Nanotechnology Classroom Program
Evaluation Report

Prepared for

OMSI
Everyday Encounters with Science

by
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EXECUTIVE SUMMARY

The present report describes the evaluation study conducted for the *Nanotechnology Classroom Program*, a one-hour traveling classroom program developed by the Oregon Museum of Science and Industry (OMSI). This outcome-based evaluation focuses on two sessions held in March 2011 in one of OMSI's partner elementary schools in Portland, Oregon.

This study is part of the larger *OMSI Energy and the Environment Initiative* Evaluation Program which was developed in 2011 to support OMSI's strategic goal of becoming a leader in education on sustainability, renewable energy, and environmental science.

The purpose of the present evaluation is to contribute to the understanding of the impact of current energy and the environment related programming at OMSI in order to inform future programs while simultaneously evaluating the *Nanotechnology Classroom Program* strengths and weaknesses in order to inform future versions.

KEY FINDINGS

The *Nanotechnology Classroom Program* exceeded almost all of the success indicators and proved to be successful in achieving the intended outcomes. Its particular strengths were found to be in the skills, attitude, and identity outcomes.

- KNOWLEDGE OUTCOMES

The majority of the participants demonstrated they understood and observed basic nanoscale properties. Also most of the participants were able to remember at least two current or potential uses of nano science in renewable energy technologies.

- SKILL OUTCOMES

The majority of the participants were able to use their recent knowledge about nanoscale and nano science to make their own predictions about the use of nanotechnology in the future, often related to harnessing solar energy and energy storage technologies.

- ATTITUDE OUTCOMES

Participants were found to be interested in learning more about nanotechnology.

- IDENITY OUTCOMES

The majority of the participants enjoyed enacting the role of a nano scientist and "thinking as a nano scientist" when exploring the stations and making predictions about the use of nanotechnology in the future.

ACKNOWLEDGMENTS

Special thanks to educators Tim Hecox, Emilee Monson, and Randall Fastabend and evaluators Liz Rosino, Scott Pattison, Steve Hassett, and Marcie Benne for all your work and support during the evaluation of this program.

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INTRODUCTION

The Oregon Museum of Science and Industry (OMSI) is an independent informal science education center in Portland, Oregon providing interactive exhibits, science camps, and class programs to the public. From October 2010 through April 2011, evaluators from OMSI's Evaluation & Visitor Studies division worked with OMSI Science Education managers and educators to evaluate a sample of OMSI programs related to energy and the environment topics.

The intent of this evaluation project was driven by the June 2010 update to OMSI's Strategic Business Plan which identified the museum's primary strategies for the 2011 fiscal year. One of these strategies was to provide "engaging science experiences that focus on *Energy and the Environment*, using evaluation to inform our efforts." Through a new museum-wide strategic focus on *Energy and the Environment*, OMSI's goal is to become a leader in education on sustainability, renewable energy, and environmental science reaching a broad audience and helping to foster the next generation of innovators in sustainable technologies.

To begin this evaluation project, evaluation staff worked with the education managers to identify the needs, audiences, impact framework, and intended outcomes for existing programs related to energy and the environment. This led to the development of a reference figure to describe the logical linkages among these items and to provide a guide for both consistent program development and evaluation planning (see Figure 1).

Figure 1. OMSI Energy and the Environment Program Evaluation Logic Model

Evaluation Need	Audiences	Impact Framework			Intended Program Outcomes	Evaluation Methods
		***CLE Impacts*[1]**	***OMSI Science Education Programs*[2]**	***NRC Strands*[3]**		
To understand the impact of current programming related to *Energy and the Environment* to inform future E&E programs.	Experience and Delivery program participants	Foster informed citizens	Inspire Wonder Science Literacy • Knowledge development • Decision-making skills • Information evaluation skills	1. Developing interest in science 2. Understanding science knowledge 3. Engaging in scientific reasoning 4. Reflecting on science 5.Engaging in scientific practices	***Knowledge*** a) Participants will understand the big ideas: "The living environment results from the interdependent relationships between the Earth as a physical system, living systems, and human society" and/or "Energy used in our daily lives comes from a variety of sources that has different impacts on the environment." ***Skills*** a) Participants will engage in scientific reasoning related to *Energy and the Environment* science topics	Embedded Assessment Observations
		Reduce gaps in STEM participation and performance Foster identities as science learners	Inspire Wonder Science Identity • Promote and support STEM careers	1. Developing interest in science 5.Engaging in scientific practices 6.Identify with the scientific enterprise	***Attitude*** a) Participants will report a high level of interest in *Energy and the Environment* science topics. ***Identity*** a) Participants will see themselves as persons who can affect their environment b) Participants will report interest in a career related to *Energy and the Environment*.	Survey

[1]OMSI Center for Learning Experiences Impact Learning Model, v 12.15.09
[2]OMSI Internal Curriculum Standards Energy and the Environment Initiative, v. 9.28.10
[3]National Research Council. (2009). Learning Science in Informal Environments: People, Places, and Pursuits.

Once a working version of the logic model was created, the team chose which programs to evaluate. Four different programs related to *Energy and the Environment* offered during the fiscal year were included in the final evaluation sample. These programs were selected because they directly related to *Energy and the Environment* topics, their scheduled dates would fall within the data collection period of the evaluation, and they reached both on- and off-site participants. The programs evaluated were *Wind Power*, *From Pond Scum to Salmon*, Science Reserved Labs, and the *Nanotechnology Classroom Program,* which is the focus of the present report.

Program Description

This evaluation report focuses on two sessions of the *Nanotechnology Classroom Program,* a traveling classroom program which was recently developed and delivered by OMSI's outreach educators starting in the fall of 2011.

The sessions were held on March 9, 2011, at Arch Bishop Howard Elementary School, a partner school with OMSI located in Portland, Oregon. There were a total of 50 participants between the two classes, with 19 fourth-grade students in the first class and 31 fifth-grade students in the second.

Nanotechnology Classroom Program is a one-hour traveling classroom program designed for grades 4 through 12 that combines activities developed by OMSI Experience and Delivery staff and the Nanoscale Informal Science Network (NISE Net), a consortium of informal science educators and researchers.

During the two sessions, participants were first introduced to nanoscale science with *What Is Nano?*, a slide show covering nanoscale, nano in nature, the unique characteristics of nanoscale materials, nanotechnology, and the risks of nanotechnology. Following the slide show and a short video, participants had 30 minutes to rotate through 11 activity stations (see Appendix A for the program outline). The class ended with a group activity in which students shared their ideas of new potential uses of nanotechnology.

OBJECTIVE

This program evaluation served two main purposes:

1. As part of the larger OMSI *Energy and the Environment* Program Evaluation to contribute to the understanding of the impact of current energy and the environment-related programming at OMSI in order to inform future programs.

2. To understand in what ways the class met or did not meet the intended outcomes of the program as set forth in the *Nanotechnology Classroom Program Measures of Success Model* (Figure 2) in order to evaluate its strengths and weaknesses and inform future versions of the class.

MEASURES OF SUCCESS MODEL

A Measures of Success model specific to the *Nanotechnology Classroom Program* was created in collaboration with the educator developing the program. This model served as a documenting tool when planning for the evaluation, as well as a guiding document for later steps in the evaluation process such as the analysis.

Figure 2 shows the *Nanotechnology Classroom Program* Measures of Success Model. Observe that in the second and third columns, the model shows how *the Energy and the Environment* outcomes relate to the intended outcomes for the *Nanotechnology Classroom Program*. The next column includes indicators related to what those unique outcomes would look like if they were to occur. Next to each indicator are the methods which were used to collect data to measure and compare what actually happened with what was anticipated to happen if the outcomes were successful.

Figure 2. *Nanotechnology Classroom Program* Measures of Success Model

Outcome Category	Outcomes		Indicators	Methods
	Energy and the Environment Programs	*Nanotechnology Classroom Program*		
Knowledge	Participants will understand the big idea: "Energy used in our daily lives comes from a variety of sources that have different impacts on the environment."	a. Participants will understand nanoscale science and engineering basic properties.	65% of participants will respond correctly for each question about nano scale and properties during the embedded assessment quiz.	Embedded Assessment
		b. Participants will conceptualize the current and potential applications of nanotechnology in renewable energy technologies.	80% of participants will recall at least three current or potential applications of nano in renewable energy technologies.	Post-Survey
Skills	Participants will engage in scientific reasoning related to E&E science topics.	Participants will observe the properties of nanoscience and nanotechnology and make predictions about their use in the future.	65% of participants will be able to make at least one prediction about the use of nanotechnology in the future.	Embedded Assessment and Post-Survey
Attitude	Participants will report a high level of interest in E&E science topics.	Participants will express a high level of interest in learning more about nanotechnology.	75% of participants will report a high level (e.g., 4 or higher on scale of 1–5) of interest in learning more about nanotechnology.	Post-Survey
Identity	Participants will report interest in a career related to E&E.	Participants will report a high level of enjoyment in enacting the role of a nanoscientist.	75% of participants will report a high level of enjoyment (e.g., 4 or higher on scale of 1–5) in enacting the role of a nanoscientist.	Post-Survey

METHODS

Qualitative and quantitative data were collected during both classes through the use of an embedded assessment quiz, an embedded assessment of student predictions, and post-surveys. This multi-method approach captured a broad range of outcomes, allowing the developer and evaluators to fully assess the impact of the program on the participants while also providing an opportunity to discover outcomes which were previously unanticipated.

Embedded Assessment

Embedded assessment (i.e., assessment integrated into classroom activities) was used twice during the class, with the educator asking participants planned questions at specific points in the classroom program. The first instance was a four-question quiz following the introductory slide show. In the second instance, students were asked to make predictions regarding possible future nano inventions. In both instances, two data collectors were nearby to record participant responses on simple tally sheets (provided in Appendix B). Data collectors included two staff members, consisting of one educator and one lead evaluator.

This embedded assessment method served two purposes. First, this style of assessment acted as a teaching tool for the educator to quickly assess participants' progress toward reaching the targeted outcome, thus providing immediate feedback for the educator to address gaps in understanding. The second purpose was to perform program evaluation, contributing to the assessment of the classes' success (along with other methods) in meeting or exceeding intended outcomes.

Post-Survey

Directly following each class, the participants were asked to individually complete a short written survey. This survey (provided in Appendix C) was designed to be age appropriate and asked questions about each participant's knowledge, attitude, and identity as it related to the intended program outcomes. School teachers returned the completed surveys by mail within one week of the program. The response rate was 90% (45 out of 50).

Data Analysis

Data entry, data coding, and data analysis were completed by evaluation staff for both the embedded assessment and post-surveys. All data procedures were undertaken in accordance with the quality control processes for handling data established by OMSI's Evaluation & Visitor Studies division. These quality control processes entail the review of all data, analysis, and reporting materials by at least two evaluation staff members in addition to the original author.

FINDINGS

Participants

There were a total of 50 participants, all of them 4th and 5th grade students at Arch Bishop Howard Elementary School. Demographic information collected was limited to gender and was self-reported by participants in the post-survey. The total respondents of the post-survey were 45 (90% of total program participants). Of those who responded on the survey, 27 were female, 16 were male, and two participants did not report their gender.

Results

Results are presented following the *Nanotechnology Classroom Program* Measures of Success Model with Results (see Figure 3). Observe that there was a column added to the original model; this final column presents the actual results, occurring after data collection and analysis. This updated model permits a comparison between the success indicators and the actual results, which helped to determine where the strengths and weaknesses lie in the program. Following the model are the results specific to each of the outcomes.

Figure 3. *Nanotechnology Classroom Program* Measures of Success with results

Outcome Category	Outcomes		Indicators	Methods	Actual Results
	Energy and the Environment Programs	*Nanotechnology Classroom Program*			
Knowledge	Participants will understand the big idea: "Energy used in our daily lives comes from a variety of sources that have different impacts on the environment."	a. Participants will understand nanoscale science and engineering basic properties.	65% of participants will respond correctly for each question about nanoscale and properties during the embedded assessment quiz.	Embedded Assessment	**At least 86% (43 out of 50) of participants responded correctly for each question about nanoscale and properties.** The mean percentage of correct answers per question is about 88%.
		b. Participants will conceptualize the current and potential applications of nanotechnology in renewable energy technologies.	80% of participants will recall at least three current or potential applications of nano in renewable energy technologies.	Post-Survey	**42% (19 out of 45) of respondents named at least three current or potential applications in renewable energy technologies.** 82% named at least two. Most were about ways to harness solar energy.
Skills	Participants will engage in scientific reasoning related to E&E science topics.	Participants will observe the properties of nanoscience and nanotechnology and make predictions about their use in the future.	65% of participants will be able to make at least one prediction about the use of nanotechnology in the future.	Embedded Assessment and Post-Survey	**During the embedded assessment, 87% (34 out of 39) made at least one prediction. On the survey, 100% (45 out of 45) made at least one prediction.** Most inventions were related to materials such as paper or textiles.
Attitude	Participants will report a high level of interest in E&E science topics.	Participants will express a high level of interest in learning more about nanotechnology.	75% of participants will report a high level (e.g., 4 or higher on scale of 1–5) of interest in learning more about nanotechnology.	Post-Survey	**76% (34 out of 45) of respondents reported a high level of interest in learning more.** The average rating of interest was 4.18 out of 5.
Identity	Participants will report interest in a career related to E&E.	Participants will report a high level of enjoyment in enacting the role of a nanoscientist.	75% of participants will report a high level of enjoyment (e.g., 4 or higher on scale of 1–5) in enacting the role of a nanoscientist.	Post-Survey	**82% (37 out of 45) of respondents reported a high level of enjoyment in enacting the role of a nanoscientist.** The average enjoyment rating was 4.26 out of 5.

Knowledge Outcomes

The intended knowledge outcomes for the class were (1) that participants would understand nanoscale science and engineering basic properties and (2) that participants would conceptualize the current and potential application of nanotechnology in renewable energy technologies. This is related to the OMSI *Energy and the Environment* program knowledge outcome of participants understanding the big idea that "energy used in our daily lives comes from a variety of sources that have different impacts on the environment."

Outcome 1. Understanding nanoscale science and basic engineering properties

Method: Embedded Assessment

The first knowledge outcome was evaluated by using embedded assessment. This formative assessment occurred at the end of the program's introductory slide show in the form of a short interactive quiz involving the educator displaying multiple-choice questions as a large projected image while asking participants to answer by raising their hands.

The measure of success indicator was that 65% of participants would respond correctly during the quiz. At least 86% (43 out of 50) of participants responded correctly for each question about nanoscale and properties, with the mean percentage of correct answers per question being approximately 88%, well above that established as an indicator of success. A complete distribution of responses is provided in Table 1 below.

Table 1. Embedded assessment quiz questions and answers

	% of participants by response (N=50)
Q1: A red blood cell is found at the nanoscale.	
1A: True	8%
1B: False (correct answer)	92%
Total	**100%**
Q2: DNA is found at the nanoscale.	
2A: True (correct answer)	86%
2B: False	14%
Total	**100%**
Q3: Things on the nanoscale can be found all around us.	
3A: True (correct answer)	86%
3B: False	14%
Total	**100%**
Q4: Nanotechnology can affect the way we move and produce energy.	
4A: True (correct answer)	86%
4B: False	14%
Total	**100%**

Outcome 2. Conceptualize the current and potential application of nanotechnology in renewable energy technologies

Method: Post-Survey

Participants were asked on the post-survey to name current or potential applications of nanotechnology in renewable energy technology. The measure of success was that 80% of participants would recall at least three current or potential applications.

About 42% (19 out of 45) of respondents were able to name at least three current or potential applications in renewable energy technologies on the survey. While this number fell short of the stated measure of success, it was also found that 82% of participants named at least two current or potential applications. Most of the responses (about 78%) were about harnessing solar energy through panels, windows, or paint.

Table 2 below shows the types of energy-related responses overall, combining the results of the first two questions on the post-survey. The first, "What are three ways in which nanotechnology helps us produce energy?", explores the current applications, while the second, "If you were a nano scientist in real life, what new things would you invent?", relates to potential future applications.

Table 2. Current or potential energy-related applications of nanotechnology

# of Responses	% of Responses	Type of Application
83	78%	**Harnessing renewable energy**, e.g., "Using solar panels to use the sun's energy to power it," "Solar powered windows," "Nano paint which is like solar panels."
4	15%	**Energy transmission**, e.g., "Not losing energy when transporting energy," "Electric nano wire instead of iron ones."
16	4%	**Energy Storage**, e.g., "Batteries."
4	4%	**Characteristics**, e.g., "It is very strong," "It is really small."
107	**100%**	**Total**

Skills Outcomes

The intended skills outcome for the class was that participants would observe the properties of nanoscience and nanotechnology and make predictions about their use in the future. This is related to the OMSI *Energy and the Environment* program knowledge outcome that participants will "engage in scientific reasoning related to *Energy and the Environment* science topics."

Method: Embedded Assessment

After rotating through 11 available activities, students were asked to make predictions about possible nano inventions in the future. The measure of success indicator was that 65% of the participants would be able to make at least one prediction about the use of nano in the future.

During the embedded assessment, 87% (34 out of 39) of participants were able to make at least one prediction about use of nano in the future. Four participants named more than one prediction. The largest percentage of predictions related to changing the characteristics of materials such as paper or textiles to make them stronger, lightweight, sticky, colorful, etc. The full distribution of responses is illustrated in Table 3 below.

Table 3. Predictions of nano use in the future (from embedded assessment)

# of Responses	% of Responses	Invention Product Type
15	39%	**Paper/Textiles/Materials**, e.g., "Bulletproof shirt that is lightweight," "Paper that would never get wet," "Person crawling on the walls like gecko or spiderman."
7	18%	**Energy**, e.g., "Shirt to plug your Iphone into," "Shoes with solar panels."
5	13%	**Info/Communication**, e.g., "Robots that cost $5/month and you can program them to do things for you," "Phone on your glasses."
5	13%	**Cosmetics**, e.g., "Hair curlers (that work in the nanoscale)," "Waterproof hair so it doesn't get wet."
4	11%	**Chemistry**, "Chemical to put in water to clean it."
1	3%	**Medical**, e.g., "Prevent cancer and not become blue."
1	3%	**Not apparently nano-related**
38	**100%**	**Total**

Method: Post-Survey

On the survey, 100% (45 out of 45) of participants were able to make at least one prediction regarding the use of nano in the future. About 69% (31 out of 45) could make two predictions. Again, the largest percentages of inventions were related to materials (29%), but answers related to energy were a close second (24%). Table 4 below illustrates the full distribution of responses.

Table 4. Predictions of nano use in the future (from post-survey)

# of Responses	% of Responses	Invention Product Type
24	29%	**Paper/Textiles/Materials**, e.g., "I will invent clothes that can kill all bacteria around," "Elevator to the moon," "I could make gloves that could climb on walls, windows, or just plain ceiling."
20	24%	**Energy**, e.g., "I would make a solar-powered tent," "Make a painted wall that is a solar panel."
15	18%	**Cosmetics**, "A man who can swim without getting wet," "A contact that you could just drop the nano water in and your eye color changes."
7	8%	**Not apparently nano-related**
6	7%	**Info/Communication**, "I could put nano thingies in my hand so my hand could be a hand iPad."
6	7%	**Medical**, e.g., "Use nanotechnology to detect cancer before it even starts and then prevent it," "I would make bacteria fighting nano-bots."
5	6%	**Chemistry**, e.g., "Water purifier device or chemical," "Paint that makes pictures."
83	**100%**	**Total**

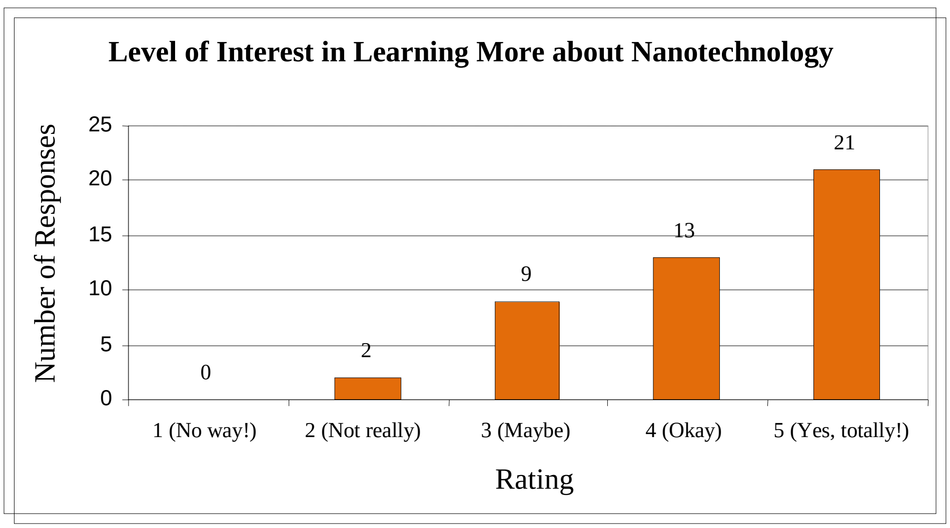
Attitude Outcome

The intended attitude outcome for the class was that participants would express a high level of interest in learning more about nanotechnology. This is related to the OMSI *Energy and the Environment* program attitude outcome that participants would "report a high level of interest in *Energy and the Environment* science topics."

Method: Post-Survey

The intended attitude outcome was that 75% of the participants would report a high level of interest (i.e., four or higher on scale of one to five) in learning more about nanotechnology. On the survey, 76% of respondents (34 out of 45) reported a high level of interest in learning more by rating a four or five on a five-point scale (1 = "No way!" / 5 = "Yes, totally!"). More respondents gave a rating of 5 ("Yes, totally!") than any other rating, with the mean rating of interest being 4.19 out of 5. Figure 4 below shows the distribution of ratings.

Figure 4. Rating of interest in learning more about nanotechnology.



IDENTITY OUTCOME

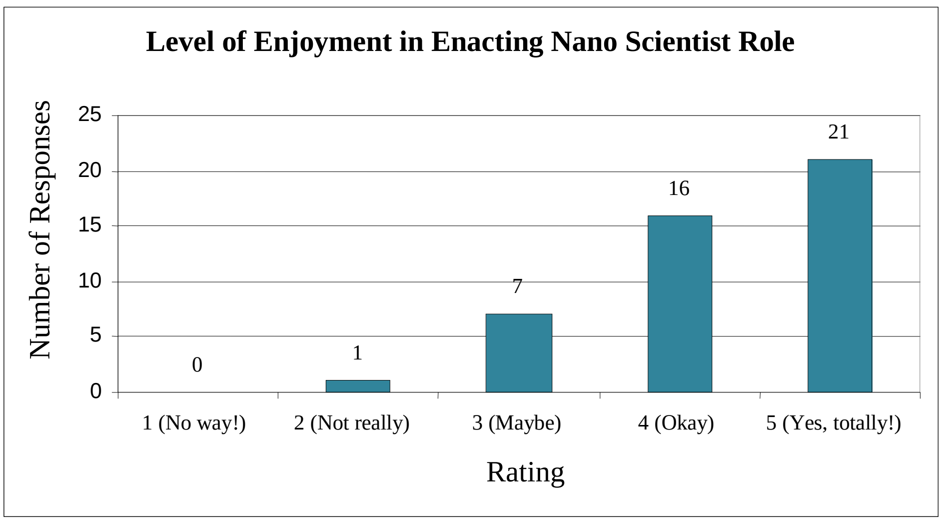
The intended identity outcome for the class was that participants would report a high level of enjoyment in enacting the role of a nano scientist. This is related to the OMSI *Energy and the Environment* program identity outcome that participants would "report interest in a career related to *Energy and the Environment*."

Method: Post-Survey

Participants were prompted to "think like nano scientists" while engaging in the 11 activity stations (Appendix C) when asked to predict what they would invent. The intended identity outcome was that at least 75% of participants would report a high level of enjoyment (i.e., four or higher on a scale of one to five) in enacting the role of nano scientist during the class.

About 82% of respondents (37 out of 45) on the post-survey reported a high level of enjoyment in performing the role of nano scientist during the class, rating a four or five on a five-point scale (1 = "No way!" / 5 = "Yes, totally!"). More respondents gave a rating of 5 ("Yes, totally!") than any other rating, and the mean enjoyment rating was 4.4 out of 5. Figure 4 below shows the distribution of ratings.

Figure 4. Rating on level of enjoyment performing the role of a nano scientist



Discussion and Recommendations

The *Nanotechnology Classroom Program* exceeded almost all of the success indicators set forth in its Measures of Success Model in Chart 1. Its particular strengths were found to be in the skills, attitude, and identity outcomes. Participants understood and observed basic nanoscale properties and used this to make predictions regarding the use of nanotechnology in the future related to renewable energy, materials and medical technologies, and other categories corresponding to topics and applications discussed in the classroom program. Participants were also found to be interested in learning more and enjoyed enacting the role of a nano scientist.

The knowledge component had two outcome indicators, each of which generated different results. For the embedded assessment quiz about basic nanoscale properties, the results far exceeded the measure of success indicator. The program only met half of the indicator developed for the second knowledge-related outcome, however, with only 40% of participants able to recall at least three current or potential applications of nano in renewable energy technologies on the post-survey.

This finding most likely resulted from an inconsistency between the indicator and the program's content. This measure of success may not have been appropriate, as only three renewable energy-related applications were mentioned in the program: solar panels, solar paint, and carbon nanotubes. Based on this, a more realistic success indicator would be to recall at least two rather than three applications. If this new measure of success were to be applied, this knowledge outcome would have been easily met, as 82% of participants were able to recall at least two applications. Revision of this program's indicator and/or inclusion of more renewable energy-related examples would be recommended for future delivery or evaluation of the program.

While evaluators strove to be as comprehensive as possible, there remain certain limitations to this program's evaluation methods. The majority of these involve the embedded assessment methods. First, when participating in sharing their predictions about the use of nanotechnology in the future, students had limited time to think about and discuss, which might have affected participant response rate, and second, it is possible that during the embedded assessment quiz, some students followed the lead of others in raising their hands when responding to questions.

The findings in this report are intended to be used by OMSI's education staff to inform future versions of the class. The report is also available to inform other members of NISE Net (the Nanoscale Informal Science Education Network) developing similar programs using the materials available through the network.

Additional anecdotal observations made by the evaluator included that the fourth grade participants "loved the class" and that there was "lots of excitement and 'wow' expressions when [participants were] observing and experimenting with activities." During the fifth-grade class, the "clapping of one kid was followed by others when [the educator] mentioned the possibility of powering a city with windows." There was also "clapping and overall verbalizing of excitement after the video finished."

Finally, a discussion took place between the teacher at the school and the educator regarding the possibility of offering this class for high school students and adults. The evaluator for this program recommends looking into this opportunity, as the program has strong potential to educate older audiences regarding nanotechnology. In this case, the program would need some adaptations of the "stretch-ability" and "carbon-tube building" activities to make them suitable for adults and teenagers (see appendix pages A-2 and A-4 respectively).

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Appendices

APPENDIX A. NANOTECHNOLOGY CLASSROOM PROGRAM EDUCATOR'S OUTLINE

APPENDIX B. EMBEDDED ASSESSMENT TALLY SHEETS

APPENDIX C. POST-SURVEY

NANOTECHNOLOGY

Outreach Traveling Program

Grades 4-12

Topic Description: Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications.

PROGRAM OUTLINE

Grades 4-12

INTRODUCTION

Begin class by introducing yourself, going over classroom program expectations and by introducing the subject of Nanotechnology. Ask students if they can share anything that they already know about nanoscale science and/or nanotechnology. This will lead into the slide show (see PowerPoint script at the end of outline) followed by the three minute video made by OMSI (saved on laptops and located at http://vimeo.com/11362918)

STATION ACTIVITIES

Stations (30 min)

The placement and layout of stations should be positioned to one another relative to subject – scale, behavior, nature, and energy. Explain to students that the activities are divided into these groups around the room.

Ask students to think like Nanoscientists while they explore the station activities. For example: While at the Nano in Nature station, ask them to think about how different properties found in living things could be applied to nanotechnology.

1. Smell on a nano-scale! *(emphasis on scale)*

http://www.nisenet.org/catalog/programs/exploring_measurement_-_molecules_nanodays_2010

Exploring Measurement – Students use their sense of smell and explore the world on the nanoscale. They learn that we can smell things that are too small to see. Have students record their hypothesis on what scent is in each balloon during station time and read aloud the correct answers in concluding discussion.

2. Nano Twist *(emphasis on scale)*

"Exploring Measurement – StretchAbility" is a hands and feet-on game that explores the different sizes of things in the world. Things come in different sizes—and size is important! In this game, we explore three different scales: the macroscale, the microscale, and the nanoscale.

3. Scale Memory Game—Optional *(emphasis on scale)*

This is a simple memory card game that visually explores the macroscale, microscale, and nanoscale.

4. Magic Sand *(emphasis on behavior)*

http://www.nisenet.org/catalog/programs/magic-sandnanosurfaces

Fill one or two clear glass bowls part way with water and add a cup or so of magic sand. Place at least one spoon in each bowl and encourage students to observe behavior of non-polar sand.

Magic Sand demonstrates how changes on the nanoscale can affect how a material behaves at the macroscale. Students learn that hydrophobic surfaces repel water and that "magic" sand repels water because of a nanoscale hydrophobic coating on the grains of sand.

When normal sand is sprinkled over water, it readily mixes with the liquid and sinks to the bottom. But when non-polar sand is sprinkled, the water molecules prefer to continue bonding with other water molecules instead of the sand. This prevents the grains of non-polar sand from breaking through the surface. The sand stays on the water's surface until enough material accumulates to overcome the surface tension. This same effect keeps non-polar sand dry. Water molecules will not attach to individual grains or flow between them. Other liquids, however, will soak into non-polar sand. For instance, oil's non-polar nature is attracted to non-polar sand and thus allows the sand to absorb large quantities of oil. Magic sand could someday be used to clean up oils spills!

Magic Sand has also been used to protect electrical and telephone wires in extremely cold climates. Wires are buried underground to protect them from extreme temperatures. Utility workers cover underground electrical junction boxes with a thick layer of Magic Sand. The hole is then capped with a thin layer of normal soil. When rain or melted snow seep into the ground, the Magic Sand repels the water and prevents it from freezing around the junction box. If workers need to perform repairs, only the thin top layer of soil is frozen.

5. Funky Ferrofluid *(emphasis on behavior)*

http://www.nisenet.org/catalog/programs/exploring_materials_-_ferrofluid_nanodays_08_09_10

Place the vile of ferrofluid on the table next to a variety of magnets. **Make sure the seal is never broken or opened on the small tube filled with water and ferrofluid.**

Ferrofluid is a strange material that can acts both like a liquid and like a solid magnet. In this activity, students experiment with this bizarre material. Magnetic nanoparticles of iron in ferrofluid only respond when exposed to a stronger magnetic field. By manipulating magnets near the ferrofluid, students can try to make cool spikes and watch as the material changes between being a liquid and being a solid.

* A larger table top exhibit is also available to put out with station activity.

6. Feel What You Can't See – SPMs and Magnets *(emphasis on behavior)*

http://www.nisenet.org/catalog/programs/exploring_tools_-_spms_nanodays_08_09_10

Place several large and small magnets and associated magnet strips for student exploration.

"SPM and Magnets" is a hands-on group activity that uses flexible magnets as a model for a scanning probe microscope (SPM). SPMs are an example of a special tool that scientists use to work on the nanoscale. The magnet is a model for how a scanning probe microscope (SPM) works. It lets you "feel" something that you can't see: in this case, a magnetic field. The north and south poles run in alternating bands across the magnet.

You feel the strip bump across the surface when it's pulled across the bands, because it's alternately attracted to and repelled by the poles it encounters. When the strip is pulled parallel to the bands, you don't feel the bumps because it's always attracted to the surface.
A scanning probe microscope similarly works by "feeling" something you can't see with your eyes. But in addition to detecting magnetic fields, an SPM can also detect lots of other kinds of things about a surface: nanometer-sized hills and valleys, atoms, conductivity, friction, stiffness, and more.

1. EXPLORING MATERIALS—LIQUID CRYSTALS ***(EMPHASIS ON BEHAVIOR)***

http://www.nisenet.org/catalog/programs/exploring_materials_-_liquid_crystals_nanodays_08_09_10

Lay out three 12"x12" liquid crystal sheets along with the heat pad on a table. Students are encouraged to observe the different properties involved with the different liquid crystal sheets by placing their hands and heat pad on or under the liquid crystals. Each of the three sheets has a different temperature range that will effect the way the material changes color.

Liquid crystals change color as a result of nanoscale shifts in the arrangement of their molecules. The way this material behaves on the macroscale is affected by its structure on the nanoscale. Changes to the liquid's molecular structure are too small to see directly, but students will observe corresponding changes in the material's properties.

Liquid crystals are used in cell phone displays, laptop computer screens, and strip thermometers. They're also being used to create nanosensors—tiny, super-sensitive devices that react to changes in their environment. Nanotechnology takes advantage of special properties at the nanoscale to create new materials and devices.

8. Exploring Nano Fabrics and Materials *(emphasis on behavior)*

http://www.nisenet.org/catalog/programs/exploring-materials-nano-fabrics

Place the two pans, greens and "nano pants" on a table with a small water bottle. It is best to have a splash pan and strainer under the greens and pants so that the water can run off the materials.

This is a hands-on activity explores how the application of nano-sized whiskers can protect clothing from stains and make materials “non-stick” when applied to pots and pans. Students investigate the hydrophobic properties on nano vs. non-nano fabrics as well as on kale vs. iceberg lettuce and non-stick pans vs. regular pans. Students will explore how a material behaves on the macroscale is affected by its structure on the nanoscale.

9. Invisible Sun block *(emphasis on behavior)*

http://www.nisenet.org/catalog/programs/invisible-sunblock

Place the two laminated sheets with white dots printed on them on a table with a small dab of non-nano sunblock on the sheet with large white dots and a small dab of nano sunblock on the sheet with small white dots. Place 2”x5” black construction paper strips with tooth picks in the middle. Encourage students to get “lifeguard noses” but to be sure that they only use a small portion of the non-nano sunblock.

Do not leave out the sunblock containers on the table for students to use.

“**Invisible Sunblock" is a hands-on activity exploring how nano-scale particles are used in mineral sunblocks to increase their transparency. Students compare nano and non-nano sunblocks to a visual representation of the effect of particle size on visibility.**

10. Build a Giant Carbon Nanotube *(emphasis on energy)*

This multi-person floor activity has students work together to build a giant carbon nanotube. Students will build off of a permanent base and assemble brightly colored foam atoms and bonds to make a carbon nanotube that stands up to 5 feet tall. The activity includes a floor mat and two colorful banners that, providing instructions, as well as explaining how, thanks to nanotechnology, scientists are building new structures out of atoms.

11. Nano in Nature—Gecko, Monarch Butterfly and Book

(emphasis on nature)

Place gecko in small clear contained labeled “Eye Crested Gecko” for students to observe gecko’s feet and their ability to walk on walls and even on glass. Also place the Monarch Butterfly encased in glass and the nano picture book at the same station table along with the appropriate signs.

CONCLUDING DISCUSSION

Go over the answers to the balloon station activity. Then facilitate a discussion by asking what crazy (yet practical) ideas students have for the use of nanotechnology in the future. Lead the discussion with a strong emphasis on how students have been playing the role of nanoscientist while interacting with the station activities. Explain that all kinds of scientist will soon have to learn and work with nanotechnology—if they don’t already. Examples: Doctors and Zoologists use gold nanoshells to cure cancers in humans and other animals, Engineers use carbon nanotubes to transfer energy, and Electricians use magic sand to insulate wires underground. Encourage all to think more about the world around them on the nanoscale!

OPTIONAL EXTENSIONS

1. Additional tabletop exhibits on nanotechnology can be brought into the classroom to allow the station activities portion of the class last longer.
    - **Funky Ferrofluid**
    - **Nano in a House (wooden block brainteaser)**
    - **Making Patterns / Self-assembly**

2. A video on Nanomedicine, found on the laptops, can be played at the end of class for a focus/take-home message on nano medicine (better for older kids).
3. Making Liquid Crystal sheets as a take home activity. Visit links:
http://www.nisenet.org/catalog/programs/exploring_materials_-_liquid_crystals_nanodays_08_09_10

Link to making Liquid Crystals (3 Chemicals Needed) -
http://mrsec.wisc.edu/Edetc/nanolab/LC_prep/index.html

TEACHER RESOURCES

www.Nisenet.org

The Nano Informal Science Education Netwrok (NISEnet).

BACKGROUND INFORMATION

Divide:

Nano **is the scientific term meaning one-billionth (1/1,000,000,000). It comes from a Greek word meaning "dwarf."**

A *nanometer* **is one one-billionth of a meter. One inch equals 25.4 million nanometers. A sheet of paper is about 100,000 nanometers thick. A human hair measures roughly 50,000 to 100,000 nanometers across. Your fingernails grow one nanometer every second!**

(Other units can also be divided by one billion. A single blink of an eye is about one-billionth of a year. An eye blink is to a year what a nanometer is to a yardstick.)

Nanoscale **refers to measurements of 1 – 100 nanometers. A virus is about 70 nm long. A cell membrane is about 9 nm thick. 10 hydrogen atoms are about 1 nm.**

At the nanoscale, **many common materials exhibit unusual properties, such as remarkably lower resistance to electricity, or faster chemical reactions.**

Nanotechnology **is the manipulation of material at the nanoscale to take advantage of these properties. This often means working with individual molecules.**

Nanoscience, nanoengineering **and other such terms refer to those activities applied to the nanoscale. "Nano," by itself, is often used as short-hand to refer to any or all of these activities.**

PowerPoint Script

Slide #'s

1. Today we are all going to be Nano Scientsits – scientists who work on the nanoscale and create nanotechnology. Can anyone tell me anything they know about Nano science, Nanotechnology or just the word "nano?"
2. In order to be a Nano Scientists, the first thing we need to understand is how small is something at the nanoscale.
3. To understand this, we need to start at what we call the macro scale. Things found at the macro scale are large enough for us to see with the naked eye. Lets look at these pictures. The bike is about one meter long, the ladybug is one centimeter long and just one single grain of sand is a millimeter wide. *All these are still visible with your eyes.*
4. Now lets look at things on the micro scale. A micrometer is one-millionth smaller than a meter. Lets go back and think about the length of that adult bicycle; a red blood cell, like in this picture, is 6-8 micrometers big – that's around a million times smaller than the length of that bicycle. Things found at the microscale are too small to see with the naked eye. Although, we can use a microscope as a scientific tool to help us see at the micro scale. *Nanoscale objects are 1000 times smaller!*
5. *A nanometer is one billionth of a meter!* That means that something found at the nanoscale is a billions times smaller that the length of that bicycle. Things found on the nanoscale are way way way too small to see! Instead of using tools like a microscope to work with objects that are small, Nano Scientists have to use tools that can feel things at the nanoscale instead of tools that help them see. A virus, that can make us sick, is 3-50 nanometers big, DNA is 2.5 nano meters big and an atom is more or less around 1 nano meter in measure.
6. Now that we know a nanometer is **EXTREMELY SMALL**, we can explore how materials behave differently at the nanoscale and how we can use this behavior to make *new* technologies.
7. We can find things on the nanoscale all around us in nature. We can see a few examples in these pictures *(discuss pictures)*.
8. The word "nano" has become very popular in naming things that are viewed as small. This car is called "nano tata." Is this car really on the nanoscale? No, it is definitely on the macro scale but it is called "nano" because it is smaller than a regular car—the same goes for this ipod nano. Other products like this shirt and plastic baby food container have nano particles embedded into them. Nano particles that reflect stains are inside this shirt and nanoscale silver particles are inside the baby food containers to kill bacteria.
9. To understand how things on the nanoscale do behave differently then when found on the macro and micro scales, we are going to look at two examples—gold and silver. We can obviously see that when at the macro scale gold has the appearance of being the color gold and silver appears to be silver.

10. If gold and silver are broken down to the nanoscale and suspended in liquid, gold appears red and silver becomes green. Can anyone guess where we can find examples of this behavior in materials people have created?

11. In stained glass windows! Gold and silver can be found in colored glass. Red stained glass windows have gold on the nanoscale inside them to make them red. Green glass has silver on the nanoscale inside to make them green. This may be the earliest use of nanotechnology in human society! Although, I'm sure they didn't call it nanotechnology at the time (ha,ha).
12. So why do we care about nanotechnology? Well Nano Scientists believe that we can utilize this new technology to make and move clean, environmentally safe energies, to kill bacteria that make us sick, and even find cures to deceases like cancer.
13. Lets look at our two examples again—gold and silver. Silver on the nanoscale can be embedded into things like athletic apparel, socks, refrigerators, storage containers and washing machines to kill bacteria. Gold on the nanoscale is already been tested to help cure cancer. Scientists have given rats gold on the nanoscale to drink. The gold particles then move into the cancer cells. Then scientists put the rats under a heat source. The nano gold particles then get hot, kill the cancer cells, and eventually exit the body in urine. Doctors have already started testing this on humans! Just think—what if you could be cured from cancer by drinking a glass of gold?
14. Nanotechnology is also being used to make clean energy. I'm sure you have all seen solar panels before, right? Solar panels are a great source for making clean energy but they are still expensive to make and they don't put out enough energy as we would often like. Nanoscientists are working to create nano-sized solar cells that can be embedded inside materials like paint, ink, plastic and even windows to harvest energy. Just imagine if the paint and windows on your house could make electricity! Products like this bag are already on the market. Using nanotechnology, this bag can harvest energy from the sun and charge people's ipods and cell phones while they walk around town!
15. Lest think about how we make energy and electricity today. This power plant is really harsh on the environment and produces a lot of bad waste. We have tried to get away from this kind of energy production and have created solar panels. Just imagine if we are able to make paint and windows create electricity – all the buildings in cities like Portland could become their own power plants!
16. Nanoscientists are also working on ways to better transport energy. Here is a picture of something called a carbon nanotube. Carbon nanotubes are only 1-2 nano meters long and are made of carbon atoms just like diamonds, graphite and coal. When carbon atoms are rearranged different materials are formed. Coal and graphite are soft while diamonds are extremely hard. Carbon nanotubes are even stronger than a diamond and are extremely lightweight! Nanoscientists are working to make a new kind of power lines using carbon nanotubes. Here are examples of power lines we use today *(hold up the two examples of power lines).* They are very heavy and are full of metals like copper that conduct electricity. If Nanoscientsists are able to transport energy with carbon nanotubes, we could move electricity from here to Japan in seconds! Today's power lines loose 10% of the energy they carry in the process of moving it. Using carbon nanotubes wouldn't waste hardly any at all! People have came up with other crazy ideas for using carbon nanotubes—like using them to make an elevator cable that could travel from earth to the moon!
17. Everything I have talked about so far has highlighted the positive uses of nanotechnology. There are potential hazards and risks involved. Like this man that drank and ingested too many nano-scale silver particles—his skin permanently turned BLUE! That can't be

healthy! Nano-scale zinc particles are often in sunscreen. Sunscreen that rubs in clear often has nano-scale zinc inside. Zinc is used to block and prevent UV rays from the sun from entering our skin. Since zinc on the nano-scale is too small to see, it allows sunscreen to rub in clear. Old school sunscreen (like on my nose!) often seen on lifeguard's noses contains zinc on the macro scale and is why it appears white. Nanotechnology is also being used to genetically modify crops. This is very controversial and we still don't know if there are negative consequences from eating such foods.

18. OMSI wants all of you to understand that no matter what kind of science people study, they will soon have to know and use nanotechnology. Whether somebody is a chemists, electric engineer, doctor, or a car mechanic they will use nanotechnology.
19. Thank you for listening. Now we are going to watch a movie that we made at OMSI on nanotechnology and review some of the concepts we just talked about. After the movie, you all get to be Nanoscientists and explore several different activities I brought in and placed around the room.

Embedded Assessment Evaluation

Use the next two slides as a evaluation tool to asses how well the class understands the basic content. If a majority of the class answers the questions wrong, you may want to review main concepts at the end of the movie. See program evaluation report for more evaluation resources and opportunities.

To see if you all were listening and to test your knowledge here are a few questions I have. Raise your hand if…

20. Question #1: A red blood cell is at the nanoscale.
    Question #2: DNA is found at the nanoscale.

21. Question #1: things at the nanoscale can be found all around us.
    Question #2: nanotechnology can affect the way we move and produce energy

APPENDIX B. EMBEDDED ASSESSMENT TALLY SHEETS

Q1. A red blood cell is found at the nanoscale.

Answer		#
1A.	True	
1B.	False	

Q2. DNA is found at the nanoscale.

Answer		#
2A.	True	
2B.	False	

Q3. Things on the nanoscale can be found all around us.

Answer		#
3A.	True	
3B.	False	

Q4. Nanotechnology can affect the way we move and produce energy.

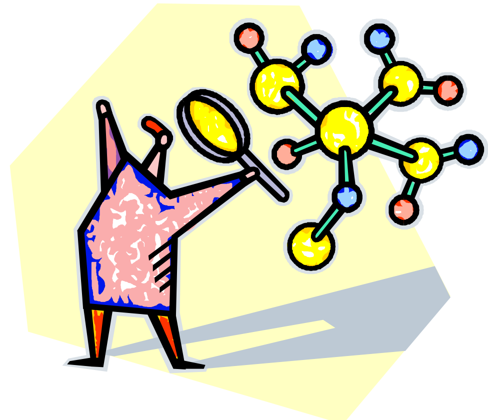
Answer		#
4A.	True	
4B.	False	

Date		
Grades		
Class time (circle)	9:30 am	10:40am
Total Participants		
Data Collector		
Educator		

If you were a nano scientist, what would you invent (considering what you know about nanotechnology and nano science?)

Subj	**Made Prediction** (check if occurred)	**Invention**
1		
2		
3		
4		
5		
6		
7		
8		

[9,10,11…]



APPENDIX C. POST-SURVEY

OMSI Nanotechnology Class

We hope you enjoyed the class!
Please respond to the following questions:

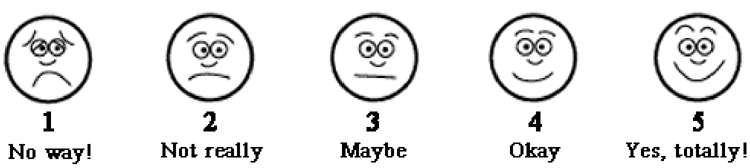
1. What are <u>three</u> ways in which nanotechnology helps us produce energy?

a.
b.
c

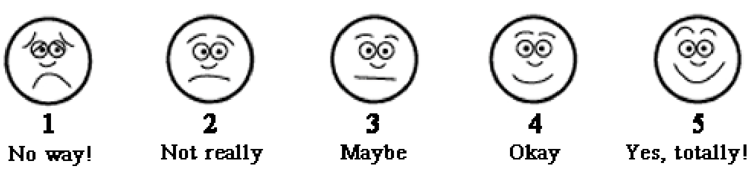
2. If you were a nanoscientist in real life, which NEW things would you invent?

Invention
Example: I would make shoes that could walk on walls or windows.

3. Do you want to learn more about nanotechnology?
circle your answer



4. Did you like being a nanoscientist today?
circle your answer



5. I am a… Boy Girl
(circle one)