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# Investigating Changes in Science Perceptions

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## Abstract
It is important to equip today's students as future scientists with knowledge of the true Nature of Science (NOS). This mixed-method study evaluated changes in a student's perceptions of science after participating in an after school PBL science program. Students completed pre/post tests derived from VNOS form C measuring perceptions of science. Multiple choice questions measured student's content knowledge. The control and treatment group study investigated whether inquiry based activities changed the students' perceptions of science. Results did show changes in their perceptions of science.

## Introduction
"To know science is to love it" and a direct correlation has been shown between a person's knowledge of science and their attitude toward the subject (Allum, Sturgis, Tabourazi & Brunton-Smith, 2008 p. 35). When the true Nature of Science is not conveyed, students' natural curiosity is diminished; which can derail their motivation for learning (Pickens and Eick, 2009). This pilot study explores how a high school after school science program affected student's perceptions of science through the use of hands-on, minds on exploratory activities addressing different areas of biological sciences. Children who participate in project based learning (PBL) activities are more enthusiastic and engaged when compared to those who only read or watch their teacher demonstrate science (Jorgenson, 2005). Data collected during student-centered activities indicated an increase in understanding of science content and the nature of science.

### *Project Based Learning*
By nature, science is an inquiry-based discipline. Teaching inquiry-based science includes letting students explore questions to build their scientific knowledge (Hsu, Lai, and Hsu, 2015). Unfortunately, some students do not get to experience science in this manner (Bartos & Lederman, 2014; Pickens & Eick, 2009). The National Science Teachers Association (NSTA) recommends that 60 to 80 percent of the instruction in science classes should be spent in active (hands-on) scientific investigations (inquiries) (NSTA, 2001). The National Science Education Standards (NSES) goal states that children should be able to participate in and understand scientific inquiry (NRC, 1996).

Hands-on does not automatically mean that the students are engaging in scientific inquiry (Huber & Moore, 2001). PBL should not only help the students understand science, but it should also promote scientific inquiry. Some teachers that use hands-on activities rely on worksheets and step-by-step instructions. These activities, though helpful, do not promote scientific inquiry (Huber& Moore, 2001). Teachers should give students opportunities to build their own knowledge and reflect on what they have learned (McCollough, 2005).

Inquiry is the process used to explore our world through asking questions that lead to discoveries and new understanding (Chen & She, 2015). Inquiry-based teaching is the creation of an environment in which students are engaged in project based activities (Jorgenson, 2005; McCollough, 2005). True inquiry is performed when students are able to come up with their own scientific questions and design experiments they can conduct to achieve the answers and gain new understanding (Campanile, Lederman, and Kampourakis, 2015). The path to full scientific inquiry is usually student-centered and is driven by their own curiosities (Eilam, 2015).

### *Nature of Science*

Nature of Science (NOS) is defined as the values and assumptions that are part of scientific knowledge (Schwartz, Lederman & Crawford, 2004). NOS includes the concepts learned through participating in scientific endeavors (Schwartz et al, 2004). Students should not only understand science content, but they should also be able to develop their own ideas of how scientists work (Akerson, Buzelli& Donnelly, 2008). "NOS instruction can create a space for all students to be successful in science" (Quigley, Pongsanon, & Akerson, 2010, pg.888)

Unfortunately, about 95% of the entire American public is considered to be illiterate in science (Gonzalez-Espada, 2009). To help produce a more science literate nation, NOS should be included in science education (Akerson et al., 2008) and there are documents mandating that teachers from kindergarten to graduate school should include instruction in aspects of the nature of science (Bell and Lederman, 2003). VNOS is a scientific questionnaire that is a meaningful assessment of the students' Nature of Science and differs from the typical tests because of its open-ended nature and correlating interviews (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).

## Methods

After observing students in informal science settings, I questioned whether hands-on minds-on activities changes students' perceptions of science. A pilot study was developed and implemented using the Science Club for students at a high school located in South Texas. We received Institutional Review Board (IRB) approval from the university to collect obtain consent and collect data.

Approximately every two weeks the Science Club had an after school meeting where students participated in a PBL activity. They learned how science could be applied to authentic situations. These "authentic science" activities are important because they spark genuine inquiry in the students as they work in a real scientific situation (Hsu & Roth, 2009). The students were asked to take short pre/post quizzes to measure what they had learned during the activity. There were nine meetings and two field trips.

To measure the students' change in their perceptions of Science, a pre and post test was administered. The test included 18 short answer and 10 multiple choice questions. The students that took the pretest included those who participated in the Science Club and a control group consisting of several students who did not participate in the Science Club. These pre/post test scores were used to evaluate the students' change in their perception of science.

Using mixed methods, the short answer questions were analyzed qualitatively and multiple choice questions were analyzed quantitatively (Johnson and Onwuegbuzie, 2004; Venkatesh, Brown, and Sullivan, 2016). The short answer questions were derived from questions in VNOS Form C. Because of the small sample size, each of the three students is treated as a case study. The pre/post test sets from the six chosen students were independently analyzed to calculate inter-rater reliability which was calculated at 90%. Inter-rater reliability is needed to protect the qualitative analysis of the data from subjective bias that would result in ineffective conclusions (McCollough, 2005). The multiple choice questions were quantitatively analyzed to measure changes in science content knowledge. The following is a list of science activities and discipline specific content covered at each meeting:

### *Introduction and Chromatography:Chemistry*

This was the first meeting and students were allowed to give input on what they would like to learn about because if the students' ideas and desires are incorporated, a science club will be more successful (Bircher and Sansenbaugher, 2015). Students did a small experiment illustrating a simplified version of Chromatography. They started with a purple mixture of food coloring and through chromatography; they were able to separate the blue and red colors from the mixture. They learned about experimental design, how chromatography works, and why scientists use chromatography.

### *Water Testing: Toxicology*

Students learned how to test pH, nitrate/nitrogen, and phosphate tests for different water samples. They were introduced to possible careers that have to do with water testing and the importance of water testing. They learned about the pH scale and how to properly handle chemical waste. The students also saw a demonstration using water testing equipment that is used in a lab that participates in marine biology research.

### *DNA Structure and Bases: Biochemistry*

The meeting began with a short lesson about Deoxyribonucleic Acid (DNA). The students learned about the double helix structure of DNA and how the structure wraps around histones to form our 23 pairs of chromosomes. The students learned about DNA's base pairs through building a small model of a double helix that they could take home with them. The students had to pair up the color-coded bases correctly and assemble them on the DNA backbone. The resulting ladder shape was twisted to form a double helix.

### *DNA Extraction: Biochemistry*

At this meeting the students extracted DNA from their own cheek cells. The students learned basic lab techniques such as pipeting and the importance of using sterile equipment. Important terms, such as lysis and precipitate, were introduced and defined. This activity taught them about how and why scientists would want to perform a DNA extraction. Because of the students' resulting curiosity, a quick demonstration of an imaginary paternity test was given. Students took home a micro centrifuge tube which held the DNA that they had extracted from their own cheek cells.

### *Salinity: Chemistry*

The field trips had been planned for the Texas State Aquarium and the Nueces Delta Preserve. Because of those upcoming trips, the next few lessons concentrated on estuaries and fish. The salinity lesson explained the importance of salt in the ocean and how different concentrations of salt have different effects on the organisms that live in the water. In the salinity experiment, the students had to find what concentration of salt would make an egg float. In the process they learned how to perform a serial dilution and performed all of the calculations themselves.

### *Fish Communication: Physiology*

The lesson first gave a brief explanation of how humans hear and communicate. Then the processes of fish hearing and communicating were explained and compared to the human processes. The students then tested how their hearing and communication would change when transmitted through water. They filled several balloons with varied amounts of water and air and were asked to describe the changes in sounds in relation to the amount of water in the balloon.

### *Fish Dissection: Anatomy*

The students were given a brief lesson on fish anatomy and the proper dissection technique prior to dissecting a Red Fish. During the previous lesson they learned about the otoliths, the swim bladder, and the lateral line of the fish. Those three structures were identified and related back to fish communication. The students were also asked to identify several other internal structures. There was time left for the students to do some exploration of the fish and ask about anything they had dissected.

### *Brown Tide: Ecology*

During the short lesson, the students learned about the cause of brown tide and its possible side effects. They reviewed photosynthesis and how sunlight is necessary for the survival of plants. The experiment involved eight clear plastic cups, eight index cards, and crayons. The students were all asked to color one side of the index card green and to put all the colors of the rainbow on the other side of the card. The cards were placed green side up underneath the plastic cups. The plastic cups each had the same amount of water, but each had a different concentration of food coloring that made the water a different shade of brown. This experiment reviewed their previous knowledge of serial dilution and demonstrated the effects of brown tide on the amount of sunlight that reached the marine plants. The students were then asked to record what colors of the rainbow were able to be seen through the different levels of brown tide.

### *Aquarium Field Trip: Biology*

The students were given a behind the scenes tour of the aquarium. They were able to see how the water was cleaned and maintained, how the meals were prepared and fed, and also where the animals rested. They toured the visitor side of the aquarium and enjoyed the shows and activities. They were also exposed to several short lessons spurred on by their questions about life under water.

### *Delta Preserve Field Trip: Ecology*

The day at the preserve began with a short lesson on animal adaptations and identification using the animal's tracks and their bones. The students were then taken to a small saltwater canal and were shown several sampling techniques as well as a review of water testing. The students were shown how to seine, use a hook and line, a cast net, and a dip net. After a short demonstration, students were able to measure the turbidity of the water with a secchi disk. Students were asked to identify anything that they caught and any common bird or plant that they saw. The students were full of curiosity and each of their questions was answered and made into a brief lesson for all the students. They continued practicing their sampling techniques at a freshwater tank and at a larger saltwater canal.

### *Taxonomy: Taxonomy*

The students learned about the importance of taxonomy in science, the taxonomy hierarchy and the full classification of Homo sapiens. The students also learned how to properly diagram the Genus species name of an organism. They were then asked to make some classifications of their own. On one of the lab tables, there was soda, pizza, cookies, and candies of all kinds. The students had to break down the "Food" kingdom into more specific groups until they found a specific "species" of candy. They had to come up with their own names for each branch of the "Food" Kingdom as if each species was a new discovery.

## Results

There were three students who completed both the pre/post tests and regularly attended the science club meetings. Andrea, Becky, and Harold (pseudonyms) are treated as a case study and their qualitative analysis of the short answer portion in the pre/post tests is compared to the students in the control group. Therefore in the qualitative analysis portion of the study the VNOS responses will be discussed. The scores A, B, and C represent the student's improvement on that question. A score of A represents answers with great improvement, B represents answers that showed more improvement than the corresponding answers of the control group, and C represents answers with some improvement.

### *Andrea*

Andrea attended every Science Club meeting and both field trips. At the first few meetings she was extremely shy and did not talk to anyone. By the end of the meetings, she was leading most of the class discussions whether they pertained to the subject of the meeting or not. Her qualitative analysis is found in table 1.

Table 1. Selected qualitative analysis of Andrea's answers.

| | Question | Pre-test Response | Post-test Response |
|---|---|---|---|
| 4 | Are experiments required in order for science to develop? Defend your answer with examples. | No response | Yes, because how will you know the answers |
| 6 | What do you think the difference is between a scientific theory and a scientific law? | The scientific law is like you have to do exactly what you have to do, like stopping at a stop sign is a law. The scientific theory is what you want to do. | Scientific law is a known fact and theory is almost a guess. |
| 9 | What types of work do scientists do? Are marine biologists scientists? Provide examples of careers that involve science. | No response | How do work, live, and why stuff in life do these things. Marine biologists are considered scientists. |

Andrea showed improvement on nine of the 18 short answer questions. Her improved answers were on questions 2, 4, 6, 7, 9, 10, 11, 12, and 13. She showed some improvement over the control group on questions 4, 7, 9, and 10 and great improvement on questions 4 and 7. Her results showed improved understanding about experimentation and the difference between a scientific theory and a scientific law. Andrea also improved her score on the multiple choice questions from 30% correct on the pre test and 40% correct on the post test.

### *Becky*

Becky was an enthusiastic member of the science club and she attended six of the nine meetings. She was disappointed when she found out that she had conflicting plans for the field trips. She also brought in several of her friends to many of the meetings. Her qualitative results are shown in Table 2.

Table 2. Selected qualitative analysis of Becky's answers.

| | Question | Pre-test Response | Post-test Response |
|---|---|---|---|
| 5 | What is the difference between a hypothesis and a theory? | one is a thought that many have - theory and one is a personal opinion - hypothesis | A theory has been tested over and over and has not been proven wrong. |
| 12 | What types of work do scientists do? Are marine biologists scientists? Provide examples of careers that involve science. | marine biologist | Scientists do many kinds of work; yes marine biologists are scientists ex. Refinery work, agriculture, teaching. |
| 16 | Define evolution. What are some ways scientists study evolution? | Sorry, I don't think we evolved from anything. God made us in his likeness on Earth. We were made to give him glory on Earth. If we evolved, then why are there still apes and chimps around? Would they not have "evolved" with us? | I don't know |
| 17 | How can genetics influence evolutionary process? | I don't know | It can change the adaptability of something causing it to either survive or to die. |

Becky showed improvement on 10 of the 18 short answer questions. Her improved answers were on questions 5, 7, 9, 10, 11, 12, 13, 14, 16, and 17. She showed some improvement over the control group on questions 7, 10, 11, 12, 13, and 17 and great improvement on 5, 12, 13, and 17. Her understanding of the difference between a hypothesis and a theory went from showing no understanding to being able to better explain the definition of a theory. She also showed great improvement in her understanding of scientific careers and what it meant to be a scientist. Her understanding of the evolutionary process also showed great improvement from not knowing anything to understanding an organism's ability to adapt and change in order to survive. She also improved her score on the multiple choice questions from 60% correct on the pre test to 70% correct on the post test.

### *Harold*

Harold attended seven of the nine meetings. He was engaged in the material and intrigued enough to ask many questions. However, the pre/post tests seemed to frustrate him. Harold provided few responses on the short answer portion, but he showed improvement in all three questions that he answered on the post test. Those three questions were 2, 5, and 6. He showed the most improvement in his understanding of the difference between a hypothesis and a theory. In Harold's pre-test response, on question number 5, "What is the difference between a hypothesis and a theory, he indicated that, "a hypothesis is a guess, a theory is something that can be proven" while on his post-test response he reported that "a hypothesis is not yet proven and a theory is proven by a scientist". He did well on the multiple choice questions on the pre test with 50% correct, but he dropped to 20% correct on the post test questions.

At each meeting the students in attendance were asked to answer two content questions in pre/post quizzes. The selected example responses of these content questions are found in Table 3. Answers that resembled the target words for that question are printed in bold to help identify what was learned by the students during the Science Club activity.

The quizzes also asked the student three additional questions to measure their understanding of the day's activities. Those questions were A) How is what we did today science? How did you act like a scientist? B) What did you learn today? C) What questions do you still have? (write at least one). The emergent theme based on question A was qualitatively analyzed by the researcher. The answers provided in the last two questions revealed potential holes in the students' understanding and allowed for insight on how to make the next lesson more effective.

Table 3. A list of pre/post quiz responses from the water testing Science Club meeting.

| | **Water Testing** | | | |
|---|---|---|---|---|
| Question | Why is water testing important? | | What do scientists test for in water? | |
| Target Words | Clean drinking water, marine life, healthy | | phosphate, pH, nitrate/nitrogen, bacteria chlorine, calcium, iron, flourine, sulfur. | |
| Answers | Pre | Post | Pre | Post |
| Andrea | for our safety | **for drinking and animal life** | test for toxic waste | **bacteria and toxic waste** |
| Becky | to check levels of chemicals | **keep environ-ment and people healthy** | different chemicals | **phosphate nitrate/nit rogen, pH levels, and others.** |
| Jenny | to see if it is infected | **clean water** | **bacteria and chemicals** | **bacteria, nitrate, pH, phosphate, molecules.** |
| Conrad | to see types of molecules | to test for bacteria | **e-coli in water we drink** | **e-coli, pH, nitrate, ect.**(sic) |

**Conclusions**

Results show that these three students improved their perceptions of science and two of them showed improvement over the control group. The students also showed improved understanding of experimentation and an appreciation for performing a lab activity.

Lederman (2014) states that after participating in authentic science activities, true understanding of NOS can be facilitated through a reflective discussion on what the students have done and why. The questions "How is what we did today science? How did you act like a scientist?" were included in every post quiz and became an emergent theme throughout the Science Club meetings. The best responses came toward the end of the year where responses show an improvement in the Science Club students' perceptions of science.

This pilot study had a small sample size of students that participated in the Science Club and took both pre/post tests. A larger sample size would allow better comparisons. Perhaps the VNOS version A (elementary version) would generate better participation and result in a more accurate measurement of the students' perceptions of science. Adding oral and/or written surveys to the pre/post tests would also provide more data regarding changed perceptions. The Views About Scientific Inquiry (VASI) is a new questionnaire that may also be more effective (J.S. Lederman, N.G. Lederman, Bartos, Bartels, Meyer, and Schwarz, 2014).

Individual interviews with the children from the Science Club after the post test would gain their insight into what they have learned and experienced throughout the year. These interviews would also help with evaluating high school students' experiences after they participated in the Science Club (Bell, Blair, Crawford & Lederman, 2003).

**Endnote**

This article is an update of an article previously published in Academic Exchange Quarterly. The previous article is titled 'An Informal Program Changes Science Perceptions' written by S. Bargmann and C. McCollough, published 2010.

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