5 (liked) whether they liked the exhibit. The number of survey respondents that spent various periods of time at the exhibit were 20, 1 – 30 sec; 21, 31 – 60 sec; and 40, >60 sec (the sum of the histogram bars in each time category of Figure 7). The average Likert score of how much visitors liked the exhibit for each of these groups had means of 4.0, 4.0, and 4.6, respectively, and medians of 4, 4, and 5. The data indicate that people who stayed at the electric eel exhibit for more than 60 seconds liked the exhibit significantly more than the people who spent less than 60 seconds at the exhibit (chi square, p<0.05).

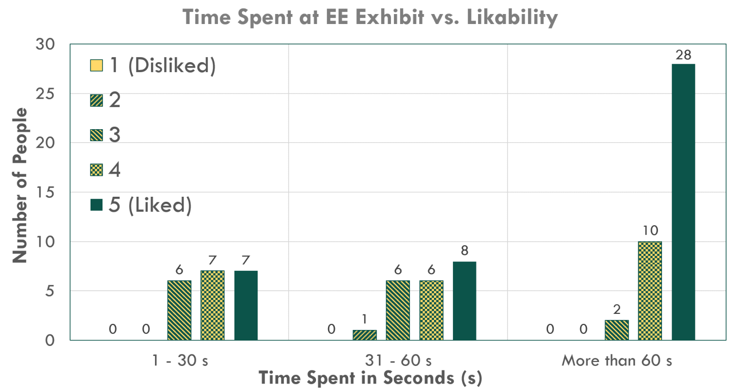

Fig. 7. Enjoyment as a function of time at the exhibit. The change in proportions of people who liked the exhibit was higher among people who were at the exhibit more time (>60 s) (chi square, p<0.03; post-hoc FET (Likert rank 5 v. ranks 1 – 4) for >60 s at exhibit v. <60 s, p < 0.03, N = 81; does not include people who said they spent no time at the exhibit and/or did not answer the "likeability" question).

5.2.3. Engagement

One of the goals of the project was to develop engaging interactive electronics that would enhance both the entertainment and educational value of the electric eel exhibit. Therefore, another question on the survey dealt with whether visitors interacted with the electronic accessories of the exhibit. More than half the people who took the post-survey reported that they or someone they were with pushed the button (Figure 8). In fact, pushing the button was associated with spending a significantly longer time at the exhibit (chi-square, p<0.05). These results strengthen the idea that engaging the public personally with a hands-on interactive electric eel button caused visitors to stay longer and enjoy themselves at the electric eel exhibit.

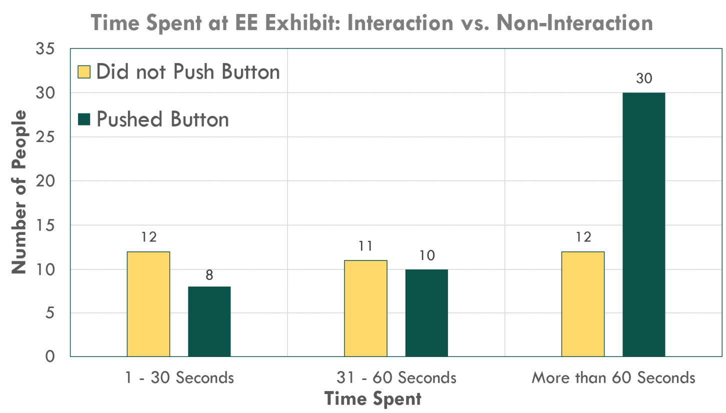

Fig. 8. Engagement: time at exhibit in relation to whether a visitor or someone they were with pushed the electric eel display button (significant at p<0.05, chi-square test, N=83; does not include people who said they spent no time at the exhibit and/or did not answer the question about pushing the button).

5.2.4 Other Analyses

For the post-survey, subjects chosen randomly from will-ing people as they were leaving the BIA included a portion (about 45%) who had also taken the pre-survey when they entered the BIA as determined from the question in the post-survey about whether the participant had taken the pre-survey. Therefore, comparing the post-survey answers of subjects who had taken the pre-survey to those who had not, we found that the proportion of correct answers was higher among visitors who had taken the pre-survey. For example, on Question 1, about

shock voltage, visitors who had taken the pre-survey got this question correct approximately 85% of the time on the post-survey whereas if they had not taken the pre-survey they got it right only about 60% of the time.
To determine whether interacting with the exhibit was sufficient to improve knowledge (i.e, without the stimulus of having taken the pre-survey about the eels), we compared the answers of visitors who had not taken the pre-survey to the answers of all visitors on the same day on the pre-survey (i.e., people who had not yet interacted with the exhibits). On one survey day, the effect of visiting the exhibit without having taken the pre-survey still showed a highly significant increase in knowledge ($p<0.001$) whereas, on another survey day, the same analysis resulted in a positive but non-significant effect ($p>0.1$).

6. Discussion and Conclusions

In this study, hardware, software, and design principles were successfully applied to transduce the electric pulses of electric eels to sound and light, to create a user interface that enabled visitors to interact with the exhibit, and to process the electrical activity for graphical display of the functionally critical variable of pulse frequency. This electric eel exhibit is the only exhibit of which we are aware in which visitors interact to *activate* parts of the display and also the only one in which pulse frequency is displayed and educational material is provided that describes its importance. Illustrating the higher pulse frequency during electric eel predatory behavior, described by Catania [5], is one of the goals of the exhibit. Other public aquariums have electric eel displays with sound and light but do not have these innovative, informative, and interactive components.

The goal of adding these enhancements to the electric eel exhibit was to engage visitors in a way that was both entertaining and educational. If length of time that visitors spent at the exhibit is a good measure of their interest (Figure 8), then the interactive button for turning on the sound effects definitely stimulated their interest. The exhibit overall was well-liked by the public, which liked it even more the longer they stayed (Figure 7). Finally, the exhibit stimulated their knowledge of electrical activity, as indicated by their higher scores when tested on factual knowledge (Figure 6). The electronic enhancements were even more effective at stimulating increases in knowledge if combined with an “alert” about the exhibit provided by doing the pre-survey. Thus, a combination of technical and social stimuli (i.e., the pre-survey) produced the biggest positive increase in knowledge.

This exhibit has the properties of “simplicity, authenticity, and immediate feedback” emphasized by Hooley [13]. Pushing a button is simple; the response is authentic in that it reflects the actual behavior and shock production of the electric eel; the response (turning on the sound so that the visitor immediately becomes aware of the eels’ electrical behavior) provides immediate feedback. While “hold time” is not a measure of effectiveness, our data shows a significant effect of the time spent at the exhibit with learning and enjoyment. Hooley[13] was skeptical about button-triggered exhibits as effective interaction devices because in most uses of buttons there is only “one action that the visitor can make and one outcome that will result.” However, in our use of the button, the eels’ behavior, is different every time the button is pushed. The graphic display, admittedly, does not require users to interact with it; however, its continually changing measurements, which are both authentic and immediate, seem to engage the visitors. The use of multiple modalities of light, sound, touch, and continually changing graphic display are also a way to appeal to visitors who vary in their learning styles, a goal for interactive displays that was emphasized by 31% of aquarium professionals [13].

Effective exhibits in science museums and aquariums may help close the gap in STEM education among both children and adults. While differences in quality of teaching in school may explain some of the discrepancies between science attitudes of advantaged and disadvantaged youth, according to Falk and Dierking [20] a more significant influence is “out-of-school” or “free choice science learning settings,” of which museums, zoos, and aquariums are a significant component. Pre-service school teachers who had part of their training at a public aquarium experienced profound positive changes that increased their confidence and sense of empowerment as science educators [21]. A program between an urban elementary school and a nearby aquarium in California improved instruction, increased the amount of science taught in the elementary school, and created new opportunities for cross-disciplinary instruction, such as in writing [22]. Self-efficacy, achievement and interest increase when African-American youth experience meaningful science enrichment activities such as science trips and hands-on lab experiences [23]. By creating more interactive and effective exhibits, such as the one demonstrated in this study, the hope is that aquariums and other similar institutions can more effectively engage, entertain, and educate youth and other members of the public.

Acknowledgement

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