ABSTRACT

BRIDGING THE GAP BETWEEN PUBLIC VISITORS AT LACAWAC SANCTUARY AND LAKE RESEARCHERS: DEVELOPING OUTREACH MATERIALS ON ADVANCED ENVIRONMENTAL SENSORS

by Jeffrey Ross Babb

The purpose of this practicum is to help Lacawac Sanctuary visitors better understand ecological monitoring and spark their interest on the data being collected there. Researchers and other guests visiting the sanctuary currently have little information about the monitoring taking place on site. To fill this void, Lacawac visitors have been provided with educational materials, displays, and a program that focuses on ecological monitoring technology and its importance to understanding the ecology of lakes. Specifically, these materials are an educational pamphlet, an interpretive sign, information for Lacawac’s website, and a short lesson plan. All of the educational materials highlight a monitoring platform on Lake Lacawac along with the parameters it measures and how the data collected are being used. Now people of all ages and backgrounds visiting Lacawac Sanctuary can enjoy, appreciate, and understand the usefulness of ecological monitoring here and throughout the world.
BRIDGING THE GAP BETWEEN PUBLIC VISITORS AT LACAWAC SANCTUARY AND LAKE RESEARCHERS: DEVELOPING OUTREACH MATERIALS ON ADVANCED ENVIRONMENTAL SENSORS

A Practicum Report

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Institute for the Environment and Sustainability
by
Jeffrey R. Babb
Miami University
Oxford, Ohio
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Advisor________________________
(Lesley Knoll)

Reader________________________
(Suzanne Zazycki)

Reader________________________
(Thomas Crist)
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Preface

Wireless sensor technology is a quickly evolving field and is now used throughout the world. I was first introduced to wireless sensors during my first year of graduate school at Miami University, Oxford, Ohio. Here, I began using wireless sensors while operating the university’s weather station that collects climatic data for three national programs: National Atmospheric Deposition Program and National Trends Network for precipitation chemistry data and the United States Environmental Protection Agency’s CASTNET (Clean Air Status and Trends Network) for tropospheric ozone. The weather station has many sensors that need to be managed, cleaned, and calibrated regularly. This experience sparked my interest in sensor technology and the many novel applications.

I also was exposed to wireless sensors during a Professional Service Project for the Talawanda School District located in Oxford, Ohio. A Professional Service Project (PSP) is a required project for first year graduate students in the Institute for the Environment and Sustainability (IES) program. PSPs are a year-long team project that helps address environmental problems and improves the sustainability of organizations in southwest Ohio. The PSP I worked on required our team to develop educational uses for 100 acres of natural land owned by the Talawanda High School. The recommendations will help the Talawanda students and the Oxford community better use the land for educational and recreational purposes. Some of the educational uses recommended included interpretive signs, brochures, mobile applications, an internet website, outdoor classrooms, a walking trail, and wireless sensors. Wireless sensors were recommended because they were considered state-of-the-art and can be used to bring science and hand-held monitoring into the classroom.

Upon the completion of the Talawanda High School PSP, I was presented with an opportunity to learn more about wireless sensor technology by Dr. Thomas Crist who is the program director of IES at Miami University. He along with Suzanne Zazycki, the outreach coordinator of IES, suggested a potential practicum idea involving wireless sensors at Lacawac Sanctuary. This opportunity was presented to me because of my experience at the weather station and with the PSP.

I was first introduced to Dr. Lesley Knoll about the potential practicum opportunity at Lacawac Sanctuary by Dr. Crist. Dr. Knoll is currently the Director of Research and Education at
Lacawac Sanctuary. Lacawac Sanctuary is located near Lake Ariel, Pennsylvania in the Pocono Mountains and operates as a nature preserve, public environmental education facility, and ecological field research station. I decided to work with Dr. Knoll and Lacawac Sanctuary to fulfill my degree requirement by completing a practicum project.

For three weeks in June of 2012, I helped researchers deploy a new profiling buoy on Lake Lacawac that was outfitted with wireless sensors monitoring 15 different parameters. While at Lacawac, I also attended the Lacawac Ecological Observatory Workshop that focused on buoy technologies, advanced sensors, and the management and analysis of large ecological datasets generated by high-frequency data. This workshop featured many different knowledgeable researchers that had experience using these types of buoys, sensors, and datasets. It was a good experience to learn from people that have a lot of knowledge on many aspects related to this field. Some researchers led discussions on sensors available on the market, various buoys used in the field, computer software used to analyze data, and testimonials of how sensors were being used at different facilities throughout the world. This was very advantageous for someone who had little experience using this type of technology.

Ecological monitoring is a highly valued and appreciated field today. Because of this, I would like to pursue a career possibly working with wireless sensors to monitor different environmental parameters of interest. This practicum along with the LEOW workshop and hands-on experience at Lacawac has given me more knowledge about the many possibilities in the field of ecological monitoring. Wireless sensors will be the future way to monitor the environment and are now used more frequently with the improvement of sensors.
Chapter 1: Introduction to Ecological Monitoring and Lacawac Sanctuary

Literature Review of Ecological Monitoring

It is well known that the growing human population of the world can cause negative impacts to environmental health. Environmental protection is highly valued today and legislation is often amended to specify acceptable levels of chemical or biological pollutant concentrations discharged to the soil, water, and air (Fay et al., 2010). Other negative impacts to environmental health can be caused from climate change, land-use alteration, loss of biodiversity, and eutrophication. Some of the negative environmental impacts caused from these issues are still not fully understood today and, as a result, new methods are being created to closely monitor these changes. Some researchers involved in the study of these environmental issues are closely monitoring lakes because lake water quality depends on the surrounding watershed and are therefore believed to be excellent indicators to their surroundings (Williamson et al., 2009; Jennings et al., 2012). Biogeochemical cycling, water level, and organic matter entering lakes can signify trends taking place within a watershed (Williamson et al., 2009).

To assess environmental health, researchers and professionals have been monitoring different ecological parameters in lakes for many decades. Traditionally, ecological monitoring has been based on infrequent sample collection and laboratory analyses, where researchers manually collect data and then run tests on the samples. Some other practices have relied on automated sensors wired to field data loggers that require going into the field and manually downloading data (Kotamäki et al., 2009). Issues associated with these types of systems were the high cost of sampling, slow response time, and lack of accurately portraying the condition of the entire ecological system (Jiang et al., 2009). For example, when studying water systems some researchers only sampled cross-sections of a waterway or collected samples daily or weekly because of the cost and time to analyze the samples. Detection of a contaminant or something of interest may be missed or be discovered well after an event has already taken place. Additionally, some ecological events are short and sporadic making it hard to study using these conventional monitoring methods (Carpenter et al. 2011).

Over the past few decades, sporadic and episodic events have been studied more closely by researchers to answer how systems are being impacted by climate change, land-use alteration, loss of biodiversity, and eutrophication (Jennings et al., 2012; Carpenter et al. 2011). These
events are known to cause severe impacts to the environment, which can ultimately cause harm to humans. For example, a shift of a lake to a eutrophic state can be thought of as a sporadic event because it is difficult to predict if and when it will take place. If signals or indicators within data could be used to predict the shift, perhaps something could be done to reverse it. Understanding this area as well as others, demonstrates how ecological monitoring could be used to alter current practices if major impacts to environmental health are identified soon enough (Carpenter et al. 2011).

Today, ecological monitoring systems have developed into real-time operational sensor networks. This allows researchers to study sporadic events and give professionals sufficient time to take action if a problem is detected (Kotamäki et al., 2009; Jennings et al., 2012; Carpenter et al. 2011). These networks use many data monitoring nodes that measure a parameter of interest and send information back to a gateway sensor node, which then transmits a data signal back to a base station (Figure 1). These node sensors are smart, small, power efficient, inexpensive, and are becoming more sophisticated as technology advances (Kotamäki et al., 2009; Jiang et al., 2009).

Wireless sensors have advanced to measure a large range of both terrestrial and aquatic environmental parameters and new applications are constantly being produced. For example, they can measure parameters such as wind speed, wind direction, precipitation, pressure, temperature, humidity, and soil moisture (Kotamäki et al., 2009). Ecological monitoring is also being used to observe different water quality parameters including dissolved oxygen, pH, turbidity, nutrients, and concentrations of algae in the water. These parameters can be used to assess water quality and ecosystem processes.

**Figure 1**: Four terrestrial wireless sensors monitoring the surrounding area (solid circles) that have the capability of communicating to one another (solid arrows). All the information collected is sent to a gateway node that broadcasts a data signal to a base station (dotted arrow).
New advancements can now measure aquatic parameters like turbidity, nitrate concentration, and dissolved and suspended organic carbon substances (Kotamäki et al., 2009). Likewise chromophoric dissolved organic matter, chlorophyll, dissolved oxygen, and phycocyanin are being measured using fluorometers. Fluorometers are used to measure fluorescence, which is the emission of light after a particular substance of interest has absorbed it. Some other types of sensors have been implemented in lakes within major agricultural areas to monitor and test the levels of nutrients that leach from agricultural fields. The purpose of this type of monitoring is that current agricultural practices can be altered if leached nutrient levels are deemed too high, therefore affecting the quality of nearby ground and surface water (Kotamäki et al., 2009).

Sensors have also been used to forecast and measure events like tsunamis, volcanoes, seismologic phenomena, potato late blight, ice cover, lake ecosystem production, and aquaculture practices (Kotamäki et al., 2009; Van de Bogert et al., 2007; Zhu et al., 2010). In China, aquaculture is a rapidly growing fish-farming operation where forecasting and water quality monitoring is vital to their success. These farms have been using wireless monitoring networks to ensure water quality parameters meet desired levels to optimize the growth of fish. They also use them to acquire real-time data, which can be used to prevent large-scale fish mortality episodes (Zhu et al., 2010). Sensors have also been used to monitor lake ice timing to understand how climate change is altering lake ecosystems. The timing of ice-on and ice-off can influence the timing, magnitude, and composition of plankton populations in the spring and can also influence winter oxygen concentrations (Adrian et al., 1999; Weyhenmeyer, 2001; Pierson et al., 2011). This makes monitoring the ice timing a regionally and globally important factor because it can have great influence on entire ecosystem function.

Researchers have used sensors to monitor entire lake ecosystem production. Ecosystem production in lakes can be calculated by measuring the diel changes in dissolved oxygen of the water. Ecosystem production is the balance between the net primary production (oxygen producers) and heterotrophic respiration (oxygen consumers). It is important because it can determine whether a lake is autotrophic or heterotrophic and can also be important for carbon budgeting. This is a well understood science, but most lake ecosystem production studies estimate the entire lake production from a single measurement of dissolved oxygen (Staehr et al., 2012). Some of these studies have found success from a single measurement, while other
researchers have attempted to develop a series of sensors around the lake to get a better estimation of the lake as a whole (Van de Bogert et al., 2007).

Along with the advancement of sensors have come alterations of current issues with this technology. One issue with wireless sensor networks is their use of energy. Solar power is a good source to recharge these batteries, but not all sensors are able to acquire sunlight because of their use or placement. To solve this problem, sensor nodes have been developed to switch to a low-energy sleep mode to conserve power (Schurgers et al., 2002; Chen et al., 2002). These nodes will still constantly monitor data, but will only transmit a forwarding signal when something abnormal has been detected. This is because signal transmission requires a lot more energy than monitoring. These networks have also been programmed to send warning alarms when monitored variables take anomalous values; this is to ensure everything is working properly and sensors are not damaged (Jiang et al., 2009).

Another advancement in wireless sensor technology are the platforms used to place water sensing equipment. The platforms need to be resistant, able to provide protection, and capable of storing the monitoring devices. One successful technique that has been employed for many years is the use of buoys as a support base for water monitoring equipment (Figure 2). These buoys are anchored to the lake bottom, which means that data are collected from a set position. The issue with these is that they may not give a good estimate of the entire lake if only a small area is sampled (Van de Bogert et al., 2007). However the number and location of the monitoring buoys have been shown to depend on the use of the data being collected, the number of days of deployment, and the needed level of accuracy for the data (Van de Bogert et al., 2012).

To account for the lack of portraying the entire lake, buoy platforms can come equipped with a winch system that can measure different parameters at varying water depths. Another technique recently becoming available is the use of remotely operated underwater vehicles (ROVs). ROVs can be built to carry many different water quality sensors and are capable of maneuvering throughout the water (Fay et al., 2010). These platforms have also been used to
ensure that stationary sensors in the field are properly calibrated. This is done by maneuvering the ROV up to a sensor node, collecting data, and then comparing the differences.

Different organizations and groups throughout the world have been assembled to address issues such as impacts from climate change, land use change, and invasive species on natural resources and biodiversity. Two groups studying these phenomena that have been created recently are the National Observatory Ecological Network (NEON) and the Global Lake Ecological Observatory Network (GLEON). NEON is a 510(c)(3) corporation that monitors different sites throughout the United States and provides data to predict trends in ecology. NEON is funded by the National Science Foundation and their network focuses on continental-scale research. GLEON is a grassroots organization that uses global lake data to predict lake ecology trends (Figure 3). Both organizations are attempting to acquire high-frequency data using wireless sensors as a major component of their data collection methods. Moreover, these organizations are attempting to monitor continental trends and apply them to global questions. This is the current focus of many types of ecological monitoring groups and researchers worldwide.

Ecological Monitoring at Lacawac Sanctuary

Lacawac Sanctuary is located near the town of Lake Ariel, which can be found in the Pocono Mountains of northeastern Pennsylvania (Figure 4). Located on the property is Lake Lacawac, which is a 52-acre glacial lake that is recognized as one of the least disturbed glacial lakes in the Eastern United States. Other features within this largely forested 565-acre nature preserve are
wetlands, a boreal bog, deer browse exclosures, botanical gardens, and managed forest demonstration areas. Further, because of the many unique features, Lake Lacawac was declared as a National Natural Landmark in 1966.

Lacawac was built in 1903 for William Connell, a wealthy railroad tycoon, and was modeled after rustic summer homes in the Adirondack Mountains of the same time period. The original five buildings at Lacawac still stand today and serve mostly for lodging, education, and research purposes (Figure 5). Today there are 3 additional buildings on site that consist of a visitor’s center, a research laboratory, and a summer home used by the past owners of the sanctuary.

Researchers frequent Lacawac mostly during the summer to perform research at different locations on the property. One major feature that attracts researchers is Lake Lacawac. The Lake has been monitored since 1992 by Lehigh University for air temperature, relative humidity, photosynthetically active radiation, solar irradiance, wind speed, wind direction, precipitation, lake water level, and water temperature at varying depths.

The data collected by these sensors at Lacawac are available to scientists worldwide. This can contribute towards regional, national, and international monitoring networks that detect global trends in data because Lacawac Sanctuary belongs to the GLEON organization. GLEON uses data collected at Lacawac, along with data from other lakes throughout the world to predict lake ecological trends. Currently, this organization has over 60 participating lakes located in 17 different countries.

Lacawac Sanctuary has been actively involved with many different types of sensor technologies over the past. Novel sensors have been tested at Lacawac to measure different
geological, hydrological, climatic, and ecological parameters. Recently these data were used to analyze lake ecosystem impacts after Tropical Cyclone Irene hit the East Coast (Figure 6) (Klug et al., 2012). Additionally in the summer of 2012, Lake Lacawac was used to test a modern profiling buoy platform equipped with sensors measuring 15 different parameters (Figure 7, left). The sensors monitored the following parameters: wind speed, wind direction, precipitation, barometric pressure, air temperature, relative humidity, and photosynthetically active radiation above the lake’s surface.

The buoy was also outfitted with a smart winch system that lowered a retractable platform to different depths underwater; which was controlled using a smart phone application (Figure 7, right). The retractable platform had sensors that measured dissolved oxygen, pH, turbidity, chlorophyll-a, blue-green algae, and chromophoric dissolved organic matter of the water. Additionally, there was a thermistor string and a submersible pressure transducer attached to one of the anchors. The thermistor string measured the water temperature at varying depths and the pressure transducer measured the water level of the lake. Measurements were collected frequently and the sensors were powered completely by batteries that were recharged by solar energy.

![Figure 6: Results from Tropical Cyclone Irene. The study was performed by Klug et al., (2012).](image1)

![Figure 7: Profiling buoy tested at Lacawac Sanctuary (left) and the winch system to lower the platform underwater (right).](image2)
energy. Readings collected by its sensors were transmitted back to a database by the buoy’s radio transmitter.

Lacawac Sanctuary is a unique place because it operates as a nature preserve, public environmental education facility, and ecological field research station. With about 5,000 visitors per year, Lacawac is a great place for environmental education because science and the public are in the same place. Lacawac currently offers programs held throughout the year to educate people living in the area as well as sanctuary visitors. Some of these programs specifically include workshops to train U.S. and international students to use sensors and monitoring platforms (Figure 8). Additionally there are information stations, interpretive signs, brochures, and a website that provides people with opportunities to learn more about this area.

Currently, researchers and other guests visiting the sanctuary have little information about the ecological monitoring taking place and how the monitoring fits into a larger picture. The goal of this practicum was to help Lacawac Sanctuary visitors better understand ecological monitoring and spark their interest on the research being performed there. To accomplish this goal, Lacawac visitors will be provided with educational materials, displays, and a program that focuses on ecological monitoring technology. All of the educational materials highlighted the monitoring platform on Lake Lacawac, specifically the parameters it measured and how the data are used to understand ecological processes of lakes.
Chapter II: Considerations for Educational Materials

Incorporating the needs of Lacawac Sanctuary

Lacawac visitors are provided with many educational materials, but have little information about the ecological monitoring taking place here. Currently there is information about the history, the buildings, the trail systems, Lake Lacawac, the types of plant and animal species, research being performed, and ecological information (Figure 9). Lacawac is a great place to learn and perform research because it is an area with little human impact and a long ecological monitoring past. Providing visitors and researchers with more information on ecological monitoring may interest or even attract people to Lacawac Sanctuary.

Common educational materials used at Lacawac Sanctuary are interpretive signs and brochures. Additionally a quarterly newsletter is published called Forest Notes, and is distributed to all sanctuary members (Figure 10). The newsletter usually contains one research focused story along with a few general naturalist stories relative to Lacawac. There are also has summer programs, a website, educational videos, native plant gardens, and deer exclosures for education, but are used to a lesser extent. For this project, it will be important to educate people using the same type of materials with different information. It was believed that by adding to the number of interpretive signs and educational pamphlets it will better improve visitors’ experience at Lacawac.
Interpretive signs are used by national and state parks, sanctuaries, nature preserves, and other organizations to provide insight about a particular subject matter (Figure 11). They are often found along trails or near areas where there is something of interest or uniqueness to educate, inform, or entertain people about (Chesapeake Ecology Center, 2011; Adams, 2012). In addition, according to Adams (2012), these signs can:

- Inspire feelings of stewardship by strengthening awareness
- Demonstrate community pride
- Provide an experience without the requirements of staff or facilities to maintain
- Deliver a message available to many visitors, at their convenience, and is available every day
- Enhance visitor perceptions of a site, city, or region

At the Chesapeake Ecology Center, interpretive signs are used to enhance the nature experience, which increases the public’s understanding of conservation landscaping and helps to empower their participation (Chesapeake Ecology Center, 2011). Similarly an interpretive sign used at Independence Lake Park educates visitors about a tallgrass prairie and some of the different plant species found there (Figure 11). Lacawac Sanctuary places interpretive signs at the entrance of historic buildings, head of certain trail systems, and at spots of significance along trials (e.g., boreal bog on Lake Lacawac trail and a historic overlook site along Big Lake trail).

Educational pamphlets or brochures are also commonly used for public education at many of the facilities mentioned previously and can also be used to market businesses or a
particular product. Figure 12 demonstrates a brochure used to inform Yosemite National Park visitors about a particular hiking trail system within the park. Educational pamphlets can be distributed to people at information desks, along trail systems, or passed out to local businesses. Lacawac has many pamphlets available to sanctuary visitors and use them along with interpretive signs to provide information and inspiration, while allowing visitors to take self-guided tours.

Additional educational materials used by many organizations are website information, podcasts, videos, PowerPoint programs, interest programs, manuals, post-it cards, illustrations, kiosks, meetings, workshops, tours, and etc. (Archbold Biological Station, 2012). Guidance for choosing materials most suitable to Lacawac Sanctuary was provided by Dr. Lesley Knoll— who served as the client and major advisor on this practicum. The additional materials were chosen based on their applicability to Lacawac, the time needed to complete them, the cost needed to produce them.

**Basic Guidelines for Public Outreach Materials**

One challenge of this project was to provide information for the many different people visiting Lacawac Sanctuary. This is because people of all ages and from all backgrounds visit Lacawac year-round. For instance, visitors could be researchers who may know a lot about ecological monitoring or could be people with little or no background knowledge on the topic. So a major component of this project was to explain ecological monitoring technology in a comprehensible and interesting manner to a broad audience. Another major challenge was to link people with the environment and interest them in the research at Lacawac. These challenges present the most difficult aspect of this project.
Public education is a well understood field and different methods have been developed to effectively engage and educate people. Information suggesting some tips for public education and outreach were provided from Brittany Potter and Taylor Leach, who both attended the annual GLEON meeting held in October 2012. Brittany is the Global Lake Temperature Collaborative Outreach Coordinator at the University of Nebraska-Lincoln and Taylor is a Zoology graduate student at Miami University. While at the meeting, both worked in the Communicating Science Working Group (CSWG), which focused mainly on public education and outreach. Another member of that group Hilary Swain, the Executive Director at the Archbold Biological Station, provided them with useful guidelines to follow when developing educational materials. Hilary has a lot of experience working with environmental monitoring, and educating K-12, undergraduate, graduate students and the public.

One recommendation for educational materials containing text was to start off with a punch line to evoke emotion to the readers (Swain, 2012). This could be done by making analogies to human health or by starting off with a story (Swain, 2012). People are thought to connect better with stories and become better engaged when reading them. This is also true when these are in connection to human health, which produces strong emotions (Swain, 2012). Along with these techniques, Swain (2012) suggests that educational materials with text:

- Ask questions within the text
- Use narratives to tell a story
- Use local happenings to relate to global context
- Speak with other voices
- Identify the audience
- Translate local to global

Some major issues with educational text, as identified by the French National Authority of Health, are when there is a lack of scientific information or when the information is inaccurate or out of date (Haute Autorité de santé, 2008). This causes the reader to distrust the educational material and deters them from reading further into the text. Another issue with educational materials is when the vocabulary used is too technical (Haute Autorité de santé, 2008). If the readers do not understand the material, they cannot learn from it. Using this information will
help produce good reading materials, along with other recommendations outlined by Adams (2012):

- Avoid using technical terms
- Use active verbs
- Do not overload readers with information
- Titles, subtitles, and artwork should support the main points of the text

**Recommendations for Educational Materials**

As previously stated, educational pamphlets and interpretive signs are the most commonly used educational materials at Lacawac and were therefore recommended for this project. Pamphlets currently used here are an 8 by 10 inch tri-fold design that are distributed throughout the sanctuary’s information stations (Figure 13). They contain many pictures and quotes from past researchers and visitors at Lacawac. Additionally, information is frequently bulleted or stated in a short paragraph. The interpretive signs are approximately 24 inches by 36 inches in size, made of plastic, and stand about 42 inches off the ground. They have fewer pictures in relation to the pamphlets and information is displayed in long paragraphs that read more like a story (Figure 14). The signs and pamphlets were an important starting place for in developing new materials for this project.

![Figure 13: Example of a tri-fold brochure used at Lacawac Sanctuary.](image)

The signs and pamphlets available at Lacawac do not follow a specified design or pattern. Therefore, a new pamphlet and interpretive sign need not exactly follow an existing design, but should respect the basic format. However, providing information in a similar manner and using
similar color schemes, as currently used at Lacawac, will be a helpful place to begin designing the materials.

One example of an interpretive sign at Lacawac educates readers how to identify invasive plants in the Pocono Mountains and how they impact native vegetation. The sign also contains an informative message how readers can help stop the spread of invasive plants (Figure 14). In other examples, interpretive signs explain the history and significance of a building present on the property. For this project the interpretive sign needs to enlighten readers about wireless sensor technology and then educate them about the research being performed at Lacawac. Recommendations for interpretive signs were also taken into the design consideration Swain (2012):

- The sign be 24 by 36 inches in size
- The number of estimated words is about 300-500 words
- There should be a take-home message
- The sign conveys 3-5 main points
- The sign should have graphical displays

Along with further recommendations from Adams (2012):

- Should complement the environment in which it is located
- The layout should be simple
- Should be a clear hierarchy of importance
- Needs to be good contrast between the text and background

All other educational materials were recommended to be produced in a similar manner as the interpretive sign. Additionally it was recommended that any educational visuals should
capture visitor’s attention, communicate the message in innovative ways, convey meaningful information or new knowledge about the subject matter, and influence viewers to change their attitudes or behavior (Chesapeake Ecology Center, 2011). To ensure these recommendations are met, along with others, a test audience should be involved in the design of the materials (Haute Autorité de santé, 2008). The audience can help evaluate the readability, understanding, and layout of the educational materials.

**Fulfillment of Grant Requirements**

In the summer of 2012, I was a recipient of the Isabel and Arthur Watres Student Research Fund. This grant supported my expenses to stay at Lacawac Sanctuary during the summer and also partially funded the costs of supplies to produce the materials. The grant required that the research deal entirely with the natural resources (biological or physical) of the Lacawac Sanctuary. Additionally, Dr. Knoll was awarded a grant of money from the Foundation for Pennsylvania Watersheds to help cover the educational materials produced for Lacawac.

To satisfy both of these grant requirements for educational materials, funding needed to be used to: 1) design and print the educational pamphlet, 2) design, print, and order the display panel and pedestal, and 3) create and print the materials used for an educational program (Table 1). Any additional money will be used by Lacawac Sanctuary to purchase a pH probe for educational purpose.
Table 1: Projected Project Budget.

<table>
<thead>
<tr>
<th></th>
<th>Total Amount</th>
<th>Percent of Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Educational Pamphlet</strong></td>
<td>$525.00</td>
<td>8.75%</td>
</tr>
<tr>
<td>Design</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Printing</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>Interpretive Sign</strong></td>
<td>$800.00</td>
<td>13.33%</td>
</tr>
<tr>
<td>Design</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Printing</td>
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<tr>
<td>Ordering the Display Panel</td>
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<tr>
<td>Ordering the Pedestal</td>
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Chapter III: Educational Materials for Lacawac Sanctuary

Educational Pamphlet

The educational pamphlet that was created for Lacawac Sanctuary was an 8 by 10 inch tri-fold design brochure (Appendix A). This design and text was chosen to be consistent with other pamphlet examples existing at Lacawac along with the recommendations for educational text and visuals. It achieves the objectives of this practicum by: 1) providing an educational material, 2) focusing on ecological monitoring, 3) containing an explanation the monitoring platform and the different parameters measured at Lacawac, 4) demonstrating how Lacawac has been involved with many different types of sensors in the past, and 5) providing how Lacawac fits into the global monitoring effort.

The information provided is short and concise for each topic, without giving too much detail (Table 2). This provides the reader with the essential information needed to understand the ecological monitoring taking place at Lacawac. It was believed that a lengthy, detailed text would lose the interest of the readers and therefore defeat the purpose of the educational pamphlet (Adams, 2012). To help keep the readers engaged, the pamphlet contained pictures that helped “tell the story” (Swain, 2012) (Table 2). The pictures were of the local scenery and also some of the sensor platforms that have been used at Lacawac (Adams, 2012; Swain, 2012). The color schemes chosen were light, earthy tones (blue, green, and brown) to represent the environment that is being monitored by ecological sensors (Adams, 2012) (Table 2).

The information was accurate and current to ensure the credibility of the pamphlet, which was recommended by the French National Authority of Health to keep readers engaged (Haute Autorité de santé, 2008). Quotations were used from past researchers as a technique to speak in different voices to the audience (Swain, 2012). This was done because reading passive educational text can become boring to the reader (Adams, 2012). The quotes provided were in an active and informative voice, which helped to break up the educational text (Swain, 2012; Adams, 2012; Chesapeake Ecology Center, 2011) (Table 2). Another technique was to translate local happenings to a global picture (Swain, 2012). This was done by explaining that data from Lacawac is being used globally by other researchers. It is thought that when readers make the
To ensure most of the recommendations were met and that the brochure was an effective method to educate visitors, a small test audience was used to evaluate the design (Haute Autorité de santé, 2008). This audience was comprised of experts on Lacawac Sanctuary, wireless sensors, and graphic design along with people having no experience with any of these particular areas. Feedback from this audience helped to provide a product with accurate information that was presented in a meaningful way (Haute Autorité de santé, 2008; Swain, 2012; Chesapeake Ecology Center, 2011; Adams, 2012).

**Interpretive Sign**

The interpretive sign will be 24 inches by 36 inches in size (Appendix B). After it has been printed, it will be covered with hard plastic, and will stand about 42 inches off the ground. Swain (2012) recommended these parameters for interpretive signs, which were also consistent with others at Lacawac. The sign will eventually be placed along the Bog Boardwalk overlooking Lake Lacawac and the monitoring platform (Figure 15). This location is a popular part of one of the hiking trails at Lacawac, the Lake Lacawac trail (Adams, 2012; Chesapeake Ecology Center, 2011).
The sign provides an introduction to ecological monitoring and how wireless sensors are being used to assess the environment. This information was not provided within the brochure, but was used to help the readers understand the importance of monitoring. The sign did however contain similar information as the pamphlet, which demonstrated the specific monitoring being conducted at Lacawac. Therefore the interpretive sign accomplished the objectives of this practicum.

There were fewer pictures in relation to the pamphlet and information was displayed in long paragraphs that read like a story (Table 3). The longer detailed text was used in this situation because there was more space to explain topics; hence narratives were used to help better connect the audience (Swain, 2012). To evoke emotion the text of the sign included connections to human health (Table 3). For example, the growing human population of the world can cause negative impacts to the environment, so monitoring it helps ensure our safety. This message will help to engage and connect the readers to their environment (Swain, 2012; Adams, 2012; Chesapeake Ecology Center, 2011).

The interpretive sign had one major take-home message, which was that the environment is where we breathe, eat, and sleep so monitoring it is very important to help us understand how ecosystems behave (Swain, 2012; Adams, 2012). Questions were placed throughout the different sections to help break-up the text and keep readers better engaged (Table 3) (Swain, 2012; Adams, 2012). Additionally, the local to global connection was used in a similar manner as for the brochure (Swain, 2012).
It was recommended by Swain (2012) that the sign have three to five main points and a total of 300-500 words. As so, the sign was made to have five main points, totaling slightly over 500 words. The main reasons for these suggestions were that a lot of text was not visually appealing and that readers do not want to read the sign for a long time (Adams, 2012). Further, blocks of text were between 40 and 90 words to give readers a rest, prolonging their attention span (Adams, 2012) (Table 3). As with the brochure, similar color patterns were used and the same test-audience gave feedback to evaluate the sign’s design (Table 3) (Adams, 2012; Haute Autorité de santé, 2008).

**Instructor Lesson Plan**

With the guidance from Dr. Knoll, a short educational program lesson plan was developed to educate Lacawac visitors. Lacawac offers a program series during the summer, mostly for children and area residents. A short program could be used by Lacawac staff as an additional activity for assisting in their ecological monitoring outreach efforts. Lacawac employs undergraduate summer interns each summer, which can use this lesson plan to lead an educational program.

The short educational activity provided was an interactive program geared for children visiting Lacawac (Appendix C). It promotes independent thinking and hands-on activity by using

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**Table 3:** Construction of the interpretive sign with recommendations.

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Action</th>
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<td>Short Blocks of Text</td>
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</tr>
<tr>
<td>Color Scheme</td>
<td><img src="Wireless_Sensors.png" alt="Image" /></td>
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</tbody>
</table>
hand-held water monitoring equipment and requires manual sample collection. The activity was then linked to some of the types of monitoring being performed at Lacawac by automated sensors. The entire activity takes about an hour to complete and was designed to keep the interest of the participants. The goals of this lesson plan were for it to be informational, interactive, and understandable to help users better comprehend this technology.

The activity requires children to collect water samples from Lake Lacawac using scientific and hands-on techniques. This was designed to be a fun activity for them, because they can play in the water and learn what it is like to collect water samples. The children will then perform a series of analyses on the samples collected to measure different parameters of the water. Once the children have collected the data from the samples, they will try to make sense of it. This will require them to think independently using their current knowledge along with the information provided from the lesson plan. Finally, the lesson plan explains how automated sensors work and demonstrates how they can eliminate the time spent to manually collect and analyze samples.

Hopefully the children participating in the Lacawac programs are able to use and learn from this lesson plan. This activity might need to be slightly altered depending on the interest or age of the participants. The target audience was middle school aged children, although adults and younger children can be expected to participate. Because of this, the lesson plan will be an iterative process at Lacawac. The success of it largely depends on the age group and the number of children participating so, Lacawac staff should take this into consideration. The different parameters measured within the lesson plan (temperature, pH, and dissolved oxygen) were based on their applicability to the Ohio Academic Content Standards: K-12 Science (Ohio State Board of Education, 2002).

**Website Information**

The final educational material provided to Lacawac was information to be posted on the Lacawac website ([www.lacawac.org](http://www.lacawac.org)). Lacawac’s website is frequently used by members and visitors to the area. Information presently exists on the site about wireless sensors, but this only explains the Lehigh monitoring platform and the applicability of the data.

The information that was provided to the website explained the broad overview of wireless sensors, their applications, and future ([http://lacawac.org/?p=102](http://lacawac.org/?p=102)). The wireless sensor
webpage was set up in a similar manner as was done for the interpretive sign. This was because it was considered an educational visual and therefore should follow a similar layout. As so, it needed to capture visitors’ attention and keep them interested while reading the page (Chesapeake Ecology Center, 2011). This was done by having small blocks of text, asking questions throughout the text, making the local to global connection, and relating it to human health (Swain, 2012; Adams, 2012). Further all the information was accurate and current to establish credibility for website visitors (Haute Autorité de santé, 2008).
Reflection on this Experience

My professional experience working with Lacawac Sanctuary has benefited me in my field of water resource management. I am currently unsure of my career path, but would like to focus on the chemistry and instrumentation used to study water quality. This practicum dealt largely with the environmental education aspect of water quality, which is a beneficial asset to have. This is because I believe a well-rounded person with experience in many different aspects of a particular discipline has a better understanding of it, therefore making them more marketable. At this point, I would like to pursue a career with an environmental education component, but not one entirely devoted to it.

The portion of the practicum that I found most interesting and applicable to my future career was learning about wireless sensor technology. The LEOW workshop and hands-on experience at Lacawac has given me more knowledge of the many possibilities in the field of water monitoring using wireless sensors. Additionally, performing literature reviews and viewing podcasts about this technology has informed me of the new improvements within this field.

Overall this was a great experience in many different ways. For one, I now have completed a professional experience working for my client Dr. Lesley Knoll of Lacawac Sanctuary. Second, I have gained valuable knowledge in the field of wireless sensors. Last, I have met many great people from this experience and expanded my professional network, which I believe is an invaluable portion of this project. From this experience I have learned from and talked with people in this field and hopefully I can find a career working with this type of technology.
Conclusion

For this practicum, information was gathered from many different sources which included experts, professionals, and literature reviews to create the products for Lacawac Sanctuary. For one, the educational materials provided to Lacawac Sanctuary have met the requirements of the granting organizations. Second, Lacawac visitors now have educational materials, displays, and a program that focuses on ecological monitoring technology and its importance to understanding lake environments.

These materials have helped accomplish the goal of the practicum, which was to help Lacawac Sanctuary visitors understand ecological monitoring and spark their interest in lake ecology. The educational pamphlet, interpretive sign, information for Lacawac’s website, and the short lesson plan can be viewed by all Lacawac visitors. The educational materials highlighted the monitoring platform on Lake Lacawac along with the parameters it measures and how the data collected are being used throughout the world. Visitors to Lacawac Sanctuary will hopefully better understand the usefulness of ecological monitoring being performed throughout the world.
Bibliography


Appendix A: Educational Pamphlet

Front Side

Applicability of Monitoring

Wireless sensors are a futuristic way to monitor the environment and are being used more frequently with the improvement of sensors.

This cutting-edge technology demonstrates the advancement of the new wave in ecological monitoring.

Ecological Monitoring At Lacawac Sanctuary
Lake Ariel, Pennsylvania

Lacawac Sanctuary Foundation
94 Sanctuary Road
Lake Ariel, PA 18436
Phone: 570-689-9494
Website: www.lacawac.org

Thank you to the Foundation for Pennsylvania Watersheds for providing financial assistance.
Monitoring at Lacawac

Lake Lacawac has been monitored since 1992 by Lehigh University for:

- Air Temperature
- Relative Humidity
- Solar Irradiance (solar energy absorbed by the sun)
- Photosynthetically Active Radiation (portion of solar radiation used by plants to produce food)
- Wind Speed
- Wind Direction
- Precipitation
- Lake Water Level
- Water Temperature with Depth

"Wireless sensors are a rapidly evolving technology and new applications are being created frequently."

Lehigh University Professor

Lacawac and the Monitoring World

The data being collected by the sensors are available to scientists worldwide. This can contribute towards regional, national, and international monitoring networks that detect global trends in lakes. Recently, this data was used to analyze lake-ecosystem impacts after Tropical Cyclone Irene hit the East Coast.

Lacawac Sanctuary belongs to the Global Lake Ecological Observatory Network (GLEON). GLEON uses data collected at Lacawac, along with data from other lakes throughout the world, to predict lake ecological trends. Currently, this organization has over 60 participating lakes located in 17 countries.

Profiling Buoy

Recently, Lake Lacawac was used to test a modern profiling buoy platform equipped with sensors measuring fifteen different parameters (shown below). The buoy is also outfitted with a smart winch system that lowers a retractable platform to different underwater depths. The retractable platform has sensors that collect measurements and is controlled using a smartphone application.

The Future of Monitoring

Lacawac Sanctuary has been actively involved with many different types of sensor technologies. Novel sensors have been tested at Lacawac in the past to measure different geologic, hydrologic, climatic, and ecological parameters. Lacawac also hosts workshops and other events to train B.S.

"High-frequency sensors are revolutionizing how we understand lakes."

Milwaukee University Student
Appendix B: Interpretive Sign

Humans and the Environment

Why is the environment important to us? This question may seem obvious, but it is an imperative one. The environment is important because it is essentially our home. It is where we breathe, eat, and sleep; everything we produce or use ultimately comes from it. It has become well known that the growing human population of the world can cause negative impacts to the environment. Today, environmental protection is highly valued and laws are made to specify acceptable levels of pollutant concentrations discharged to the soil, water, and air from our activities.

Ecological Monitoring

To ensure environmental health and balance, researchers and professionals have been monitoring different ecological parameters for many decades. This monitor for so long you may ask? This is done to better understand the natural processes, cycles, and changes that take place over long periods of time. On the other hand, some ecological events can happen on a much shorter timeline.

These events are studied so current practices can be stopped or increased, if needed, to protect the environment. These events can be, for example, wildfires, floods, or even a sudden increase in pollution.

One problem with measuring short-term ecological events is that they can be unpredictable and sporadic. Another problem is that ecological monitoring has traditionally been limited to infrequent sample collection and time-consuming sample analysis. Due to both of these facts, studying short ecological events can be difficult using conventional monitoring methods.

Wireless Sensors

Wireless sensors are increasingly being used for ecological monitoring because they can measure a large range of both land and water ecological parameters. Additionally, they can collect data at high frequency, providing scientists with the minute-to-minute scale. These sensors have been designed to operate in various conditions and can be easily installed in natural environments. With the advancement of technology, wireless sensors can allow researchers to study specific events and give professionals sufficient time to take action when contaminants are detected in a particular area. Shown right, are four terrestrial wireless sensors that have the capability of communicating to one another; the dotted arrow signifies a signal being transmitted to a computer database.

Monitoring on Lake Lacawac

Lake Lacawac has been monitored since 1992 by Lehigh University for air temperature, relative humidity, solar radiation (solar energy emitted by the sun), photosynthetically active radiation (light plants need to produce food), wind speed, wind direction, precipitation, lake water level, and water temperature at varying depths (monitoring platform shown left).

How does monitoring at Lacawac fit into the global monitoring effort? The data being collected by the sensors are available to scientists worldwide. This can contribute towards regional, national, and international monitoring networks that detect global trends in lakes. In fact, Lacawac Sanctuary belongs to the Global Lake Ecological Observatory Network (GLEON). GLEON uses data collected at Lacawac, along with data from other lakes throughout the world, to predict lake ecological trends. Currently, this organization has over 60 participating lakes located in 37 countries.

Lacawac as a Testing Ground for New Technology

Lacawac Sanctuary has been actively involved with many different types of sensor technologies. Novel sensors have been tested at Lacawac in the past to measure different geologic, hydrologic, climate, and ecological parameters. Recently, Lake Lacawac was used to test a modern profiling buoy platform equipped with sensors measuring fifteen different parameters (shown right). The buoy is also outfitted with a smart acoustic system that lowers a retractable platform to different underwater depths. Wireless sensors are a futuristic way to monitor the environment and are being used more frequently with the improvement of sensors. This cutting-edge technology demonstrates the advancement of the new wave in scientific technology.

Acknowledgements: To the Foundation for Pennsylvania Watersheds and the瀑布 and Arthur Ditka Jr. for providing funds and equipment for this project.
Appendix C: Lesson Plan

Lake Sampling and Data Collection

Objective
In this exercise the children will learn about some of the common techniques used to measure different parameters in lakes. All of the samples will be collected and analyzed from Lake Lacawac. Samples will be obtained from both the surface and the bottom of the lake. All of the samples will be tested for dissolved oxygen, pH, and temperature because these parameters change in important ways with depth.

Equipment
VanDorn Sampler
Plastic Bottles and Lids
Thermometer
Dissolved Oxygen Probe
pH Probe

Sample Collection
1. You will first collect a surface water sample using a plastic bottle and lid. Begin by rinsing out the bottle and lid a few times with lake water to ensure that it is clean. After this step, fill the bottle with water from the lake’s surface and place the cap on the lid.

2. Next you will collect a sample from the bottom of the lake (subsurface sample) using a device known as a Van Dorn sampler, demonstrate how this device works. The water collected from the sampler will then be placed in a bottle with a lid for later analysis.

Van Dorn samplers are used to collect water for chemical analyses. In addition, they can be used to capture small planktonic organisms, such as phytoplankton (algae) and bacteria. However, they are less effective at capturing zooplankton (consumers of algae), because some of these organisms can avoid the sampler.
Questions to Ask

- How does the surface sample differ from the subsurface sample? For example, do they appear or smell different from one another?

- Why might these samples be different from one another? Describe some differences between the surface water and subsurface water habitats.

Sample Analysis

1. Allow the children to operate the temperature probe by completely submersing it into the surface water sample. Ensue they wait until the reading has stopped changing before removing the probe. Once the reading has stabilized, have them write down the temperature value. Repeat this procedure for the subsurface sample.

   Temperature is one of the most basic and important physical parameters to any ecosystem. In our example, temperature measures how hot or cold the water is. All organisms, including humans, can only survive within a certain range of temperatures. In lakes, such as Lake Lacawac, temperatures vary with depth and can change greatly over the seasons; this is because of thermal stratification.

   Thermal stratification in lakes is the change in water temperature with depth, which is caused by the density change of water. The warmer the water is, the less dense it becomes and the colder it is the denser it becomes until it freezes. During the summer, the surface of the lake is warmed by the sun. So as a result, the warmer less dense water stays on the surface; while the cold dense water stays on the bottom. In the winter some lakes freeze and ice is formed on the surface of the lake. This is because when water freezes it becomes less dense than liquid water, which is why ice floats.

2. Have the children dip the dissolved oxygen probe completely into the surface water sample and have them wait until the reading has stopped changing before removing the probe. Once the reading has stabilized, have them write down the percent oxygen value received. Repeat this procedure for the subsurface sample.

   Oxygen is required by most organisms to survive, including creatures living in the water. Oxygen in the atmosphere readily diffuses into water allowing water dwelling creatures to breathe, this is called dissolved oxygen. Dissolved oxygen can also be released from the water back to the atmosphere. The oxygen concentration in the water is dependent on temperature, and cold water can hold more oxygen than warmer water. Oxygen concentration in the water is
also affected by photosynthesis carried out by algae (like trees on land create oxygen through photosynthesis).

3. Have the children dip the pH probe completely into the surface water sample bottle and wait until the reading has stopped changing before removing the probe. Once the reading has stabilized, have them write down the pH value received. Repeat this procedure for the subsurface sample.

pH is a measure of the acidity or alkalinity of the water. It is measured on a logarithmic scale from 1 to 14; acidic water is indicated by a pH value less than 7, while basic water is indicated by a pH value greater than 7. pH ultimately depends on the amount of hydrogen ions are present in the water. All organisms can only survive within a certain range of pH values, usually between 5 and 9.

Questions to Ask

**Temperature:**
- As they record temperature, have them determine if the samples are different from one another. How does temperature change with depth and why?
- What might be some consequences of this temperature variation to biological life? Also, think about how these temperature differences will change during the winter when the lake freezes.

**Dissolved Oxygen:**
- As they record dissolved oxygen concentrations, have them determine if the samples are different from one another. How does dissolved oxygen vary with depth and why?
- Does the temperature of the water agree with the physical property that cooler water can hold more oxygen than warm water? If not, why not?
- What biological and environmental factors might influence oxygen concentrations in the water?

**pH:**
- As they record pH, have them determine if the samples are different from one another. How might pH vary with depth and why?

**Comparison:**
- Do any of these parameters (temperature, dissolved oxygen, pH) follow the same or opposite pattern? Why might this be?
Automated sampling

Not all water sampling is performed using the methods performed above. This is because manual sampling can cost a lot of money and can take a long time to perform. Today sampling can be done using automated sensors that measure many different. These sensors can then transmit a signal of the data they collected back to a computer database. This cuts down the cost of sampling and allows researchers to see the data at the exact moment the measurement was taken.

Lake Lacawac has automated sampling devices located on the raft near the middle of the lake. The sensors can measure nine different parameters both above and below the water’s surface. The sensors on the platform allow scientists and students to observe water quality and weather condition readings.

The graph shown below demonstrates the dissolved oxygen concentration during one day of sampling. The samples were collected every hour using an automatic sensor. These sensors can be programmed to collect samples more frequently if it is desired. Have the children use their acquired knowledge of dissolved oxygen at answer- why would you expect that DO decreases from 1am to 7am (1 and 7 on the graph’s time of day)? Then why does it increase from 7am to 6pm (7 and 18 on the graph’s time of day)?

![Graph of dissolved oxygen concentration](image)

**Figure 1:** The dissolved oxygen concentration sampled every hour for one day.
Lake Sampling and Data Collection

Name: ________________    Time: ________________
Date: ________________

Sample Observations:

Hypothesized Differences:

Temperature: 
Surface: ______ °C  Subsurface: ______ °C

Dissolved Oxygen: 
Surface: ______ mg/L  Subsurface: ______ mg/L

pH: 
Surface: ______  Subsurface: ______

Hypotheses:
Lesson Plan Checklist

- Print off raw data sheets for the participants.

- 1 VanDorn Sampler
  4 Plastic Bottles and 4 Lids
  1 Thermometer
  1 Dissolved Oxygen Probe
  1 pH Probe

- Calibrate each of the probes using the stepwise manuals, prior to the arrival of the children.

- Demonstrate how a VanDorn Sampler works and what they are used for and then collect a subsurface sample. Show the children how to collect the surface water samples and encourage them to try. Allow them collect the surface water samples for analysis.

- Bottle and cap each sample and allow the participants to visually observe differences between the samples. Ask them questions to stimulate participation and independent thinking.

- Demonstrate how the temperature, dissolved oxygen, and pH probes work and have the children measure each parameter for every sample. Ensure that the procedures are being followed and that equipment is being handled properly.

- Have the children record the instrument reading on their datasheets. Once again ask the participants questions throughout the lesson.

- Dump the samples back into the lake, and place all equipment back into their boxes. Ensure the pH probe is immersed in liquid for storage.
Answer Key

Questions

- The subsurface sample might have a different smell and may be murkier from the surface sample.

- The subsurface sample was collected from the bottom of the lake where there is muck. The bottom of the lake can have sediment, aquatic plants, decaying plant and animal matter, and etc. For an older audience, the main reason for the smell difference is that when oxygen is depleted at the bottom of a lake, anaerobic bacteria partially break down sediments. In the process, they expel hydrogen sulfide gas (which smells like rotten eggs).

Temperature:

- The subsurface sample should be colder in comparison to the surface (this will depend on how quickly samples are analyzed after they are collected). The reason for this difference is because of thermal stratification in lakes. The surface of the lake is warmed by the sun. So the warmer less dense water stays on the surface; while the cold dense water stays on the bottom.

- Certain creatures like cold water and others like warm water habitat. During the winter, lakes freeze and ice is formed on the surface of the lake. This is because when water freezes it becomes less dense than liquid water, which is why ice floats.

Dissolved Oxygen:

- The surface sample should have more oxygen present in comparison to the subsurface (this will depend on how quickly samples are analyzed after they are collected). This is because oxygen in the atmosphere diffuses into water, which takes place on the surface. Also because oxygen concentration is affected by photosynthesis. There is more light available near the surface of the lake (light attenuation) and so there is more photosynthesis.

- No. This is because, in theory, colder subsurface water should hold more oxygen. This is not the case because atmospheric diffusion and photosynthesis have greater dependency on DO than the physical property.

pH:

- pH should decrease with depth, but may not be noticeable (this can also depend on how quickly samples are analyzed after they are collected). This is because of
anaerobic bacteria are present in the deep water (little oxygen) decomposing organic matter (dead fish, plankton, leaves, and etc.). The decomposition processes performed by the bacteria lowers the pH.

Comparison:
- pH, dissolved oxygen, and temperature all decrease with depth. pH and dissolved oxygen are partially dependent on temperature. The colder the water, the more dissolved gases are in the water (CO₂ and oxygen). The more carbon dioxide dissolved in the water, the lower the pH (because of bicarbonate). These physical properties can be overruled by certain biological activities that have been previously described. These are complex concepts for children, so the presenter should take into account their audience for how detailed they cover this section.