

nano-based education through generation-nano.org

Alejandra Magana

Gerhard Klimeck



Agenda

- Motivation
- Problem Description
- Project Goals
- Approach, Strategy, and Content
- www.Generation-nano.org
- Design Process and Pedagogical Foundation
- Evaluation and Results
- Conclusion and Future Work



Why nano? Why Now?

New tools have been developed.
They allow research at the scale of atoms and molecules.

Can be compared to the telecommunications and
information technology boom in 1998.

Nano research crosses various scientific disciplines.
Chemists, biologists, doctors, physicists, engineers, and computer scientists
are intimately involved.

Nano has moved from the world of the future to present.
It has moved from the science fiction to the science reality.



Why Middle School?

The NSF estimates for the year 2015:

- “*nano-related goods and services could be a \$1 trillion market*”
- “*this market will need two million nanotechnology workers*”

This is about the time today’s middle school students will be entering college.

Researchers and educators have recently stressed the importance of
children becoming “*nano-literate*” to meet the future needs.



Problem, Challenge, and Opportunity

Problem:

Researchers and educators have stressed the importance of our children becoming “nano-literate” in order to meet the future needs in this field.

Challenge:

Fundamental knowledge and awareness must be conveyed to large population.

Opportunity:

Reinforce current topics of science and math aligned with standards and demonstrate how these concepts are the basis of real-world exciting applications.



Recent Findings

Castellini 2007 et. al surveyed 500 participants

Respondents	Visible object or nonsense
Elementary students	66%
Middle school	20%
Early high school	48%
Older high school	14%
College educated	10%
High-school educated adults	45%



Recent Findings (contd.)

Waldron 2006 et. al surveyed 1500 participants

Respondents	Visible object or nonsense
6 to 8 years old	70%
18-22 years old	<30%
Adults	50%



Recent Findings (contd.)

“People lack true understanding of concepts associated with atoms and the size of the nanoscale regime.” (Castellini, 2006).

“The general public have limited knowledge and consistent misconceptions about atoms, molecules, DNA, cells, and other things the interviewees cannot see.” (Edu.Inc, n.d.)



Recent Findings (contd.)

“... *engaging students requires that they have a firm grasp on size and scale, a prerequisite for any further inquiry into nanoscale science and engineering.*”
(Waldron 2006).

“*The problem is conceptual and practical
Objects and concepts at the nanoscale are:*

- *hard to visualize,*
- *difficult to describe,*
- *abstract,*
- *and their relationships to the observable world can be counterintuitive.*”
(Sabelli 2005).



Generation-nano.org Goals

- a) Get students *interested* and *excited* in Nanoscience and Nanotechnology,
- b) Start *educating* middle school students to become aware of nanotechnology,
- c) facilitate a *deeper understanding* of the underlying concepts of nanoscience and nanotechnology, and
- d) provide to educators and parents the *tools, techniques, and resources* to attain this goal.



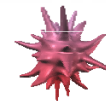
- 1) Identified documented topic related problems and solutions in science teaching:
 - In formal and informal settings
 - use them as a framework
- 2) Based on “The Big Ideas of Nanoscience”
- 3) Aligned with:
 - National Science Standards,
 - Project 2061’s Benchmark of the American Association for the Advancement of Science (AAAS),
 - National Assessment of Scientific Progress (NAEP)
- 4) Collaboration with organizations focused on teaching nanoscale science:
 - National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT)
 - SRI International
- 5) Formative evaluation for assessing the effectiveness of the materials



Curriculum: The Big Ideas of Nanoscience

Size & Scale:

As size and scale change, the properties of matter change, and different laws of physics are needed to explain these properties.

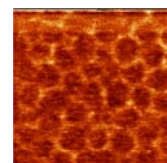


Structure of Matter:

All matter is composed of atoms that are in constant motion. Atoms interact with each other to form molecules.

Size-Dependent Properties:

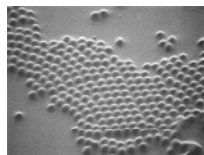
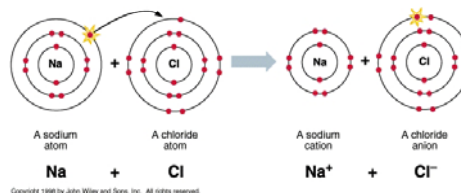
The properties of matter can change with scale. In particular, as the size of a material approaches the nanoscale, it often exhibits unexpected properties that lead to new functionality.



Curriculum: The Big Ideas of Nanoscience

Forces:

All interactions can be described by multiple types of forces, but the relative impact of these forces changes with scale. On the nanoscale, a range of electrical forces with varying strengths tends to dominate the interactions between objects.

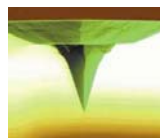


Self-Assembly:

Under specific conditions, some materials can spontaneously assemble into organized structures. This process provides a useful means for manipulating matter at the nanoscale.

Tools & Instrumentation:

Development of new tools and instruments helps drive scientific progress.



<http://www.phys.uri.edu/~sps/STM/stm10.jpg>; <http://www.nanoptek.com/digitalptm.html>

<http://www.geo.arizona.edu/xtal/nats101/s04-18.html>

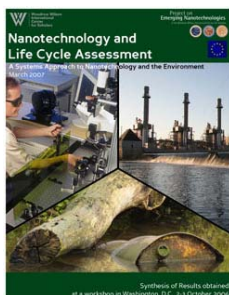
Frankel Felice, with technical help from Love Christopher J. (September 2001). Little Big Science by Gary Stix.



Curriculum: The Big Ideas of Nanoscience

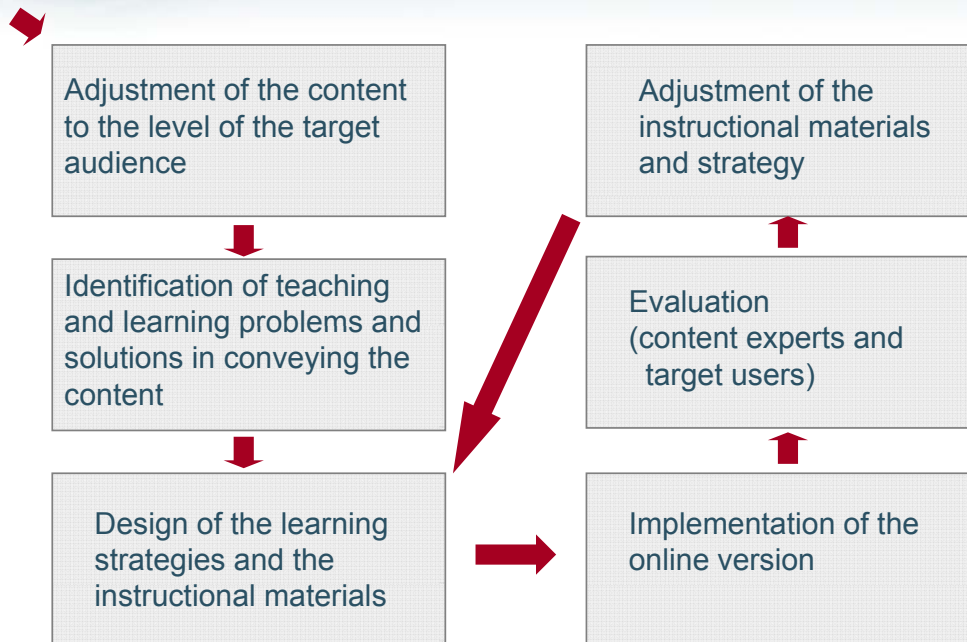
Models & Simulations:

Because nanoscale objects and phenomena are, by their very nature, too small to see, models are needed to understand, visualize, predict, hypothesize, explain, and interpret data about them.



Nano & Society:

The field of nanotechnology is driven by the aim to advance broad societal goals. As with other technological advances, the products of nanotechnology may impact our lives in both positive and negative ways.



Concept:

- Story-based design
- Interactive learning environment
- Scenes inspired by the Purdue Birck Nanotechnology Center
- Users can enroll as agents into a training program to become Nanoscientists
 - completing activities advances users to the next level and
 - granting access to virtual cleanroom and labs
- Learning modules presented as “missions”:
 - rules of the game (presenting content with guidance)
 - missions (practice and immediate feedback)

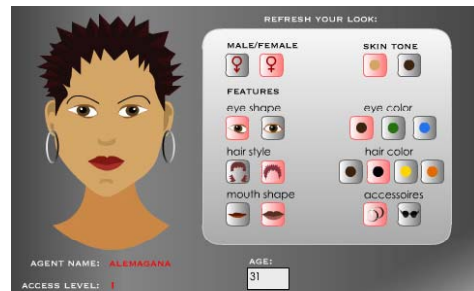


- **Technology:**

Web-Based, Adobe Flash, Video, Audio, Animation

- **Features:**

user registration, avatar personalization, progress tracking, levels

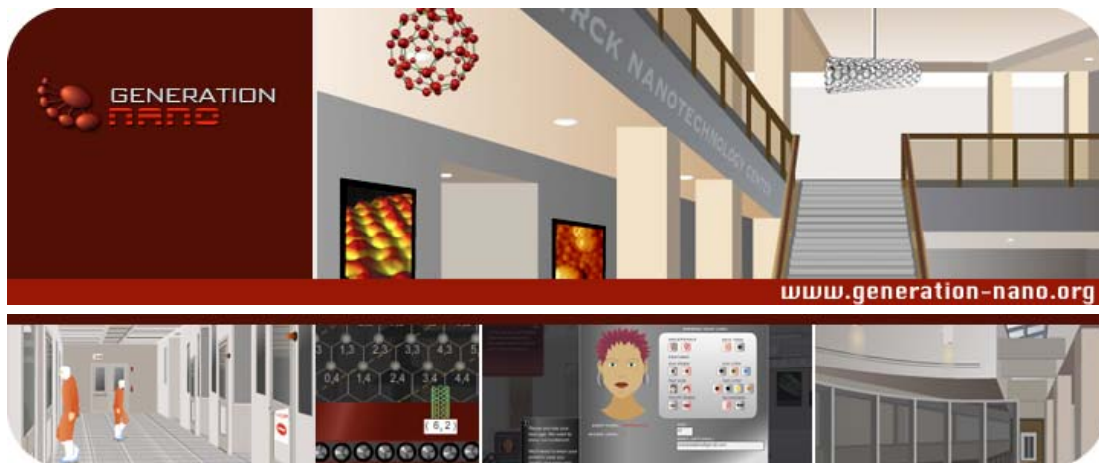


- **Plus:**

Adapted (junior) versions from www.nanoHUB.org simulation tools



The Portal

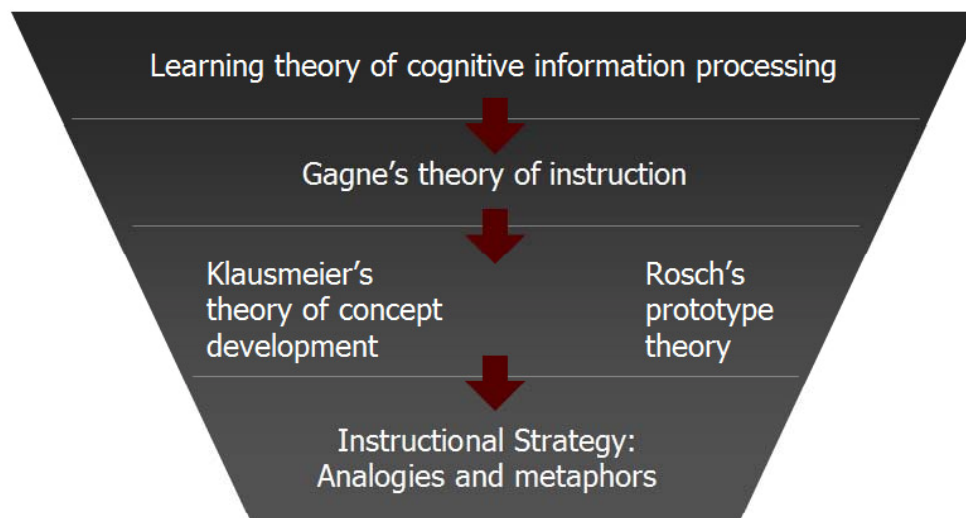


<http://www.generation-nano.org/>

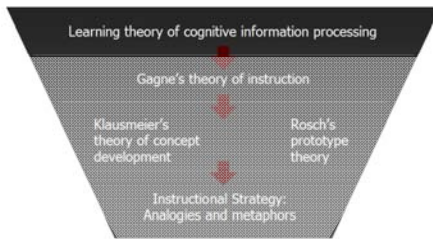


Instructional Objectives

- Learners will recall that all matter is made up of atoms and that atoms bond together to form molecules.
- Learners will identify nanoscale objects as different from microscale objects.
- Given examples of macro, micro and nano sized objects; learners will classify them in micro sized objects, nano-sized objects and atomic-sized objects.
- Given macro-sized, nano-sized, and micro-sized objects, learners will make scale comparisons of them and will order them.



Theory of Cognitive Information Processing



Abstract thought is required for conveying the concept of nanoscale.

Piaget developmental perspective:

- the preoperational thought stage
- the sensorimotor stage
- the concrete operations, and
- the formal operations.

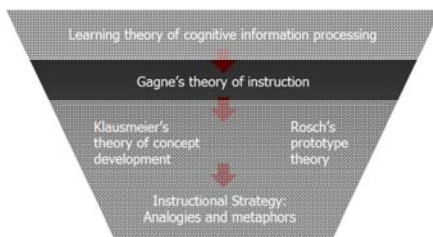
The alternative theories of cognitive development are build upon Piaget's genetic epistemology.

These alternative theories incorporate elements of the cognitive information processing perspective.

- topic-related formal instruction,
- knowledge of the subject matter,
- reasoning and reflective strategies,
- feedback for self-monitoring, and
- integration of the new information with prior knowledge.



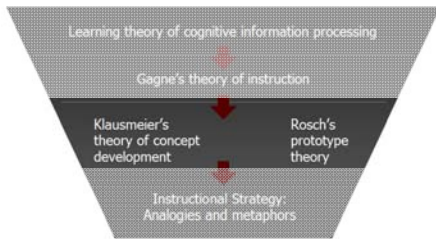
Gagne's Theory of Instruction



Event	Content description
Gaining attention	Emphasize importance of Nanotechnology. Describe the role of new tools and techniques. Introduce novel applications of Nanotechnology.
Informing the learner of the objective	Identify the difference between microscale and nanoscale objects. Describe the difference and relationship between nanoscience, nanotechnology, and Nanoscale
Stimulating recall of prior knowledge	Recall that all mater is made up of atoms Recall that atoms bond together to form molecules Recall conversion procedures between feet and meters.
Presenting the stimulus and guidance	Identify the difference between macroscale, microscale and nanoscale objects.
Eliciting performance and providing feedback	Learners classified several objects according to their scale (micro, macro, or nanoscale). Feedback was provided.
Enhancing retention and transfer	In groups, learners created their own scale analogies. These analogies were discussed with the rest of the class.
Assessing performance	Learners sorted and ordered objects in the scale.



Concept Development Theory and Prototype Theory



Klausmeier's theory of concept development:

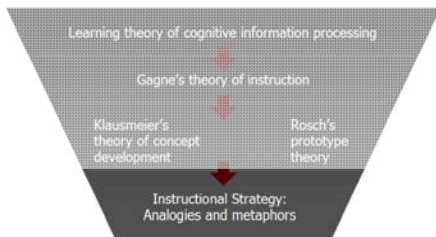
- iterates principles of learning and development.
- describes how a given concept is attained at four successively higher levels of understanding.
- specifies the cognitive processes involved in attaining each level,
- indicates the uses made of the concept when attained at each level and
- specifies the instructional conditions that facilitate learning at each level.

Prototype Theory:

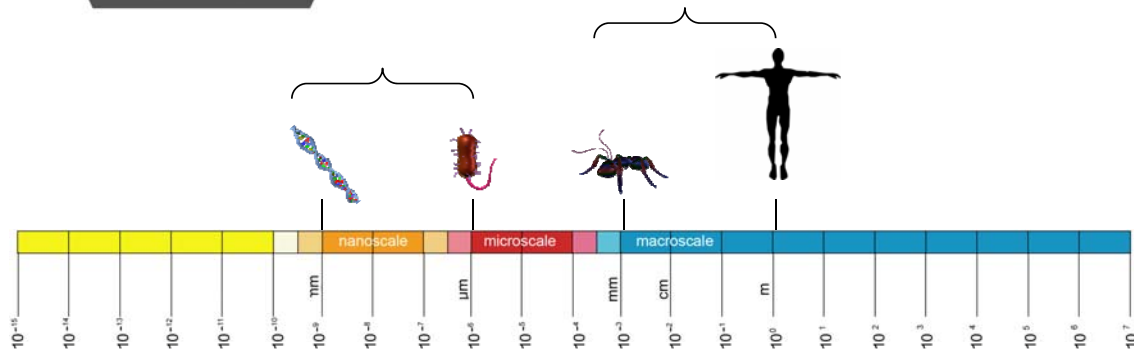
- A concept is learned and represented as a prototype of a class of objects.
- A prototype is an image constructed from experiences.
- After a prototype is formed, newly encountered instances are identified by comparison with the prototype



Instructional Strategy

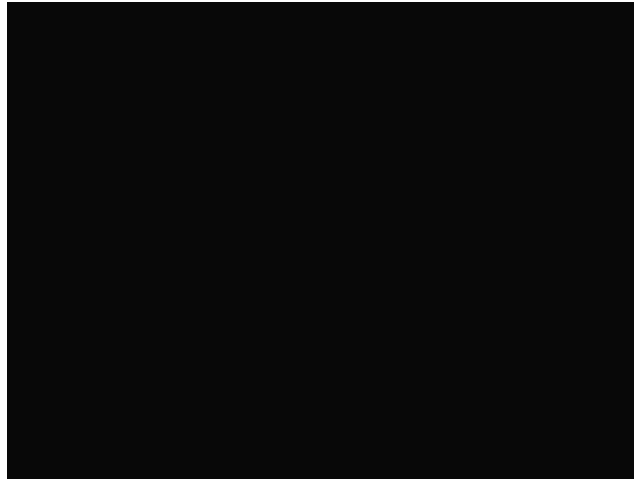


Analogies and metaphors as a strategy for scaffolding the cognitive processes required for attaining scale cognition:



Formative evaluation process:

- Task analysis review
- Design review
- Content expert reviews (3)
- Expert on the learners review
- Review on assessment specifications
- Field trial with 130 students



Learning objective:

Given examples of macro, micro, and nano sized objects; learners will classify them in macro-sized objects, micro-sized objects and nano-sized objects.

Classification proposed by students	Percentage
Small, medium, large	56%
Seen with electron microscope, microscope, and eye	3%
No classification	11%
Used the term microscopic inconsistently	5%
Other	25%

According to student's classifications, groups were formed:

Group 1: the 59% of students who classified the objects by size.

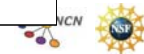
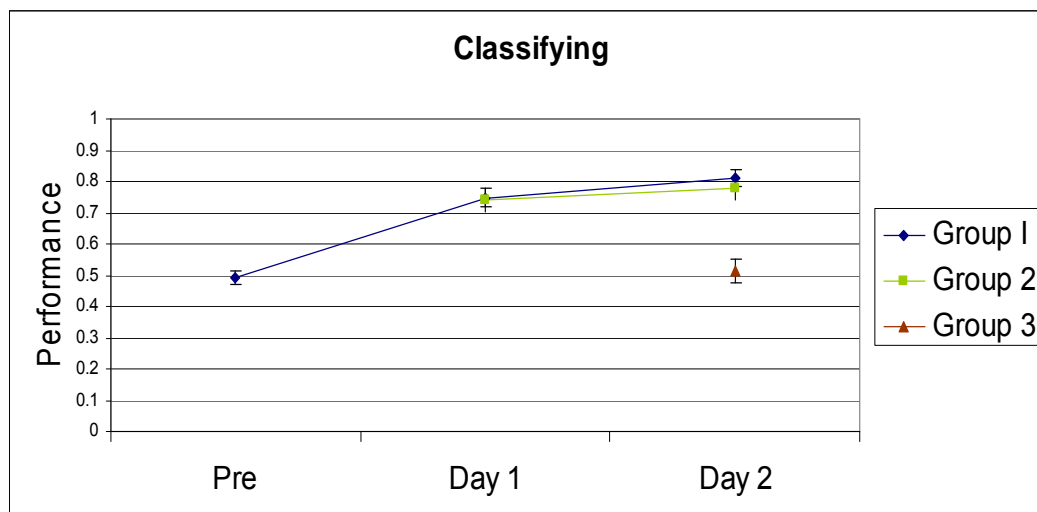
Group 2: students that did not classified by size.

Group 3: students who did not receive the instruction based on analogies and metaphors, but were exposed to an informal learning environment.



Learning objective (classifying):

Given examples of macro, micro, and nano sized objects; learners will **classify** them in macro-sized objects, micro-sized objects and nano-sized objects.



Learning objective (classifying):

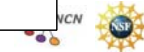
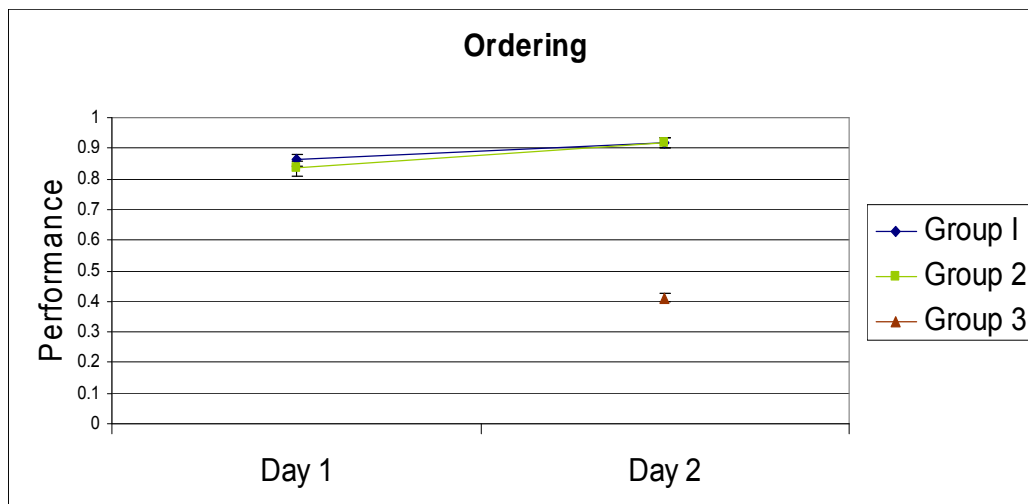
Given examples of macro, micro, and nano sized objects; learners will **classify** them in macro-sized objects, micro-sized objects and nano-sized objects.

	Classified by size 59% (group 1)	Other classification 41% (group 2)	Informal learning env. (group 3)
Prior instruction	μ of 0.49 δ 0.02		
After first day of instruction	μ of 0.75 δ 0.03	μ of 0.74 δ 0.04	
After second day of instruction	μ of 0.81 δ 0.03	μ of 0.78 δ 0.04	μ of 0.51 δ 0.04



Learning objective (ordering):

Given macro-sized, micro-sized, and nano-sized objects, learners will make scale comparisons of these objects and will order them.



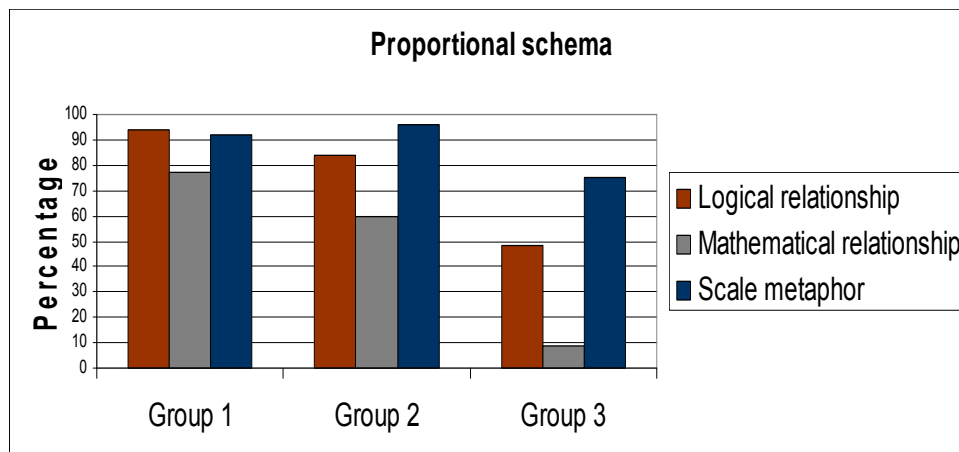
Learning objective (classifying):

Given examples of macro, micro, and nano sized objects; learners will classify them in macro-sized objects, micro-sized objects and nano-sized objects.

	Classified by size 59% (group 1)	Other classification 41% (group 2)	Informal learning env. (group 3)
Prior instruction	μ of 0.86 δ 0.02	μ of 0.83 δ 0.03	
After second day of instruction	μ of 0.92 δ 0.02	μ of 0.91 δ 0.02	μ of 0.41 δ 0.01



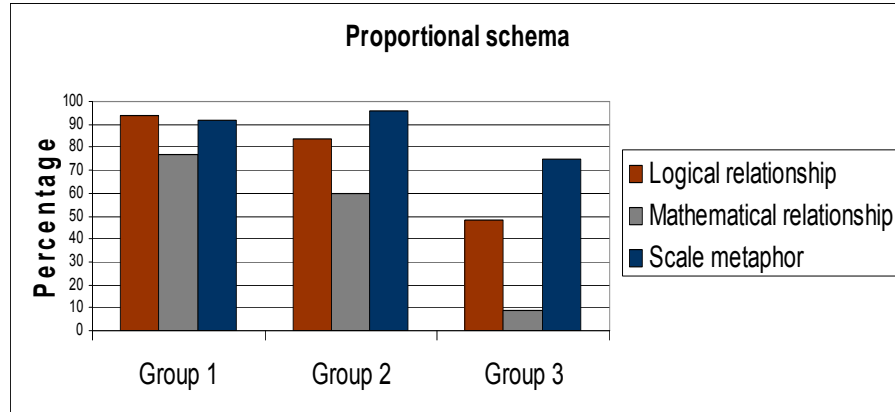
After instruction, students exposed to analogies and metaphors improved their performance in classifying objects and ordering objects.



The majority of the students exposed to analogies and metaphors:

-Identified the proportional relationship demonstrated and

-identified in numerical terms the difference in sizes by using the scale metaphor.



Students that were not exposed to the proportional analogies recognized the metaphor represented with the scale.



- We have identified the need of children becoming “nano-literate”
- We have presented one approach that addresses the identified problem with the aim to fulfill this need
- We have described the proposed curriculum that reinforces the underlying concepts of nanotechnology
- We have demonstrated an instructional design process focused on middle school level
- We have developed a complete module based on size and scale related concepts
- We are looking for help in the creation of further missions that meet fundamental learning requirements.



References and Contact Information

Alejandra Magana
Purdue University
admagana@purdue.edu

Castellini, O. M., Walejko, G. K., Holladay, C. E., Thiem, T. J., Zenner, G. M., & Crone, W. C. (2007). Nanotechnology and the public: Effectively communicating nanoscale science and engineering concepts. *Journal of Nanoparticle Research*, 9(2), 183-189.

Edu.Inc. (n.d.). *Evaluating museum visitors' readiness for and interest in learning new science*. Retrieved on May 8, 2005 from <http://www.nanozone.org/museum.htm>.

Sabelli, N., Schank, P., Rosenquist, A., Stanford, T., Patton, C., Cormia, R., et al. (2005, October). *Science and technology education at the nanoscale* (Report of the Workshop (draft)). SRI International.

Waldron, A. (2006, May). Nanotechnology in public. *Nano Today*. Retrieved on June 23, 2006 from http://www.nanotoday.com/pdfs/nanotoday_02_2006/Opinion-Waldron.pdf, 1 (2), 56.

Waldron, A. M., Spencer, D., & Batt., C. A. (2006). The current state of public understanding of nanotechnology. *Journal of Nanoparticle Research* 8, 569-575.

