Nanotechnology Outreach at Mall of America: Fostering STEAM Interest

Robert Giasolli[1*], David Tao[2], Sue Neuen[3].

[1]*Chief Technical Officer, Cagent Vascular Incorporated, Wayne, PA 19087, USA*

[2] *Natural Sciences Division, Pasadena City College, Pasadena, CA 91106, USA*

[3]*Science Curriculum Consultant, Educate for Tomorrow, Honolulu, HI 96824, USA*

**rgiasolli@cagentvascular.com*

Abstract: This paper describes a simple outreach approach to engage and educate learners about the scale of familiar items, all smaller than the width of human hair. In less than 10 minutes, participants were guided through a game-like hands-on 'nanotechnology' activity. The term 'nanotechnology' and its association with scaled objects was utilized to spark participant curiosity and enthusiasm in STEAM (science, technology, engineering, arts, and math). To assess effectiveness, a pre and post-Likert scale self-assessment was given to 91 participants. Although the data is limited in size, control, and environmental factors, the results showed a positive trend in participant enjoyment and self-confidence in STEAM subjects after engagement in this simple outreach approach.

Keywords: STEAM, STEM, nanotechnology, education

Introduction

In the STEAM fields, there is a need for workforce growth, inclusive of a broad demographic, without limitations on women and minority populations [1-3]. In line with the need to increase the workforce is a need for creative and effective approaches to engage students of all demographics in STEAM subjects. Incorporating nanotechnology into hands-on engagement approaches offers opportunities to add a "spark" to learning something new in the fascinating world of the small. Students can begin to see the interconnectedness of the STEAM subjects due to nanotechnology's far-reaching applications, spanning medicine, electronics, energy, and materials science [4, 5]. By introducing students to nanotechnology, they gain a window into the limitless possibilities of STEAM and its practical applications in their lives.

Several educational institutions and teachers have embraced nanotechnology to enrich STEAM education [6-13]. Participants were engaged in a simple nanotechnology hands-on activity during this exploratory case study. The authors observed and collected data showing a positive average increase in STEAM interest of 10% in the general public (ages 9-18) wanting to learn more about the world of the small.

Methods

To celebrate its 30th Birthday, The Mall of America partnered with the Advanced Technological Education Community and the National Science Foundation for the purpose of making STEAM subjects accessible and exciting for young people outside the traditional classroom setting. The Micro Nano Technology Education Center (MNT-EC), funded by the National Science Foundation under DUE ATE #2000281, collaborated with Educate for Tomorrow (E for T) at the STEAM event to offer engaging activities aimed at building awareness of nanotechnology, its impact and career pathway possibilities. In this exploratory case study, the authors considered how a shopping center, transformed into an educational hub, could be a venue for engaging young minds by sharing the fascinating world of nanotechnology.

The activity from which the authors gathered data was taken from "Exploring the World of the Small," an E for T teaching module appropriate for students above 6th grade and applicable to most learning environments [14].

To first guide their understanding of scale and how small a nanometer actually is, the instructors presented the students with a single dark, human hair taped onto white cardstock. The students were asked to imagine slicing the width of that hair 100,000 times to represent a nanometer. Next, students were asked to find one millimeter on a metric ruler. Using these simple, tangible objects, the instructors explained that one millimeter is equivalent to one thousand micrometers; one micrometer is equivalent to one thousand nanometers.

In the "Exploring the World of the Small" activity, students were challenged to arrange scrambled images displayed on ten 8 x 8-inch cards from largest to smallest in size. All objects were based on the nanoscale ranging from 0.15 to 100,000 nanometers, the largest being a human hair, which they had just observed. The objects on the cards included images of human hair, UV and IR wavelengths, blood cells, bacteria, dust particles, DNA helix, computer wire chips, a carbon atom, and even the distance between two carbon atoms.

Figure 1: Arranging images from "The World of the Small" from largest to smallest.

Many of the groups that engaged in the activity struggled with understanding the scale of the images. To reduce the difficulty for some of the groups, the instructors would ask questions about image pairs that were out of order. The most common image that was misplaced was the width of the computer chip wire, where the common placement was second or third in the ten-card order of scale. The instructors encouraged the groups to openly discuss their thinking with each other and asked them to consider alternate pieces of information to guide them. For instance, when sizing the computer chip wire, the instructors might say, "Did you know that visible light is too large to see computer chip wires?" For larger objects, the instructors might say, "Which of these objects have you seen through a classroom microscope?" By the end of the exercise, the instructor would have asked enough questions to guide the group in arranging the images in the correct order.

To assess the outcomes of the materials and methods, the authors gathered ninety-one pre and post-assessments from middle school and high school students. The assessments gauged the effectiveness of the materials and the student's comfort level in learning new ideas in the nano-science world. The students were asked to evaluate their comfort level and interest in STEAM areas on a scale of 1-5 before and after engaging in the activity. On the scale given, one would represent being "not interested," while a five would represent being "highly interested." The participants were also asked which fields in STEAM interested them the most.

The survey included the following questions:

- How much do you enjoy discovering new things about your world?
- How much do you enjoy doing a math problem?
- How interested are you in learning about the world of small things?
- How much do you enjoy exploring new areas in STEAM?
- Pre assessment (PRE-) only- Does a career in a STEAM field interest you?
- Pre assessment only- Which field of STEAM interests you the most?
- Post assessment (POST-) only- Did you learn something new from the activities?
- Post assessment only- After today, do you plan to explore more about nanotechnology?

Results

From student responses, the pre-assessment number and percentage of the ninety-one participants who were interested in the various STEAM fields are as follows in decreasing order: Art 24.6% (29/91), Technology 22.9% (27/91), Engineering 22.0% (26/91), Science 21.2% (25/91), and Mathematics 9.3% (11/91).

Table 1. Tabulated data of 91 participants, the field of interest, the mean of responses (on a scale of 1-5), and percent change post engagement.

STEAM field that interests you the most	SCIENCE		TECHNOLOGY		ENGINEERING		ART		MATH		ALL PARTICIPANTS	
	MEAN	% CHANGE	MEAN	% CHANGE	MEAN	% CHANGE	MEAN	% CHANGE	MEAN	% CHANGE	MEAN	% CHANGE
PRE-How much do you enjoy discovering new things about your world?	4.5	4%	4.22	5%	4.35	-4%	4.28	3%	3.91	9%	4.22	3% p=0.124
POST-How much do you enjoy discovering new things about your world?	4.7		4.44		4.19		4.41		4.27		4.34	
PRE-How much do you enjoy doing a math problem?	3.0	7%	3.15	7%	3.23	6%	3.00	6%	4.45	-2%	3.19	5% p=0.022
POST-How much do you enjoy doing a math problem?	3.2		3.37		3.42		3.17		4.36		3.34	
PRE-How interested are you in learning about the world of small things?	4.2	0%	3.70	14%	3.81	8%	3.76	13%	3.82	10%	3.76	10% p=9.6E-07
POST-How interested are you in learning about the world of small things?	4.2		4.22		4.12		4.24		4.18		4.13	
PRE-How much do you enjoy exploring new areas in STEAM?	4.2	3%	4.15	7%	4.35	-2%	4.00	5%	3.55	15%	4.01	5% p=0.019
POST-How much do you enjoy exploring new areas in STEAM?	4.4		4.44		4.27		4.21		4.09		4.22	
Did you learn something new from the activity?	4.8		4.74		4.69		4.79		4.82		4.67	

The data in Table 1 indicates both a positive trend from the pre-activity to post-activity assessments and that the data is unlikely due to random chance. The most significant increase pertained to the question, "How interested are you in learning about the world of small things?" Here, there was a mean increase for all participants of 10% with a p-value of 9.6E-07 when applying a t-test function to the data. For the second and third questions related to solving math problems or exploring new areas in STEAM, all participants had a mean 5% increase with corresponding p-values of 0.022 and 0.019. All three of these data sets show low p-values, indicating that it is unlikely the change in the data set occurred due to random chance. Only the first question showed no statistical difference with a p-value of 0.124, although the mean score increased by 3% from the pre- to post-assessment. The positive mean improvements and the statistical differences shown from pre to post align with what the authors observed during the activity. One repeated comment was the group's surprise that light wavelengths were in the middle of the image set and that the width of the computer chip wire was below the width of light wavelengths. These types of statements were often followed by "How do they make things that small?" Of course, the instructors were more than happy to explain.

A set of small negative changes in the mean were collected for two of the questions in groups identified as most interested in Engineering and for one of the questions in the Math group. The two negative data sets in the Engineering group are from similar questions (i.e., "How much do you enjoy discovering new things about the world?" and "How interested are you in learning about the world of the small?"). Since the questions are similar, the authors could also anticipate the responses to be similar. What is unclear is what drove the respondents to reduce their interest in discovery. Separately, the negative data set from the Math group was related to their enjoyment of doing math problems. There is no sure explanation for why the Engineering and Math-minded students decreased some responses post-activity; the authors considered the possibility that the activity itself or the group they were paired with may have led some to lose interest or self-confidence when introduced to something totally new.

At the completion of the exercise, in addition to the post questions listed above, the students were asked two new questions. One, "Did you learn something new from the activity?" about three-fourths or 76% of the participants selected a "5," representing "Yes, I did!" Another 16% selected a rating of "4" also indicating a positive learning experience. And two, "After today do you plan to explore more about Nanotechnology?" Here, 32% of the students claimed that they most likely would explore more about nanotechnology, and 52% indicated that they might.

Conclusion

The authors recognize that the size of the study, lack of a control group, not collecting demographic information, and the challenges associated with the environment where the data was collected all limit the ability to draw meaningful conclusions from the results outlined in Table 1. Subjectively, since it was not collected rigorously, the authors observed no distinct demographic group, recalling a broad range of ethnicities and a nearly equal pairing of genders. Our method included open dialogue and group discussion, positive encouragement of the authors to aid understanding, and hints using familiar items, all with no limit on time or discussion. How any of these guided learning approaches might have influenced the increase or decrease in mean values is not clear, nor was it controlled for. Independent of these limitations, the authors were encouraged by the positive trends shown in most of the segmented groups and thought such activities entwined with advanced technologies should be considered to enhance interest in STEAM. In future research, the authors recommend exploring a broader set of activities with more structure to enable repeatability and greater confidence in the outcomes.

Despite the difficulty of unfamiliar nanoscale content, many participants said, "I enjoyed the Nanotechnology Scale Card game," and asked where they could get a copy. When asked how they would describe their learning experience, they simply said, "It was awesome" or "I didn't know there were things that small!"

Acknowledgements. This work was supported by the National Science Foundation (NSF) under the NSF ATE Award #2000281, Micro Nano Technology Education Center.

Disclosures. The authors declare no conflicts of interest.

References

[1] National Research Council. “Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics”. *National Academies Press* (2011).

[2] National Center for Science and Engineering Statistics. "Women, minorities, and persons with disabilities in science and engineering." (2019).

[3] Committee on STEM Education National Science and Technology Council. “Charting a Course for Success: America's Strategy for STEM Education”. U.S. Government Publishing Office (2018).

[4] Singh, Archana, Smita Dubey, and Harish K. Dubey. "Nanotechnology: The future engineering." Nanotechnology 6.2 (2019): 230-3.

[5] Bhushan, Bharat. "Introduction to nanotechnology." Springer handbook of nanotechnology (2017): 1-19.

[6] Sakhnini, Sohair, and Ron Blonder. "Nanotechnology applications as a context for teaching the essential concepts of NST." International Journal of Science Education 38.3 (2016): 521-538.

[7] Mandrikas, Achilleas, Emily Michailidi, and Dimitris Stavrou. "Teaching nanotechnology in primary education." Research in Science & Technological Education 38.4 (2020): 377-395.

[8] Ghattas, Nadira I., and Jeffrey S. Carver. "Integrating nanotechnology into school education: A review of the literature." Research in Science & Technological Education 30.3 (2012): 271-284.

[9] Lisotti, Annamaria, Valentina De Renzi, and Guido Goldoni. "The NANOLAB project: educational nanoscience at high school." MRS Online Proceedings Library (OPL) 1657 (2014): mrsf13-1657.

[10] Feather, Judith Light, and Miquel F. Aznar. Nanoscience education, workforce training, and K-12 resources. CRC Press (2018).

[11] Mallmann, Matthias. "Nanotechnology in school." http://www. scienceinschool.org (2008).

[12] Bhushan, Bharat. "Introduction to nanotechnology: History, status, and importance of nanoscience and nanotechnology education." Global perspectives of nanoscience and engineering education (2016): 1-31.

[13] Arabacioglu, Sertaç. "Can Nanotechnology Keep Us Dry in the Rain: An Inquiry-Based Activity to Help Students Improve Their Investigation Skills." International Journal of Technology in Education and Science 6.3 (2022): 410-426.

[14] Giasolli, Robert and Neuen, Sue. “Exploring the World of the Small.” https://drive.google.com/drive/folders/1QAddzahCpIeSztrsL-g0Dp8roqgmOtGB.