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Nano Science ~ The Invisible Science!: An Evaluation of the Efficacy of a Nanoscale Science Summer Camp

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Abstract

This study evaluated a nanoscale science summer camp called *Nano Science ~ the invisible science!* The program was held at **Hands On!-A Child's Gallery,** the non-profit educational children's museum in Hendersonville, North Carolina. The program was designed for older elementary to middle-school age students (ages 8-11) and incorporated a variety hands on activities to teach children about the scientific world of unseen phenomena. In addition, the program sought to inspire an interest in science in general. This study measured the camper's interest in and attitudes toward science; how much they learned specific programmatic content; and whether and how they might apply what they learned to their everyday lives. Data addressing these questions was collected primarily with a pre-camp and post-camp test. The test measured the campers' knowledge acquisition (e.g., Why does the "memory metal" move under high heat? What is the difference between Ferrofluid and Blacks sand?) and science attitudes. Chi-square tests were used to compare pre-post camp proportions of correct answers to test items. Answers to several test items were significantly more likely to be correct after the children completed the camp. Results of this study will be discussed in terms of practical implications for the Hands On! staff. In addition, results will be discussed in the context of the theory and research on informal science learning.

1. Introduction

Today, children seem more interested in social media, electronics, and television programs than learning about science and how the technology they use actually works. Schools continually seek new science teaching and learning techniques, in part because of all the electronic media distractions in and outside the classroom. Sadly, according to research, becoming a scientifically informed individual is "not a high priority for many students."[1]

Much of the research on children's science learning measures their learning after completion of a generalized science curriculum within a standard.[2] Informal science learning programs, such as the programs developed by the Nanoscale Informal Science Education (NISE) Network, are made for children to experience science first hand and to acquire scientific knowledge in a fun environment, outside the classroom. The NISE Network is committed to working with science-based children learning centers to impart nano science fundamentals. Nano science is a relatively new kind science that operates on a much smaller scale; an atomic and molecular scale. Introducing nano science to young children may influence them to be open minded to the reality of unseen phenomena and their influence upon the world in which we live.

Nano science is a rapidly developing field, quickly assuming social significance. Indeed, one of the key reasons for nanotechnologies' importance is its social relevance, such as improved understanding of nature, increased productivity, more advanced and efficient healthcare and enhanced sustainable developments and human potential.[3] Lin, Lin, and Wu (2012) studied the public's nanotechnology knowledge and attitudes. The results indicated that about 70% of participants did not understand most of the six vital concepts (size and scale, structure of matter, size-dependent properties, forces and interactions, tools and instruments, and science-technology-society) involved in nanotechnology.[3] In spite of this lack of knowledge about the concepts undergirding the nanotechnology field, the research participants recognized that nanotechnology provides both great benefits as well as significant risks to society.[3]

Jarmon and Keating (2008) conducted research to determine the value of role-playing to help teach the societal effects of nanotechnology. Their research describes the *Nano Scenario,* a dramatic face-to-face simulation that exposes the public to the potential social, ethical, and political outcomes and challenges of nanotechnology.[4] Their research is relevant to the goal of this study, in which a program utilizing a hands on and involved approach to teach the concepts and consequences of nanotechnology is evaluated in terms of the participant's interest and understanding. The *Nano Scenario* showed that involved and especially stimulating learning techniques produce more knowledge and understanding of the social, political, and environmental effects of nanotechnology.[4]

2. Nano Science ~ The Invisible Science!

Hands On! - A Child's Gallery, the non-profit educational children's museum located in Hendersonville, North Carolina worked with the NISE Network to create a summer camp program designed to introduce nano science concepts using fun and interactive activities. This camp science program was developed for children ages 8-11. The camp program was calibrated to match the participants' cognitive abilities. The critical concepts taught in the camp included nano-related topics such as capillary action, the nanoscale, and how a binary code works. Most of the activities focused on bringing attention to the importance of nano science concepts in a fun and visually stimulating way. Many of the activities such as *Measure Yourself* and *Memory Metal* utilized everyday size scales normally taught in the classrooms and compared them to the nanoscale. Memory Metal is a type of alloy that when manipulated will return to its prior state when under high heat due to the atoms rearranging. These activities in particular attempt to communicate to the children that the nanoscale is a dramatically smaller yet exact scale of measurement. The activities were designed to teach that certain materials and substances behave dramatically differently on the nanoscale.

Several camp activities sought to teach participants how much nano science affects our everyday lives. Program elements, such as *Would you Buy That* and *Robots & People,* informed students about the past and present of nanotechnology and its risks and benefits. The activity *Would you Buy That* takes the pupils on a mock shopping trip to the grocery store and encourages the students to consider and ask questions about what products they are buying and what effects this will have on themselves and their families. *Robots & People* is an activity that teaches the students about robots and nanobots and what role they will plausibly have in our near future. After the information sessions participants were instructed to create their own interpretations and possible applications of nanotechnology.

The purpose of this study was to evaluate the effectiveness of the nanotechnology science camp in terms of content delivery as well as its ability to inspire interest in and appreciation for science in the participating students. In addition, this study sought to help evolve and facilitate ideas about how informal science can be an effective teaching tool and to demonstrate that scientific concepts such as those included in nano-based science can be taught effectively outside of the classroom.

Informal science learning programs include both inquiry-based learning, in which students are given the freedom to answer science questions on their own, as well as hands on activities. Many informal learning programs also include "science role models and close mentoring because these elements have been identified as important for the promotions of science interest and achievement."[5] Many of the science programs such as *Hands On!'s* summer science camps are voluntary while many are incorporated into a school's formal curriculum as an effective supplemental learning tool.[6] Many informal science programs have been shown to boost scientific knowledge and comprehension, however, "the effectiveness of these programs for improving science attitudes and increasing aspirations for science careers is much less certain."[5]

This study will not only address the specific question as to whether nanotechnology ideas taught through an informal science learning environment will be comprehended, it will also attempt to determine if the program inspires young students to learn more about science in general.

Previous research has shown that informal science learning programs generally have a positive effect on children and their interest and involvement in science. For example, middle school aged students who took part in an inquiry-based scientific program demonstrated positive advances in science achievement, cognitive development, science process skills, and understanding of science as a whole compared to students taught with a more traditional approach.[7] The present study seeks to contribute to the literature on informal science learning by measuring the impact that the *Hands On!* camp has on its participants. This study specifically seeks to determine if the nano-scale program, as taught through this summer camp, is an effective learning tool and whether the camp sparks a general interest in science.

3. Method

3.1 Research participants

The research participants for this study were later elementary through middle school students from ages 7 to 12. They were campers that partook in the Nano-science based summer learning program at *Hands On! - A Child's Gallery, the non-profit educational children's museum* in Hendersonville, NC. The summer camp, *Nano Science ~ the invisible science!* took place on August 4th 2014. There were a total of 11 participants. There were 6 female participants and 5 male participants. All of these participants were previously signed up for the camp prior to arrival on the day of the camp. Permission to participate in the research was obtained from parental guardians when campers and their guardians arrived at the camp. A copy of the permission form is shown below.

Parental Permission for Participation of a Child in a Research Study
An Evaluation of the Efficacy of an Informal Learning Nano-science Based Summer Science Camp

Description of the research and your child's participation
You are invited to participate in a research study conducted by Nora Sugar, Beth Bockhoven, and Mark Harvey. The purpose of this research is to evaluate the effectiveness of the Nano-technology science camp.
Your child's participation will involve completing a brief survey asking questions about the camp before and after the camp.
The amount of time required for your child's participation will be only a few minutes.

Risks and discomforts
There are no risks associated with this research.

Potential benefits
There are no known benefits to the child that would result from the child's participation in this research.

Protection of confidentiality
The survey results will be kept totally anonymous and confidential.

Voluntary participation
Participation in this research study is voluntary. You may refuse to allow your child to participate or withdraw your child from the study at any time. Your child will not be penalized in any way should you decide not to allow your child to participate or to withdraw your child from this study.

Contact information
If you have any questions or concerns about this study or if any problems arise, please contact (Beth Bockoven) at Hands On! (828-697-8333) or Mark Harvey, UNC Asheville (828-251-6831).

Consent
I have read this parental permission form and have been given the opportunity to ask questions. I give my permission for my child to participate in this study.

Participant's signature________________________________ Date:_________________

Child's Name:____

A copy of this parental permission form should be given to you.

3.2 Materials

A survey was developed to measure participants' learning and interest in science. Science attitude items used a 5-point Likert scale (strongly disagree, disagree, neutral, agree, and strongly agree). The survey featured content specific questions utilizing a multiple choice format (A, B, C) in which one option was the correct answer. A copy of the survey is provided below.

Age:_______ Please check: ___male ___female

For the following questions, please choose the best answer (this is not graded!):
1. How much of a meter is one nano-meter?
A. One-thousandth of a meter
B. One-tenth of a meter
C. One-billionth of a meter

2. What is Capillary Action?
A. When water fills into big spaces
B. When colors mix together to make a new color
C. The ability of liquid to flow into narrow spaces against gravity

3. What is the difference between Ferrofluid and Black sand?
A. One is made out of magnetite the other is not
B. Their size is different
C. One is black the other is purple

4. How important is it to learn the risk and benefits of nanotechnology?
A. Very important because the risks and benefits cannot always be predicted
B. Not really important, nanotechnology is only used by scientists
C. Not important at all

5. Which one of these items uses nanotechnology?
A. An oven uses it to bake pies
B. A computer uses it to store data
C. A motorcycle uses it to go fast

6. What type of code do computers use to store information?
A. Binary code
B. Electric code
C.A photo code

7. What two numbers are used in the binary code?
A. 1 & 2
B. 5 & 7
C. 1 & 0

8. Why does the "memory metal" move under high heat?
A, The atoms rearrange
B. The heat pulls the spring
C. It does not move at all

9. Which one of these space technologies uses "memory metal"?
A. A space suit
B. A space ship
C. The Mars Rover

10. What is Oobleck made out of?
A. Cornstarch and water
B. Glue and water
C. Paint and glue

11. What is a possible use of Oobleck that can be useful to humans?
A. It can serve as a heat source
B. For protection
C. It can be used as food

12. Oobleck is both a _____ and a _____
A. Gas and a liquid
B. Solid and a gas
C. Liquid and a solid

13. In what ways can Nanotechnology better human life?
A. Nanotechnology takes advantage of special materials on the nanoscale to make helpful products
B. Nanotechnology helps us explore new frontiers such as space
C. Both are correct

14. What are nanobots?
A. Robots that look just like people
B. Robots the size of cells or molecules that do not exist yet
C. Robots that go to space

15. How do items on the nanoscale behave compared to those on the Macro scale?
A. They behave different and have different properties
B. They behave the same
C. Neither of these answers are correct

16. Do you understand that Nanotechnology like other forms of new technology comes with benefits as well as risks?
A. No I do not understand this
B. I understand it a little bit
C. I understand this completely

For each of the following statements, please circle the number that best shows how you feel.

1. I think science is cool

Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
1	2	3	4	5

2. This program helped me learn about Nanoscience and nanotechnology

Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
1	2	3	4	5

3. I will tell my family and friends about this program and about nano science

Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
1	2	3	4	5

4. I will continue to learn about nano science

Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
1	2	3	4	5

5. Science is my favorite subject in school

Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
1	2	3	4	5

6. After this camp I will continue to learn more about science

Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
1	2	3	4	5

3.3 Procedure

The procedure for this study had two parts. The first part was the administration of the pre-test survey. The survey was administered before the camp began and took approximately 15 minutes. Reading the survey questions out loud was necessary for some of the participants to fully understand. All of the students took the pre-survey. The duration of the camp session was 4 hours and was divided into different activities. The first few activities were ones including lessons such as binary code and measurement in nano-meters. These activities included all the campers participating together. Following these activities was a lunch break. After lunch, the campers were split into groups of three or four and these groups rotated through three different stations. Each station included one adult teacher. The author volunteered to teach to one of the stations. Each station had two lessons accompanied by an activity provided for the campers. Once the camp was concluded the same eleven participants took the post-test survey. This included the same exact survey questions as the pre-test. This took approximately 10 minutes. Upon the second survey administration the students seemed to better understand the questions and made it through the survey in a bit less time.

4. Results

Chi square tests were performed on each of the sixteen multiple choice survey items to compare student performance between the pre- and post-surveys. Next, a one-way ANOVA was performed to evaluate the six interest rating questions to compare before v. after camp. Presented in **Table 1** are each 16 multiple choice questions showing the correct and incorrect answers on pre- and post-surveys. The Chi square tests revealed that students were significantly more likely to correctly answer six of the sixteen multiple choice survey questions after the program. One of these items, (item 8) was significant in the opposite direction—more participants got that item incorrect in the post survey than in the pre survey. Items that were statistically significant can be viewed in **Table 1**. It should be noted that while several items did not show a statistically significant improvement, the results clearly show that more students, generally, chose correct answers after program exposure. The one-way ANOVA used to assess the interest rating questions found no difference between the pre and post surveys.

Table 1. results of knowledge items on pre- and post-test survey.

Survey Item	**Number Correct**	**Number Incorrect**	**Significant Difference**
How much of a meter is one nano-meter? **Pre(1)**	3	7	
Post(2)	7	3	No, $p>.05$
What is Capillary Action? **(1)**	4	6	
(2)	7	4	No, $p>.05$
What is the difference between Ferro fluid and black sand? **(1)**	3	7	
(2)	6	5	No, $p>.05$
How important is it to learn the risks and benefits of nanotechnology? **(1)**	9	1	
(2)	7	3	No, $p>.05$
Which one of these items uses nanotechnology? **(1)**	8	2	
(2)	10	1	No, $p>.05$
What type of code do computers use to store information? (1)	5	5	
(2)	10	1	**Yes, the difference was statistically significant: $x^2=4.3$, $p<.038$**
What two numbers are used in the binary code? **(1)**	2	8	
(2)	11	0	**Yes, the difference was statistically significant: $x^2=14.2$, $p<.000$**
Why does the “memory metal” move under high heat? **(1)**	6	4	
(2)	2	9	**Yes, the difference was statistically significant: $x^2=3.9$, $p<.049$**
Which one of these space technologies uses “memory metal”? **(1)**	2	8	
(2)	9	2	**Yes, the difference was statistically significant: $x^2=8.03$, $p<.005$**

What is oobleck made out of? **(1)**	4	6	
(2)	10	1	**Yes, the difference was statistically significant: x^2=6.11, p<.013**
What is a possible use of oobleck that can be useful to humans? **(1)**	5	5	
(2)	11	0	**Yes, the difference was statistically significant: x^2=7.22, p<.007**
Oobleck is both a ___ and a ___ **(1)**	7	3	
(2)	9	2	No, p>.05
In what ways can nanotechnology better human life? **(1)**	7	3	
(2)	6	5	No, p>.05
What are nanobots? **(1)**	6	4	
(2)	7	4	No, p>.05
How do items on the nanoscale behave compared to those on the macro scale? **(1)**	8	2	
(**2)**	5	6	No, p>.05
Do you understand that nanotechnology comes with benefits as well as risks? **(1)**	2	8	
(**2)**	4	7	No, p>.05

5. Discussion

Overall, these findings show that *Nano Science ~ the invisible science!* camp at *Hands On!* was successful in educating the young campers on nano science concepts. Six out of sixteen survey items showed a significant difference between pre and post conditions. This indicates that there was a substantial difference in the number correct before and after (i.e., greater than chance improvement). On five out of six of these survey items, the post survey question had a substantial increase in the number of children answering correctly. The results clearly demonstrate that the camp was and will continue to be very effective. Though some test items did not show a statistically significant difference in correct responses after the camp, most of the remaining items showed improvement. This study confirms the pedagogical efficacy of the particular camp.

The first two items that showed a statistically significant improvement in correct responses after the camp, “What type of code do computers use to store information?” and “What two numbers are used in the binary code?” were both derived from the same lesson about binary code. Almost all of the camp participants got both of these items correct on the post survey. A probable reason for why these two questions were answered correctly the second time around was the way in which the material was taught—it may have been especially memorable because it involved a hands-on activity. The leaders of the camp first provided an explanation of what exactly binary code is and how it works. Then the campers were able to experience binary code first hand by completing an activity requiring them to translate their names into binary code and vice-versa. The personal nature of this activity may have been why this lesson was so easy to recall. This explanation is consistent with previous[5] that examined the effects of self-focused attention on recognizing previously presented self-relevant and irrelevant stimuli. Panayiotou, G., Brown, R., & Vrana, S. R. (2007) found that a self-focused activity during learning enhances memory for words.

The sole survey item that showed a statistically significant *decrease* in correct responding after camp exposure was item number eight, “Why does the “memory metal” move under high heat?” The item was based off the “memory metal” station and learning activity that used a demonstration of a spring reacting to a high level of heat. Surprisingly, a high number of students answered this question incorrectly compared to those who answered correctly on the pre survey. Why did this occur? There are a few possible reasons for why this happened. Perhaps the information as to why the metal moves (the atoms rearranged) was not specifically stated but merely implied through the lesson. It is interesting to note that the next statistically significant item was about the memory metal activity as well, “Which one of these space technologies uses ’memory metal’?” This item was significant in the right direction—more participants got it correct on the post survey. Perhaps the information about the Mars Rover containing the memory metal was explicitly presented and provided a dramatic, memorable example—the participants may have found the example to be more interesting than the material covering why the metal moved under high heat.

Items number ten and eleven were the next statistically significant survey questions. These questions were both derived from the hands on activity “Oobleck”: “What is oobleck made out of?” and “What is a possible use of oobleck that can be useful to humans?” The next question on the survey, “Oobleck is both a ____ and a _____.” (Liquid and a solid) did not, however, show a significant improvement though all three items were based on the same activity (though it did show some improvement, with 7 answering correctly pre-camp and 9 answering correctly after the camp). The two statistically significant questions had a substantial difference perhaps due to hands on nature of the activity. Oobleck, a non-Newtonian fluid, is an interesting and fun to manipulate substance that all ages can enjoy.

The other test items showed no statistically significant difference between the conditions. Students, of course, frequently forget specific factual information when later tested. In addition, it is likely that some students may have had more interest in one area of the nano-science camp curriculum than another area, thereby resulting in no differences on the items between the pre- and post-tests. For example, the oobleck activity was a highly sense-stimulating activity when compared to the ferroufuid activity, even though students seemed to enjoy that component of the camp as well.

The interest rating questions showed no differences between the pre- and post-tests. Does this finding necessarily mean that the camp did not enhance interest in science generally or in nano-science in particular? The lack of a difference may have occurred for a few reasons. First, the interest rating questions could have been structured differently. A few of these items asked students how they felt about the camp prior to its commencement. Those items were likely confusing and so they answered it either in a neutral or ambivalent manner. Another possible reason for this result could be that some of these children were at the camp because of their parent’s wishes rather than their own personal interest on the topic. Many of the participants were homeschooled and were with their fellow students from the same co-operative. This may have an influence in that all children within the co-operative were to attend the camp regardless of personal interest in the subject matter. Moreover, these were also the last questions on the surveys. Students may have been fatigued by this point, after the camp’s activities and then taking what amounts to a science test.

Lin, Lin, and Wu’s study (2012) found that even though the majority of the public did not completely understand the concepts behind nanotechnology they still understood that the field of nanotechnology delivers benefits as well as risks to society. This summer camp sought to teach young students the concepts as well as the idea of the risks and benefits of nano science. It is interesting that the survey items that addressed the risks and benefits of nano science, excluding one item which addressed understanding, most students got correct on the pre- test. However, the factual questions that tested the concepts behind the science, for the most part, were incorrect on the pre compared to the post test. Perhaps these young students have heard about nanotechnology issues (maybe from popular media sources such as television shows and movies) and therefore understood the potential impact of nano science without any specific technical knowledge prior to the camp.

As the results show, this science learning camp increased participants’ knowledge of the nano science world and comprehension of some of the fundamental concepts. However, the interest rating items showed no difference indicating student’s attitudes towards science and interest did not change in regard to the program being assessed. These results contrast with Stake and Mare’s (2001) findings regarding inquiry-based science learning techniques. These findings sought to examine the impact of inquiry based science learning programs on participant’s overall interests and aspirations. They found that there was a noticeable difference in the student’s interest in science immediately after the program. It should be noted that the present study used a small sample size and this may have influenced the results. A larger sample size may have provided sufficient statistical power to detect what is likely a very small effect (i.e., enhancing science interest is a tall order to fill and is most likely to result from prolonged, positive interactions with science material and scientists).

Most all of the learning activities involved in the nano science camp were hands on in nature. The *Nano-Scenario* described by Jarmon and Keating (2008) was a drama-based attempt to convey the societal impact of nano science, and was successful in that aim. The present study showed that a well-constructed nano curriculum, hands-activities, and professional delivery of content successfully enhances science learning.

There were a couple limitations to the present study. First, conducting a study with such a small sample size is usually regarded as a limitation. Always, if possible, a larger sample size is ideal. Even though the sample size was small, the results yielded from this study used a statistical technique appropriate for small samples. Nevertheless, a larger sample size would feature more statistical power and the results would likely have been even more positive. Second, there was no measurement of the camper's long-term memory for the material weeks or months after the camp. Although this study cannot address whether the material learned from the camp was lasting, it can confirm that the camp was successful in teaching the nano science concepts with a hands on approach to these students.

Further research on informal science learning and nano science learning in particular should be explored. In particular, future research might productively investigate the role that informal learning environments can play in long-term science learning. Perhaps such research could correlate ultimate career choices with informal science learning participation.

6. Acknowledgements

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