Thank you for your request to our REL Reference Desk regarding evidence-based information about for teaching nanoscience concepts. Ask A REL is a collaborative reference desk service provided by the ten regional educational laboratories (REL) that, by design, functions much in the same way as a technical reference library. It provides references, referrals, and brief responses in the form of citations on research based education questions.

The information below represents the most rigorous research available. Researchers consider the type of methodology and give priority to research reports that employ well described and thorough methods. The resources were also selected based on the date of the publication with a preference for research from the last ten years. Additional criteria for inclusion include the source and funder of the resource.

Question: *Are there research based practices for teaching nanoscience concepts?*

Search Process

Key words and search strings used in the search: *nanoscience* AND *instruction* OR *teach; nanoscience* AND *student learning*

Search databases and websites:

1. ERIC: http://www.eric.ed.gov/
2. JSTOR: http://www.jstor.org/action/showAdvancedSearch
3. Google Scholar: www.google.com/scholar
4. Institute of Education Sciences (IES) Resources: http://ies.ed.gov
5. What Works Clearinghouse: http://ies.ed.gov/ncee/wwc/

Results:

Based on the database searches described above, there were no results that reflected *rigorous research*, as defined by the Department of Education – Institute of Education Sciences. Below are some resources that represent current thinking in the area of teaching nanoscience.

Other Resources *(NOTE: Abstracts and executive summaries are copied directly from the reports when possible to ensure accuracy)***:**

Jones, G. M., Krebs, D. L., & Banks, A. J. (2011). We scream for nano ice cream. *Science Activities: Classroom Projects and Curriculum Ideas, 48*, 107-110.

Abstract/Summary: There is a wide range of new products emerging from nanotechnology, and "nano ice cream" is an easy one that you can use to teach topics from surface area to volume

applications. In this activity, students learn how ice cream can be made smoother and creamier tasting through nanoscience. By using liquid nitrogen to cool the cream mixture, students can sample nano ice cream and investigate how decreasing the size of the ice crystal affects the taste and texture of the ice cream.

Furlan, P. Y. (2009). Engaging students in early exploration of nanoscience topics using hands-on activities and scanning tunneling microscopy. *Journal of Chemical Education, 86,* 705-711. doi: 10.1021/ed086p705

Abstract/Summary: This manuscript reports on efforts to introduce beginning college students to the modern nanoscience field. These include: implementing selected experiments into sequencing core first-year and second-year chemistry laboratory courses; providing students with a first research experience; and engaging them in service learning and outreach programs where they act as activity presenters. The various projects, emphasizing hands-on learning, have affected a large number of science and engineering students and also thousands of students in grades K-12. The program provides students with experiences working with nano materials and using scanning tunneling microscopy. By participating in these projects, students have increased their awareness and knowledge of different areas of nanoscience and improved their attitudes toward chemistry.

Ng, W. (2009). Nanoscience and nanotechnology for the middle years. *Teaching Science, 55*, 16-24.

Abstract/Summary: Capturing students' interest in science at the junior levels is crucial to not only improving the uptake of science at senior levels but to promoting science literacy in all students in order to prepare them for a society that is very science and technologically driven. This paper presents nanotechnology as an emerging science that is both factual and imaginative to motivate science learning with middle years students. Its objective is to present a trial led module on nanoscience and associated technologies that is suitable for middle years students. The paper will also present the views of 139 Year 6 students on learning about nanotechnology, and in particular those aspects of the topic that left an impression on them at the end of a nanotechnology day.

Gardner, G. E., & Jones, G. M. (2009). Bacteria buster: Testing antibiotic properties of silver nanoparticles. *American Biology Teacher, 71*, 231-234. doi: 10.1662/005.071.0409

Abstract/Summary: Nanoscale science and engineering are disciplines that examine the unique behaviors and properties of materials that emerge at the size range of 1 to 100 nanometers (a billionth of a meter). Nano biotechnology is a sub-discipline of nanoscience that has arisen more recently. Nano biotechnology is already impacting the fields of healthcare and biomedical engineering, and promises to be critical in advances in other related fields. Even though it spans multiple science disciplines, the abstract nature of nanoscience in general can challenge instructors to find practical ways to teach about this concept in the classroom. This article describes a quick and simple laboratory investigation for high school or undergraduate students utilizing nanotechnology in a biological context. It addresses biology content standards in both personal and community health as well as the future challenges of science and technology to society. This activity requires a limited amount of materials and yields visible results. The investigation has two basic objectives: (1) make students aware of nanotechnology and its potential biological interface; and (2) have students examine and explore the accuracy of claims made about emerging technologies.

Planinsic, G., & Kovac, J. (2008). Nano goes to school: A teaching model of the atomic force microscope. *Physics Education*, *43*, 37-45.

Abstract/Summary: The paper describes a teaching model of the atomic force microscope (AFM), which proved to be successful in the role of an introduction to nanoscience in high school. The model can demonstrate the two modes of operation of the AFM (contact mode and oscillating mode) as well as some basic principles that limit the resolution of the method. It can be used either as a demonstration experiment, simple laboratory experiment or home experiment that students can make by themselves.

Taylor, A., Jones, G., & Pearl, T. P. (2008). Bumpy, sticky, and shaky: Nanoscale science and the curriculum. *Science Scope*, *31*(7), 28-35.

Abstract/Summary: Nanoscience, or the study of the world at the size of a billionth of a meter, has the potential to help students see how all of the sciences are related. Behavior of materials at the nanoscale differs from materials at the macroscale. This article introduces three nanoscale properties and how they relate to various science domains. Three activities following an adapted learning cycle model are suggested for student exploration of three properties of the nanoscale: bumpy, sticky, and shaky.

Meenakshi, V., Babayan, Y., & Odom, T. W. (2007). Benchtop nanoscale patterning using soft lithography. *Journal of Chemical Education*, *84*, 1795-1798. doi: 10.1021/ed084p1795

Abstract/Summary: This paper outlines several bench top nanoscale patterning experiments that can be incorporated into undergraduate laboratories or advanced high school chemistry curricula. The experiments, supplemented by an online video lab manual, are based on soft lithographic techniques such as replica molding, micro-molding in capillaries, and micro-contact printing and etching. These simple labs were designed using readily available and inexpensive materials such as compact discs, glass microscope slides, and curable polymers. In these labs, students could generate polymeric and metallic structures with feature sizes as small as 110 nm. The feasibility of these experiments was tested in a two-quarter, research-based course on nanoscienceand technology for first- and second-year students at Northwestern University.

Tang, K. (2013). Instantiation of multimodal semiotic systems in science classroom discourse. *Language Sciences, 37*, 22-35. doi: 10.1016/j.langsci.2012.08.003

Abstract/Summary: Science classroom discourse is inherently multimodal in that scientific meanings are made through an integration of multiple semiotic systems (e.g., language, diagrams, equations). Although some studies have described this multimodal nature, few have examined and explained the relationship between the integration of multiple semiotic systems and the instantiation of science content knowledge. Based on the notion of instantiation from systemic functional theory, this paper proposes a theoretical framework to account for how specific scientific meanings are instantiated in local acts of multimodal meaning-making. Using data from a series of nanoscience lessons, four exemplars of middle school students' acts of meaning-making were analyzed to illustrate the theoretical framework. Specifically, each exemplar illustrates how a distinctive ideational meaning was instantiated through the co-deployment of verbal, visual, and gestural modes used in the students' explanations of a physical phenomenon. This will be useful in furthering our understanding of the structure of science classroom discourse and its instantiation patterns in human semiosis.

Wise, A., Schank, P., Stanford, T., & Horsma, G. (2009). The science behind nanosun-screens: Learning about nanoparticulate ingredients used to block the sun's ultraviolet rays. *Science Teacher, 76*(6), 46-51.

Abstract/Summary: In this article, the authors provide a brief overview of the emerging field of nanoscience and why it is an important area of education. They next explain the science behind the new nanoparticulate sunscreens, describe the different elements of the unit, and reflect on some of the opportunities and challenges of teaching nanoscience at the high school level.

Referrals

Organizations:

- National Science Teachers Association: http://www.nsta.org/
- National Association for Research in Science Teaching: https://www.narst.org/
- National Academy of Sciences, National Science Education Standards: http://www.nap.edu/openbook.php?record_id=4962
- Next Generation Science Standards: http://www.nextgenscience.org/

- **National Institute of Child Health & Human Development (http://www.nichd.nih.gov/Pages/index.aspx)**
    - **http://www.nichd.nih.gov/pages/search.aspx?q=professional%20development**
- **What Works Clearinghouse (http://ies.ed.gov/ncee/wwc/)**

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