National Center for Learning and Teaching (NCLT): Building National Capacity in Nanoscale Science and Engineering Education[i]

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The National Center for Learning and Teaching (NCLT) is the first national center for nanoscale science and engineering education (NSEE) in the United States. Established by the National Nanotechnology Initiative (NNI) in 2004, the Center has a two-fold mandate: (1) build national capacity in NSEE; and (2) use the exciting, interdisciplinary field of nanoscale science and engineering (NSE) to improve the overall quality of national STEM (Science, Technology, Engineering, and Mathematics) education.

The NNI estimates that nearly seven hundred thousand nano-literate workers will be needed in the US over the next 10 to 15 years.[ii] Moreover, a recent report published by the National Academies confirms that the country must train more US-born researchers and technicians in all areas of science and engineering if it is to remain globally competitive.[iii] This "gathering storm" demands that all US education institutions take up the important challenge of building a strong national scientific and technical workforce, with special attention to providing high quality educational opportunities to growing US minority populations.

For decades, US students have studied science and engineering concepts as they pertain to the macroscale, the microscale, and even the atomic scale. Long missing from our curricula, however, has been the study of the nanoscale - the largely unexplored region from roughly few nanometers to couple hundred nanometers. New industrial and social applications are making NSE an increasingly vital area of study for US students. NCLT works to integrate basic NSE concepts into pre-college and college level classrooms. The key elements of our approach are:

- ***An NSEE Community*** – The Center unites two distinct communities that have long operated independently of one another – the scientific and engineering community and the education community. These groups are now evolving into an integrated NSEE community with shared language and infrastructure for improving NSE and STEM education.
- ***Leadership Development*** – To maximize its impact, the Center is developing a diverse cadre of NSEE leaders - from nano-literate science teachers to education-saavy nanoscentists - who will continue to educate and inspire their peers in years to come.
- ***Curricula*** – The Center inserts NSE concepts into existing courses and curricula as well as developing new NSE courses as electives. When NSE concepts are linked to the general concepts that students are already learning, integration becomes more rapid, and NSE becomes more relevant to everyday life.

Integrated Program

The Center's integrated program consists of the following component areas, each carried out by an interdisciplinary working group:

- Nano Concept Research – New educational content is developed for grades 7-16, including two-week mini-units and semester-long courses. Content uses the successful "inquiry-and-design" model, which lets students become scientists and engineers in the classroom.
- Learning Technology – New learning tools are being researched and developed to enable students to visualize and interact with the unseen nanoworld.
- Professional Development – Seminars, workshops and outreach events are held to prepare and motivate secondary science teachers to use new NSE content. Graduate and undergraduate degree programs are being developed to train future leaders in NSEE.
- Learning Research – Studies are conducted to discover what students already know about nanoscale science and technology and understand how they learn new NSE concepts. An inventory of key NSE concepts and learning goals is also under development.

Achievement of the Center's mandate requires that these components be advanced in parallel via the interdisciplinary collaboration of NSE researchers, educators, and cognitive scientists.

Research Focus

The Center's technical research focus is Nanostructured Materials and Their Properties. Materials, by virtue of their tangible "concrete" nature and diverse applications to everyday life, help make NSE more accessible and relevant to new learners. Three driving questions and six corresponding thematic areas guide new content development and related activities:

Driving Questions	Thematic Areas
1. What makes nanomaterials unique?	1. Manipulation of Light in the Nanoworld 2. Physical Properties of Nanomaterials
2. How can nanomaterials be used?	3. Information Storage and Processing 4. Nanomaterials for Energy, Environment, and Pharmaceuticals
3. How can nanomaterials be made and characterized?	5. Tools for Probing the Nanoworld 6. Design and Fabrication of Nanomaterials

The following "big" nano ideas are introduced: 1) the scale of matter determines its nature and properties; (2) dominant forces in the nanoworld are different from those in the macro world; ((3) materials and phenomena at the nanoscale may or may not behave the same way as at the macroscale; (4) new concepts can be derived from interdisciplinarity and complexity (5) geometry can have an impact on materials design and application; and (6) the unique properties of nanomaterials can be used to advance technology and improve quality of life.

At the same time, the study of objects, dominant forces and phenomena at the nanoscale presents unique challenges and exciting opportunities for educators and students alike. Therefore, the Center performs cognitive / education research to identify best practices and improve the national knowledge base in the emerging field of NSEE. Specific research topics include interdisciplinary learning, progressions in learning, effectiveness of learning technologies, etc.

Integrating NSE Concepts into US Classrooms

Our biggest challenge has been to introduce NSE content into classrooms where teachers lack time, training, and resources. Convenient yet effective professional development must be provided. Learning activities must be safe, inexpensive, in alignment with national science

standards, and performable within 45 minutes. Given these constraints, how can NSE activities be introduced without compromising the scientific principles behind them?

The integration is accomplished by developing educational content that links key NSE concepts to science concepts that students are already learning. For example, chemistry students often study the concept of surface–to-volume ratio in relation to catalytic converters and fuel cells. In this context, they learn that a larger surface area will increase the speed of a chemical reaction. NCLT content inserted into a Chemistry course would demonstrate the importance of this concept for understanding nanoscale properties and phenomena. These NSE concepts can be inserted into existing science courses. Science teachers help to ensure the feasibility and effectiveness of all new content and methodologies. Learning scientists ensure that NCLT content is age-appropriate, course- appropriate, and suited to student's prior knowledge. The Center finds alignment with national science standards wherever possible and informs the NSEE community when standards are lacking.

Field of Impact

The Center will meet the immediate and long-term needs of US industry by training new NSE workers. It will build US capacity to train more nano-literate workers and citizens in decades to come. Finally, it will strengthen the US workforce by stimulating interest in science and engineering among US students and enhancing national STEM education.

Collaborations

The ten partner institutions that comprise the NCLT cooperate with a larger community of nanotechnology research facilities, education research centers, school districts, science teachers, and students to integrate NSE concepts into US classrooms. The Center also interacts with international research centers and networks to incorporate best practices from around the world.

Notable results

Nano concepts and full-length courses, and a new set of NSE-related learning goals are currently under development for US students. New teaching practices and learning tools are being developed and evaluated to help students visualize and simulate nanoscale phenomena.

More than one dozen professional development and student outreach events have been held since the Center opened, including a two-week Summer Science Camp organized with the University of Michigan and the Ypsilanti Public School District, a teacher training event at Fisk University and a "Super Saturday" enrichment program at Purdue for academically, creatively and artistically gifted students from pre-K through eighth grades.

The Center webcasts monthly lectures on NSE research and NSE education topics. The NCLT cyberinfrastructure now includes a Nanoeducation Resource Portal, which will help the Center enhance its networking capabilities and reach thousands more students and teachers nationwide.

References

[i] For further information about this project link to **http://www.nclt.us** or email **nclt@northwestern.edu**
[ii] National Nanotechnology Initiative website http://www.nano.gov/html/edu/home_edu.html
[iii] Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future, Committee on Science, Engineering, and Public Policy. National Academies Press (2006)