

Tall, Short, Thick, and Thin: They're All Models
A Lesson on Models in the Context of Nanoscale Science and Engineering (PD Version)

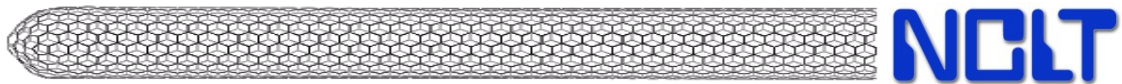
Shanna R. Daly

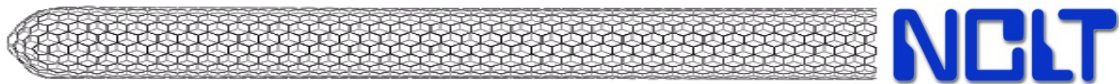
June 1, 2009

Please cite as:

Daly, S. (2009). Tall, short, thick, and thin: They're all models (PD version). A lesson on models in the context of nanoscale science and engineering. Retrieved on [insert date] from <http://www.physics.purdue.edu/psas/>

This work was funded by NSF Award #ESI-0426328: NCLT: A Center to Develop Nanoscale Science and Engineering Educators with Leadership Capabilities





Tall, Short, Thick, and Thin: They're all Models

A Lesson on Models in the Context of Nanoscale Science and Engineering
(PD Version)

Author: Shanna Daly
Draft Date: June 1, 2009

Content Area: Science, Engineering
Level: Teachers in Professional Development Programs

LESSON OVERVIEW

Estimated Time of Lesson: 4- 5 hours

Lesson Description

Topic: This lesson focuses on the role of models and modeling science, engineering, and education, contextualized in important concepts for nanoscale science and engineering (NSE). This lesson is specifically written for teacher professional development programs. Portions of this lesson are utilized in a lesson by the same name written for students (Daly, 2009).

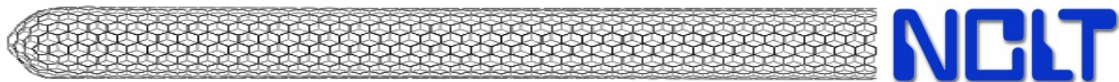
Importance of the topic: Models are crucial in science and engineering as tools to communicate, investigate, develop, and express ideas. This role is even more important when working with objects and phenomena at the nanoscale as they cannot be “seen;” they can only be viewed with technology or physical representations. Models also play a crucial role in NSE education (NSEE). They make the invisible world visible, however, models can and should be used in instruction beyond just a tool for visualization and explanation. The development of best practices with models is an important aspect of successful NSE instruction.

Description of what the students will do to investigate the topic: Teachers will investigate models of multiple types used for multiple purposes, answer questions about the models and the phenomena they represent, and evaluate their significance. Teachers will also discuss misconceptions students have when using models and the practices that can help limit these misconceptions. They will also incorporate models into a lesson on an NSE topic based on their ideas of best practices with models.

Learning Goals

Teachers will be able to:

- Describe a variety of different types of models.
- Critique the accuracy of models and explain how models are still useful even with their inaccuracies.
- Discuss the limitations of models and how these limitations can be taken into account when using models to learn.
- Make a case that multiple models often create a more complete understanding of a phenomena since no one model is completely accurate.



- Explain how models are tools used and designed in science and engineering to help conceptualize ideas, answer questions, hypothesize how something works, communicate to others, investigate properties, etc. (models as part of NOS and NOE; design of models).
- Describe multiple ways models can be used in instruction, with emphasis that models can help us answer questions and are useful beyond a “show-and-tell” tool.
- Synthesize an argument for why models are especially important to the education of nanoscale science, engineering, and technology.
- Design instruction that utilizes models in a way that represents their idea of good educational practices with models.

Big Ideas in Nano

Models and Modeling: Models help us understand, visualize, predict, hypothesize and interpret data about natural and manufactured nanoscale objects and phenomena, which by their very nature are too small to see (Stevens et al., 2009).

- This lesson emphasizes the broad range of model types in existence, and how these models are used to understand, visualize, predict, hypothesize, and interpret.

Standards

Indiana State Standards (Indiana’s Academic Standards and Resources, 2009)

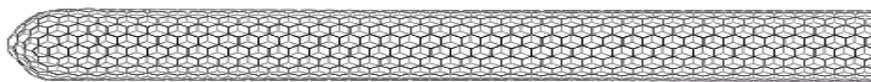
- 7.1.7
- 7.7.2
- 8.1.6
- 8.1.8

Benchmarks (AAAS, 1993)

- 6-8: 11B

NSES (NRC, 1996)

- STS 5-8



LESSON PREPARATION

Background for Teachers

This is an interesting area because models are used in science and engineering all of the time. Models come in many different types and are used for many different purposes; recognizing the role of models as tools and representations, can bring about the realization that models are not the real phenomena, but can help us understand, discover, explore, and predict something about concepts and phenomena.

Models typology included in supplemental materials.

Student Prior Knowledge Expectations

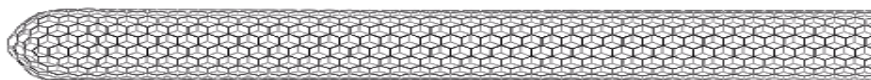
Potential Student Alternative Ideas

Often students conceive of models as accurate representations of an object or phenomena. They also often do not recognize that models are useful beyond a “show-and-tell” format. It is expected that they will come in with this knowledge that is not necessarily incorrect, but is certainly limited in the ways that models are used by scientists and engineers, and the ways they can interact and construct ideas for themselves with models.

Potential Student Difficulties

Materials

Item	Description/ Explanation
Concrete Material Static Model	A model or description of each type of model is used in the opening activity. Descriptions of the types of models follow and example models are pictured in the appendix. A concrete model is a three-dimensional object. Visual pictorial models can be drawings, figures or computer animations or simulations. A gestural bodily model is something that you use your hands or body to "act out." Static means the model is not manipulative. Dynamic deterministic means that the model is moveable but it always moves in the same way. You do not input some kind of action or information and get a response dependent on that action or information. A dynamic stochastic model is a model that responds based on the information that has been inputted. For example, if temperature information were inputted into a computer animation, the animation would change in response to the inputted temperature.
Concrete Material Dynamic Deterministic Model	
Concrete Material Dynamic Stochastic Model	
Visual Pictorial Static Model	
Visual Pictorial Dynamic Deterministic Model	
Visual Pictorial Dynamic Stochastic Model	
Gestural Bodily Dynamic Deterministic Model	
Beads	These supplies are craft supplies to be used the station where they make their own model to represent DNA origami.
Ribbon	
Construction paper	
Glue	



Scissors	
Tape	
Thin bendable wire	
String	
3 models of a molecule	
3 models of quantum dots/ DNA origami/ some nanoscale phenomena	These can be any that you want, but the idea is to include different types, i.e. some that are on the computer, some that are three-dimensional, some that are photos, some that are pictures, some that are equations, some are hand-made, etc. Pictures of the models we use are included in the following section.
3 models of DNA	
3 models of the atom over time (i.e. plumb pudding model, solar system model, etc.)	

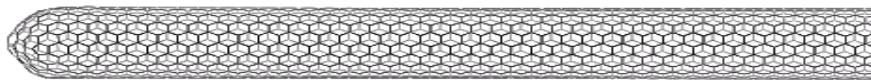
Pre-Class Preparation

Getting the Materials Ready

Prepare the models and the stations.

<i>Where in Lesson</i>	<i>Example Models</i>
Opening: Model Types	
Station 1: Need for Multiple Models	
Station 2: Critiquing Models	
Station 3: Models as Tools for Investigation	
Station 4: Models as Part of NOS and NOE	
Station 5: Designing Models	

Note: Station 5 takes a longer than the rest of the stations and can get clogged. It is beneficial to set up two of this station.



DOING THE LESSON

Opening

- Teachers will be presented with five to ten different objects, pictures, representations, etc. (using Boulter & Buckley's (2000) typology as a guide to diversity model types) that could be considered models (examples are pictured above). They either walk by the models and cast a vote if they consider the object to be a model or each model is held up one at a time and teachers write down "yes" or "no" to respond to the question, "Is this a model?"

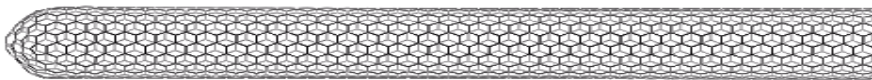
Concept Development

Activity 1- Reflecting on Experiences with Models (~30 minutes – 1 hour)

- Teachers complete the written worksheet titled "Thinking about Models and Their Use" as homework or in class.
- Upon completion of the written questions, students are asked to share their ideas in a small group (20 minutes).
 - Explain the example you wrote about a lesson you teach (or for students: have been taught) that utilizes a model or models.
- Groups report out, followed by a short discussion. Discussion questions should include those from the worksheet "Thinking about Models and Their Use," and can also include the following:
 - How were the ways you use models similar or different to other members of your group?
 - Are there ways you want to use models after hearing how others talked about how they use models?
 - Why do you think models are important for NSEE?

Activity 2– Stations (~1 hour)

- Teachers investigate a variety of models and the different roles they play in science and engineering, with an emphasis on how they are used when objects or phenomena cannot be seen, which is the case for nanoscale objects and phenomena.
 1. Need for Multiple Models: This station will include multiple models of the same phenomena, in this case, models of a molecule (balloon, ball and stick, computer models, etc.).
 2. Critiquing Models: This station will include some text about a concept that students should be fairly familiar with and a few models that represent that concept, in this case, models of DNA.
 3. Models as Tools for Investigation: This station will have a model or models that allow students to investigate a phenomenon, in this case phase changes (computer simulations) from Molecular Workbench (Concord Consortium website) and Brownian motion simulations from Molecular Workbench.
 4. Models as Part of NOS and NOE: This station will have models of a concept as the concept changed over time, in this case models of the atom over time and text describing the evolution of the models.



5. Designing Models: This station will include a description of a phenomenon that students should be moderately familiar with and include text that describes the phenomena, in this case, DNA Origami (using the actual article or a summary created from Rothmund, 2006). (Note: This station takes a little longer than the rest and can get clogged. It is beneficial to set up two of this station.)
- After teachers have completed the stations, the group talks through each station's questions as well as the following:
 1. For each station, what do you think the take-home message is? Why?
 2. Show votes on which were considered models from the opening activity.
 - a. Are you surprised by the votes? Would you change your votes now?
 3. How do think scientists and engineers are able to create models of nanoscale phenomena since they can't "seen," even with a light microscope?
 4. How useful do you think models are of things that have never been actually seen?
 5. Did any of the stations impact your ideas about how models can be used in teaching and learning?

Activity 3 – Literature Jigsaw

- Teachers are divided into groups of three and each member of the group reads a different article. Suggested articles include:

Coll, R. K., France, B., & Taylor, I. (2005). The role of models/and analogies in science education: Implications from research. *International Journal of Science Education*, 27(2), 183-198.

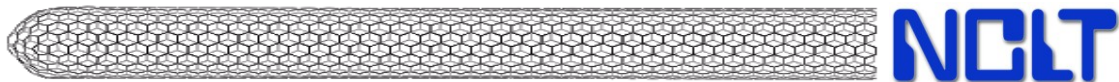
Harrison, A. G., & Treagust, D. F. (2000). Learning about atoms, molecules, and chemical bonds: A case study of multiple-model use in grade 11 chemistry. *Science Education*, 84(3), 352-381.

Grosslight, L., Unger, C., & Jay, E. (1991). Understanding models and their use in science: Conceptions of middle and high school students and experts. *Journal of Research in Science Teaching*, 28, 799.

- Teachers jigsaw the articles. To jigsaw, means that each person that read the same article meets for 15 minutes and helps each other make sense of the main points. They then return to their small groups and share the articles with each other.
- The whole group participates in a discussion after article jigsaw. The following questions are used to guide this discussion:
 - a. What is the take-home message of each article?
 - b. How do the take-home messages apply to teaching and learning NSE?

Activity 4 – Incorporating a Model into a Lesson on a Nanoscale Phenomena

- Teachers find or create a model that they choose to incorporate into a lesson on a nanoscale concept or phenomenon. They can use whatever resources they would like, including books and the internet, as well as craft supplies.



- Teachers describe how they would use the model in the context of their instruction by answering the questions on the handout: Using Models in a Nano Lesson Plan.

Wrap-up

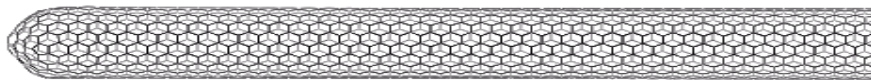
Small and large groups sharing of ideas. Discussion questions include:

- How do the models compare among your group?
- What was similar about the models you chose?
- What was different about the models you chose?
- What was similar in how you would use them?
- What was different in how you would use them?
- Why are models important to nanoscale science, engineering, and technology?
- How are they used in the field?
- How does your use of models compare to how they are used in the field?

Assessment

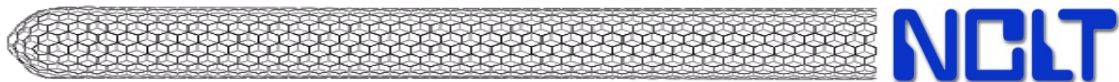
Formative Assessments Table

Assessments	Where in lesson	Possible correct responses
Station Questions	Body	Those that align with the learning goals
Models used in lesson plans	Follow-up	Those that incorporate ideas from the learning goals



RESOURCES

- American Association for the Advancement of Science [AAAS]. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.
- Boulter, C., & Buckley, B. (2000). Constructing a typology of models for science education. In Gilbert & Boulter (2000). *Developing models in science education*. Dordrecht: Kluwer.
- Coll, R. K., France, B., & Taylor, I. (2005). The role of models/and analogies in science education: Implications from research. *International Journal of Science Education*, 27(2), 183-198.
- Daly, S. (2009). Tall, short, thick, and thin: They're all models. Retrieved on January 28, 2010 from <http://www.physics.purdue.edu/psas/>
- DNA. (2008, June 9). In *Wikipedia, The Free Encyclopedia*. Retrieved 16:12, June 10, 2008, from <http://en.wikipedia.org/w/index.php?title=DNA&oldid=218234343>
- Grosslight, L., Unger, C., & Jay, E. (1991). Understanding models and their use in science: Conceptions of middle and high school students and experts. *Journal of Research in Science Teaching*, 28, 799.
- Harrison, A. G., & Treagust, D. F. (2000). Learning about atoms, molecules, and chemical bonds: A case study of multiple-model use in grade 11 chemistry. *Science Education*, 84(3), 352-381.
- Indiana's Academic Standards and Resources. (2009). Available: <http://www.indianastandards.org/index.asp>.
- National Research Council [NRC]. (1996). *National science education standards: Observe, interact, change, learn*. Washington, DC: National Academy Press.
- Rothmund, P. (2006). Folding DNA to create nanoscale shapes and patterns. *Nature*, 440(7082), 297-302.
- Stevens, S. Y., Sutherland, L. M., & Krajcik, J. S. (2009). *The big ideas of nanoscale science and engineering: A guidebook for secondary teachers*. Arlington, VA: NSTA Press.



SUPPLEMENTAL MATERIALS

Standards

Indiana State Standards

Grade 7

7.1.7 – Explain how engineers, architects, and others who engage in design and technology use scientific knowledge to solve practical problems.

7.7.2 – Use different models to represent the same thing, noting that the kind of model and its complexity should depend on its purpose.

Grade 8

8.1.6 – Identify the constraints that must be taken into account as a new design is developed, such as gravity and the properties of the materials to be used.

8.1.8 – Explain that humans help shape the future by generating knowledge, developing new technologies, and communicating ideas to others.

Benchmarks

11 B 6-8 Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly, or that are too vast to be changed deliberately, or that are potentially dangerous.

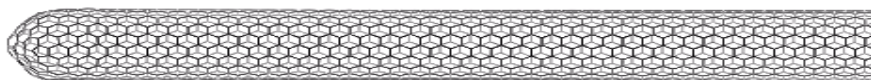
11 B Grades 6-8 Different models can be used to represent the same thing. What kind of a model to use and how complex it should be depends on its purpose. The usefulness of a model may be limited if it is too simple or if it is needlessly complicated. Choosing a useful model is one of the instances in which intuition and creativity come into play in science, mathematics, and engineering.

NSES

Science and technology 5-8

Understanding about science and technology

Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.



**Model Typology
Boulter & Buckley Model Typology (2000)**

Modes of Representation

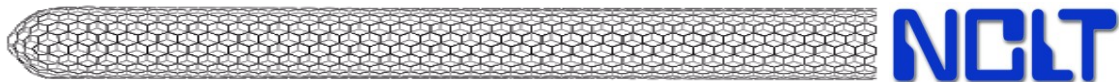
Concrete	3D material models; e.g. a plastic heart
Verbal	Models that are heard or read, of description, explanation, narrative, argument, analogy, and metaphor; e.g. The heart is a pump.
Visual	Models that are seen, such as diagrams, animations, some simulations, video; e.g. circle and line drawing of an eclipse.
Mathematical	Models that are formulae, equations, and some simulations; e.g. equations of planetary motion.
Gestural	Models that are movements of the body or its parts; e.g. a solar system made of pupils moving around each other.

Attributes of Representation

Quantitative versus Qualitative	Is the representation precise as in scale drawings or equations or is it qualitative?
Static versus Dynamic	Is the representation a static one such as a diagram or a dynamic one such as an animation?
Deterministic vs. Stochastic	If the representation is dynamic, is the behavior of the representation always the same (deterministic) or is its behavior based on probabilities (stochastic) and therefore variable?

Typology Table

	Static	Dynamic: Deterministic	Dynamic: Stochastic
Concrete Material	3D Model; Scale Models	3D models that move; Working scale replicas	Physical simulations
Visual Pictorial	Diagram; Drawing; Photographs	Sequenced diagrams; Animations; Video of live phenomena	Graphical Displays
Verbal Written/ Oral	Analogy; Description; Metaphor; Description with size or distance		
Mathematical Formulaic	Equations; Chemical formulae	Formulae; Computer simulations	Formulae
Gestural Bodily	Showing Positions; Showing size	Acting out set movements; Gesturing relative behaviors	Hand gestures



Thinking about Models and Their Use

Part 1

1. What factors guided your determination of which were models and which were not? Make a list and explain how each factor is associated with what models are.
2. How would you define a model?

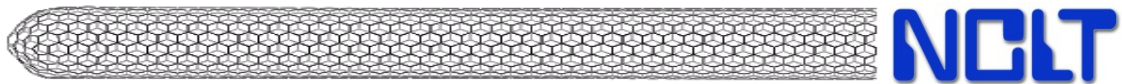
Part 2

Describe a lesson that you teach that includes a model or models. If you use models to teach about something that cannot be seen (i.e. a topic that is closely related to nanoscale concepts), use this lesson as your example.

1. What model(s) do you use?
2. What concept or phenomena is represented by the model(s)?
3. Why do you use a model or models in this lesson?
4. Describe the sequence of events related to the use of the model for learning.
5. What do you say to your students about the model?
6. What do you do with the model?
7. What do your students do with the model?
8. What role do(es) the model(s) play in learning?

Part 3

1. Based on your discussion of models in Parts 1 and 2, what do you think are the purposes of models?
2. Why are models important for teaching and learning in the fields of nanoscale science and engineering? Is this different than why models are important in micro- or macroscale science and engineering?

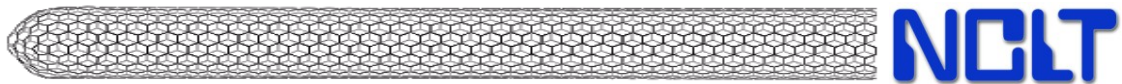


Station 4:

1. Is there value to the older models made of the atom? Explain your reasoning?

2. Why do models of the same thing change?

3. How do models contribute to science and engineering progress?

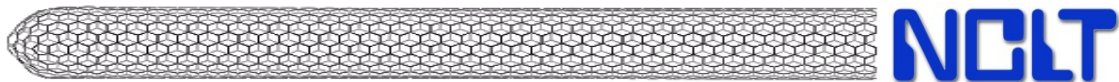


Station 5:

1. Design a model to represent how a DNA origami staple works as discussed in the text. Describe the model you created. Take a picture of your model to be inserted later.

2. Was it easy or difficult to design a model? Why?

3. What did you learn from designing the model?



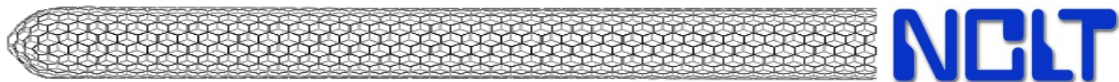
DNA Info Sheet from Wikipedia

DNA. (2008, June 9). In *Wikipedia, The Free Encyclopedia*. Retrieved 16:12, June 10, 2008, from <http://en.wikipedia.org/w/index.php?title=DNA&oldid=218234343>

Deoxyribonucleic acid (DNA) is a nucleic acid that contains the genetic instructions used in the development and functioning of all known living organisms and some viruses. The main role of DNA molecules is the long-term storage of information. DNA is often compared to a set of blueprints or a recipe, since it contains the instructions needed to construct other components of cells, such as proteins and RNA molecules. The DNA segments that carry this genetic information are called genes, but other DNA sequences have structural purposes, or are involved in regulating the use of this genetic information.

Chemically, DNA is a long polymer of simple units called nucleotides, with a backbone made of sugars and phosphate groups joined by ester bonds. Attached to each sugar is one of four types of molecules called bases. It is the sequence of these four bases along the backbone that encodes information. This information is read using the genetic code, which specifies the sequence of the amino acids within proteins. The code is read by copying stretches of DNA into the related nucleic acid RNA, in a process called transcription.

Within cells, DNA is organized into structures called chromosomes. These chromosomes are duplicated before cells divide, in a process called DNA replication. Eukaryotic organisms (animals, plants, and fungi) store their DNA inside the cell nucleus, while in prokaryotes (bacteria and archae) it is found in the cell's cytoplasm. Within the chromosomes, chromatin proteins such as histones compact and organize DNA. These compact structures guide the interactions between DNA and other proteins, helping control which parts of the DNA are transcribed.



Using Models in a Nano Lesson Plan

In the lesson plan that you develop as a part of this institute, answer the following questions about the model(s) included in your lesson.

1. List the models you are using in your lesson.
2. For each model you are using, describe the concept(s) you are trying to help convey with that model.
3. For each model you are using, describe how you believe it will help students learn about the concept.
4. For each model you are using, explain why you selected that model for your lesson.
5. For each model, describe how it will be used within the lesson. What will you do with it? What will students do with it?
6. Based on how you chose to use models in your lesson, what role do you think models play in nanoscale science and engineering education?