Sustainable Nano-Engineering for Water Treatment

An Active Learning Based Theory and Laboratory Course for Nano Education

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Need for Problem Based Learning

"Productive work on societal implications needs to be engaged with the research from the start. Ethicists need to go into the lab to understand what's possible. ***Scientists and engineers need to engage with humanists to start thinking about this aspect of their work.*** *Only thus, working together in dialog, will we make genuine progress on the societal and ethical issues that nanotechnology poses."*

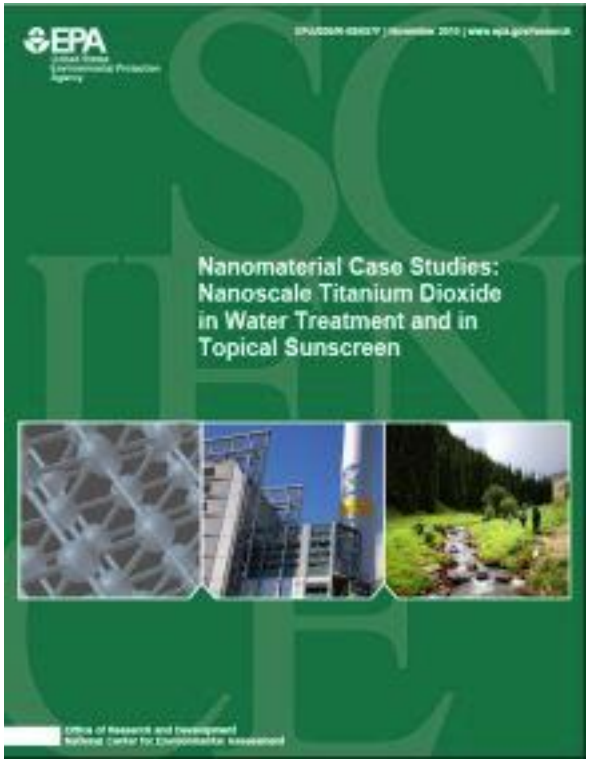
Davis Baird, Testimony to the Senate Committee, 2003

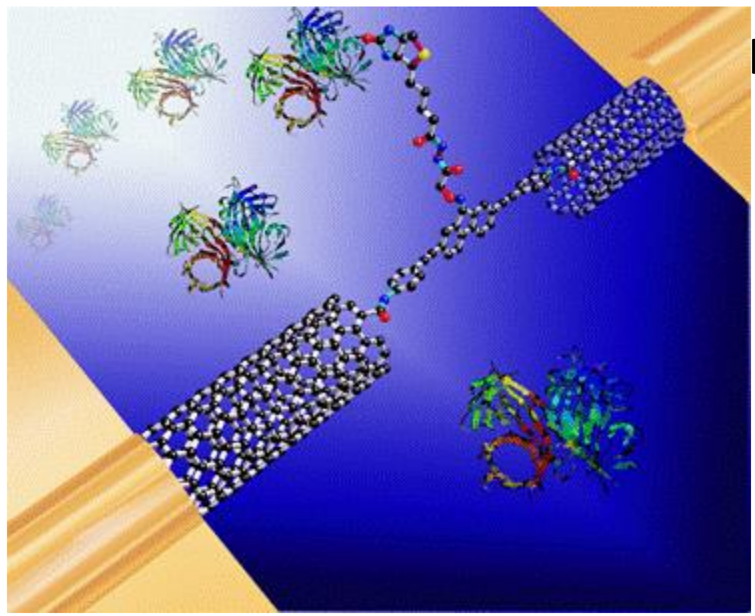
What Problem Based Learning Can Do

"Information is presented in a context of attempting to solve complex, realistic problems"

Bransford, J. et al., How People Learn, 2000, National Academy Press

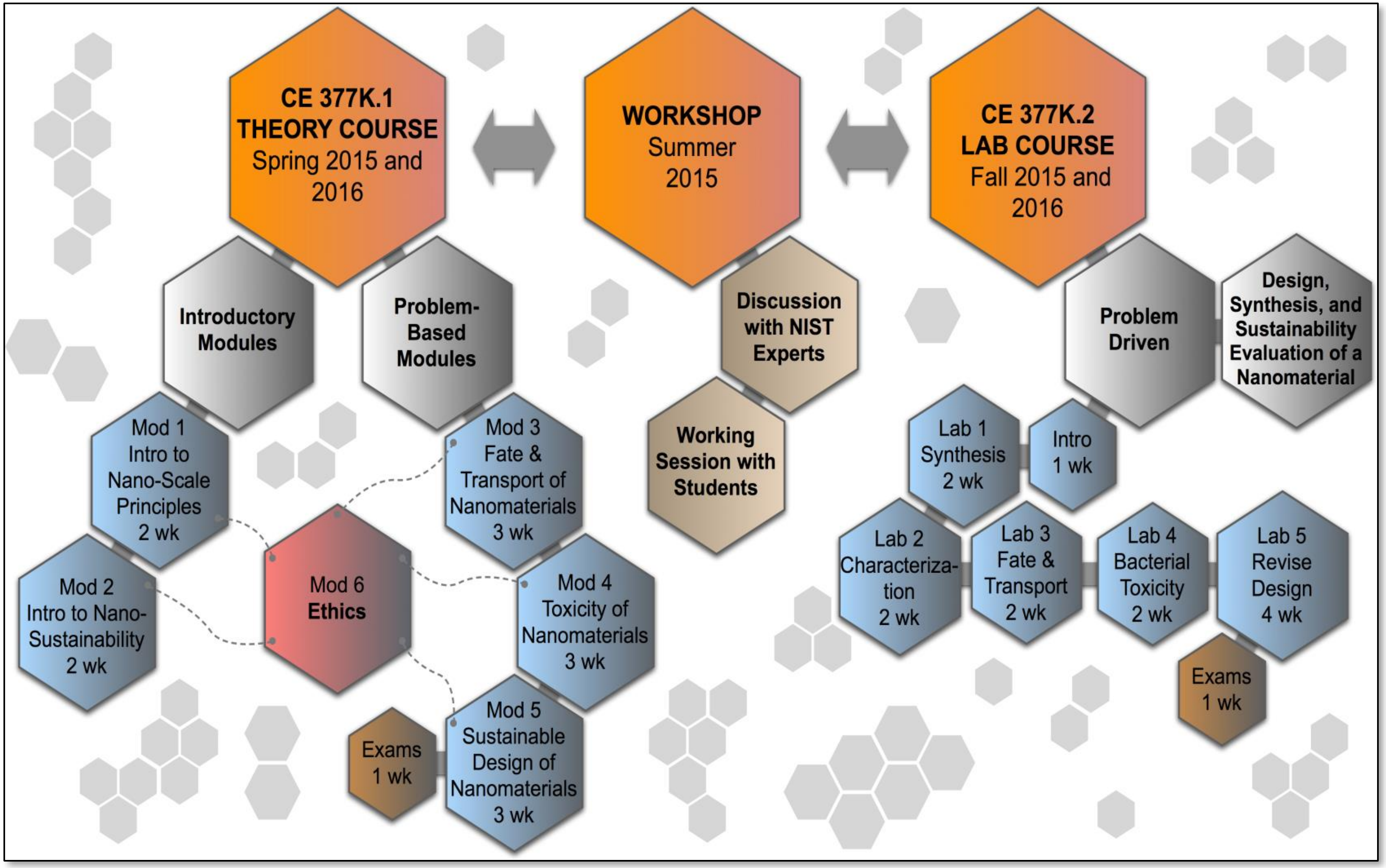
The Context



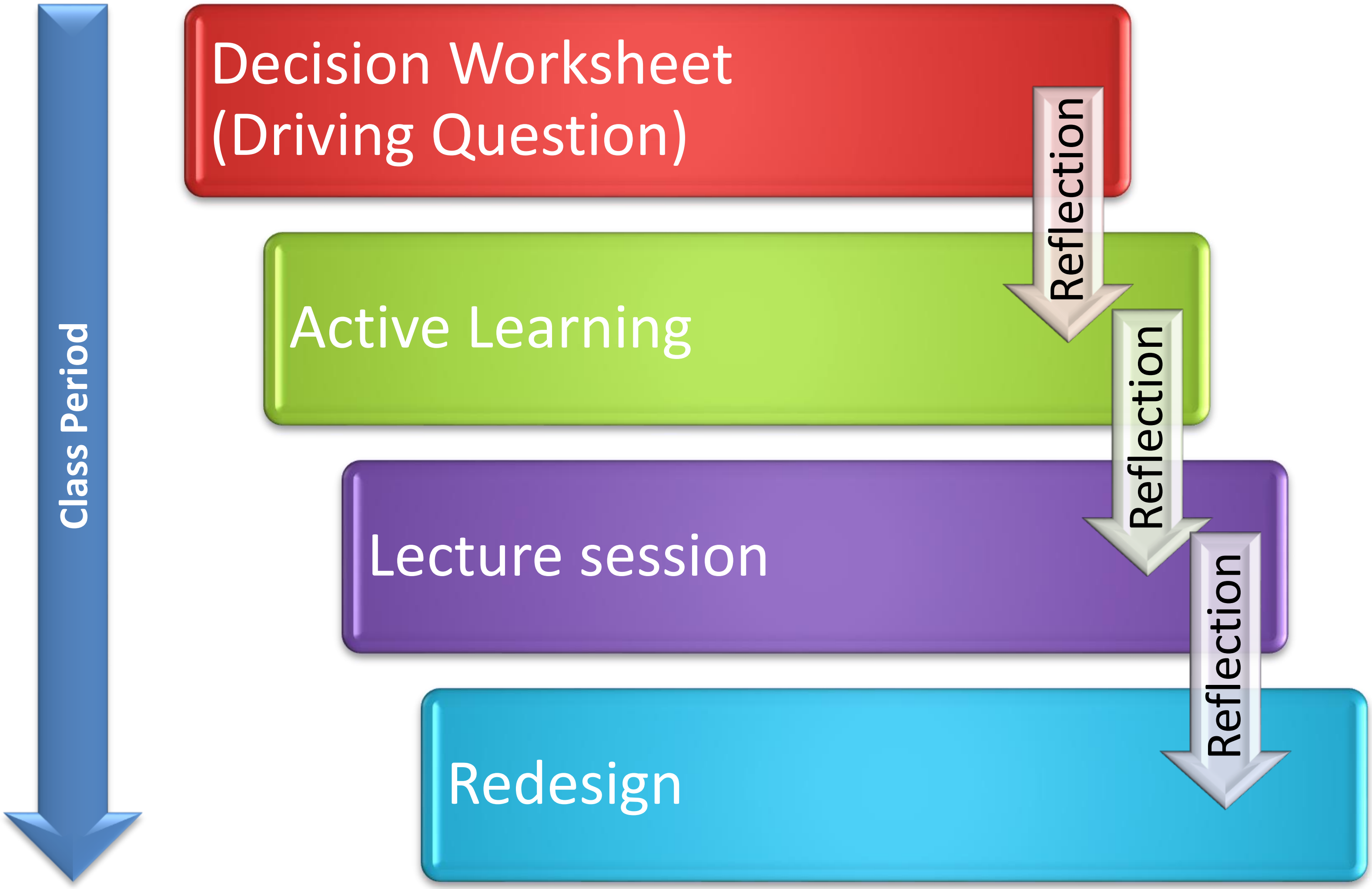


- Safety and sustainability of nanomaterials

Sustainable Nano Technology Courses at UT

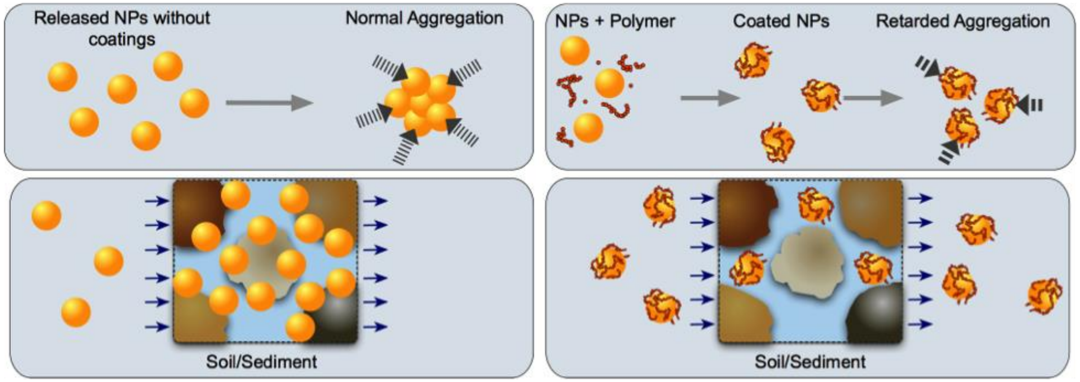


PBL Approach (EFFECTs)



Decision Worksheet-1

Once nanomaterials are released in aqueous systems, understanding their fate and transport is critical to estimate potential environmental and human exposure. There are two key mechanisms in this environmental process; i.e., aggregation between the particles and deposition onto environmental matrices, e.g., sediment or soil. Nanoparticle surfaces interact with the surrounding water envelope and thus this interface between nanoparticle and water become critical to control aggregation and deposition processes. How the nanoparticle surfaces are decorated (i.e., with what functionality) governs their aggregation and deposition behavior. Thus designing nanomaterials with restricted environmental transport will require careful functionalization of nanomaterial surfaces.



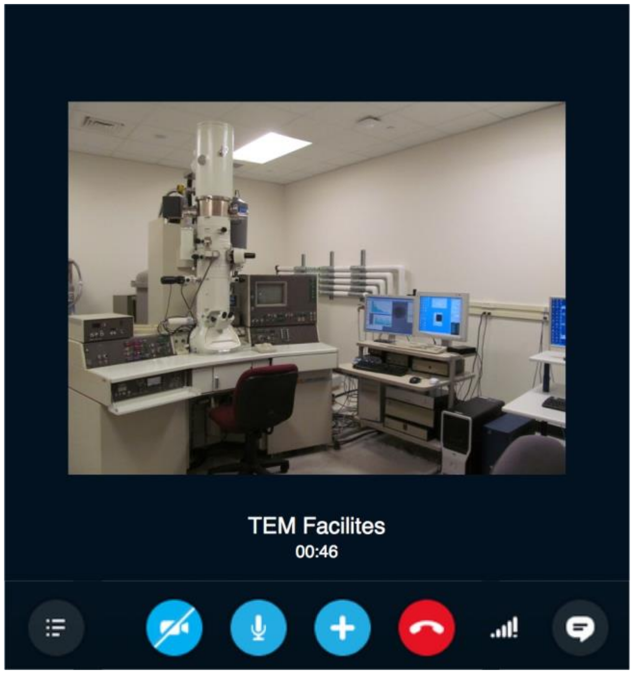
Driving Question: **Design a nanoparticle with limited mobility in the environment. Aggregation and settling of nanoparticles in less than 1 hour and deposition of less than 1% particles before traveling 1 Km can be considered as 'limited' transportability. Assume 100 mg/L nanoparticle has been released.**

Supporting Questions:

(i) Choose a nanoparticle (type, size, etc.) and the desired surface functionality.
(ii) What concepts do you need to know to answer the driving question?
(iii) Determine aggregate size after 1 hour and settling velocity of the particles.
(iv) Determine travel distance of 1% nanoparticle mass.
(v) What are the social and ethical implications of a nanoparticle not having limited mobility?

Concepts

- The size perspective
- Surface area to volume ratio
- Fate and transport


TEM Facilites
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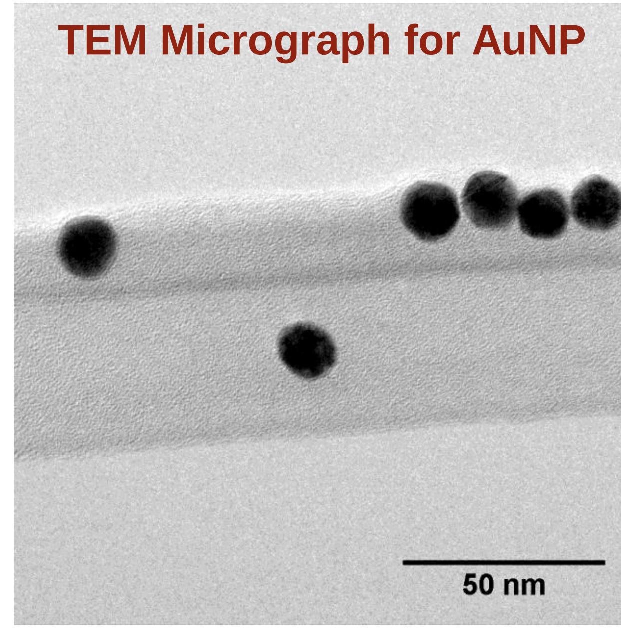
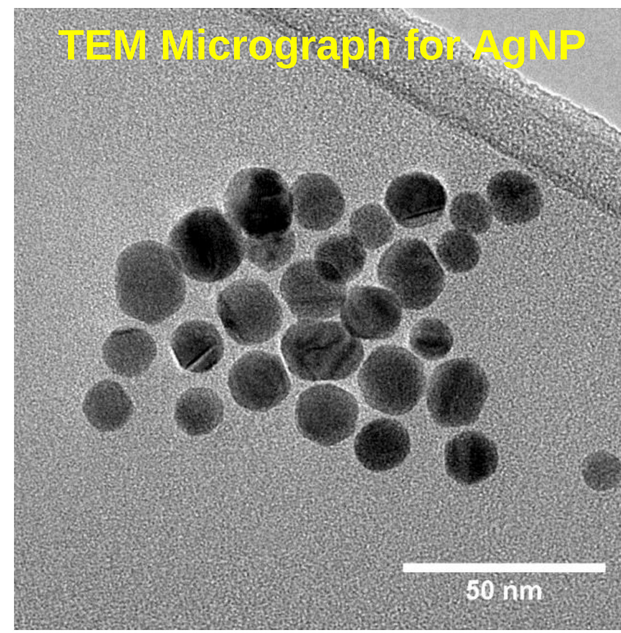
AuNP
AgNP

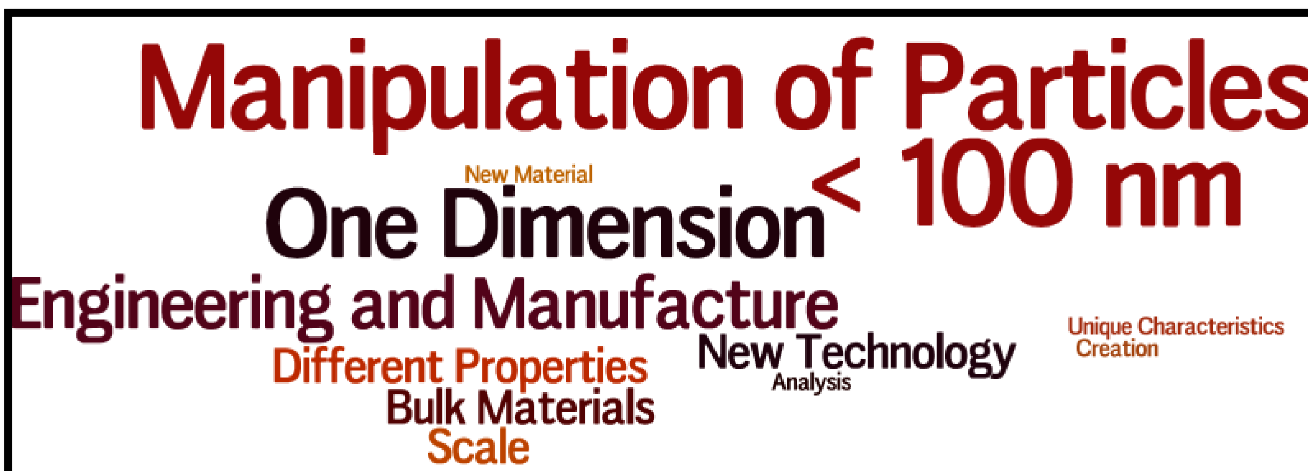

TEM Micrograph for AuNP
50 nm


TEM Micrograph for AgNP
50 nm

Active Learning Exercise for SA/Vol Concept

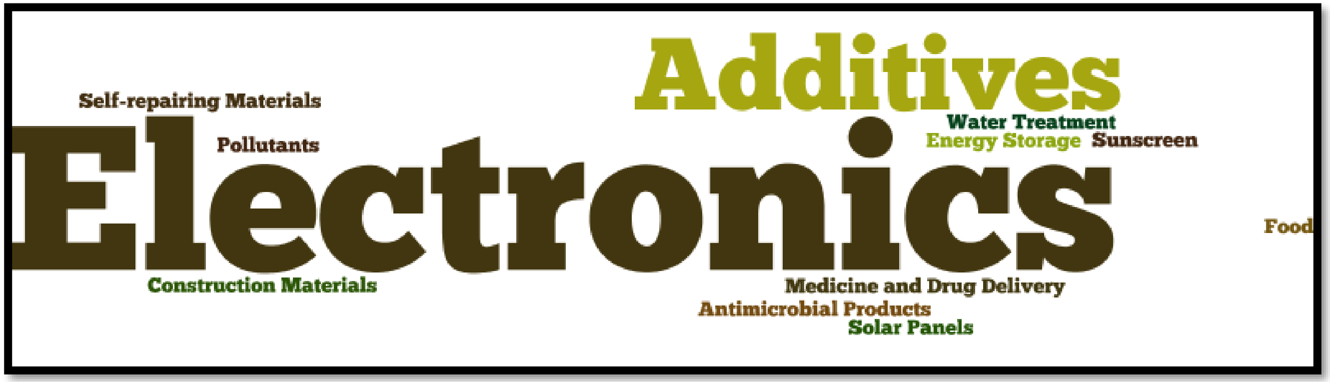
Student Learning: Pre/Post Test

Ques: What is nanotechnology?



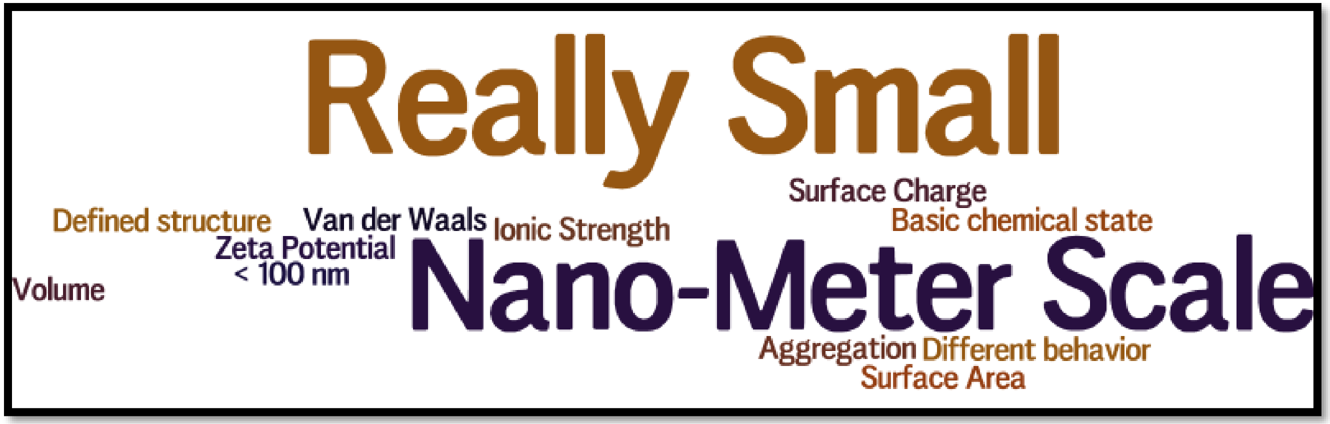
Student Learning: Pre/Post Test

Ques: What are the potential uses of nano particles?



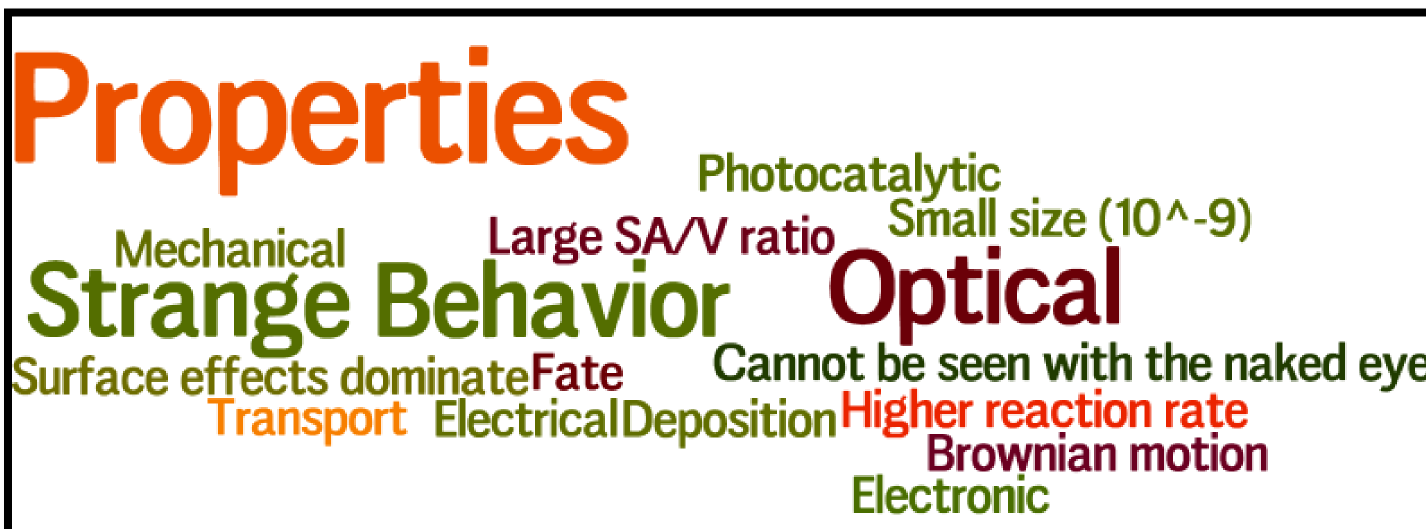
Student Learning: Pre/Post Test

Ques: What are the main characteristics of nanoparticles?



Student Learning: Pre/Post Test

Ques: How is the "nano world" different than ours?



Student Learning: Pre/Post Test

Ques: What are some ethical and social implications of engineering and technology?

Course Design for CE 377K Lab

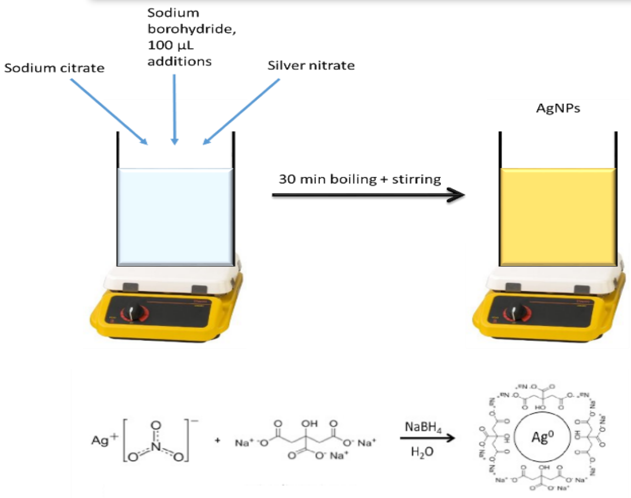
Lab 1
- Synthesis
- Characterization
- 2 weeks

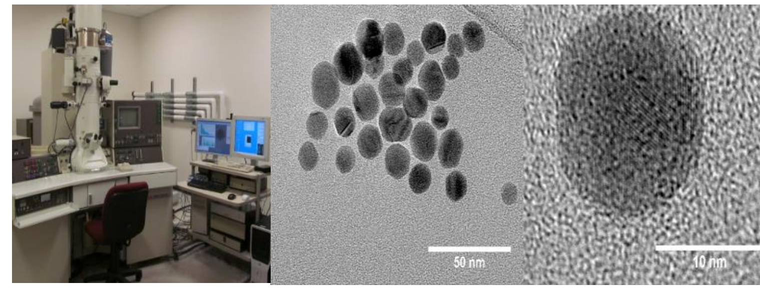
Lab 2
- Fate and Transport
- 2 weeks

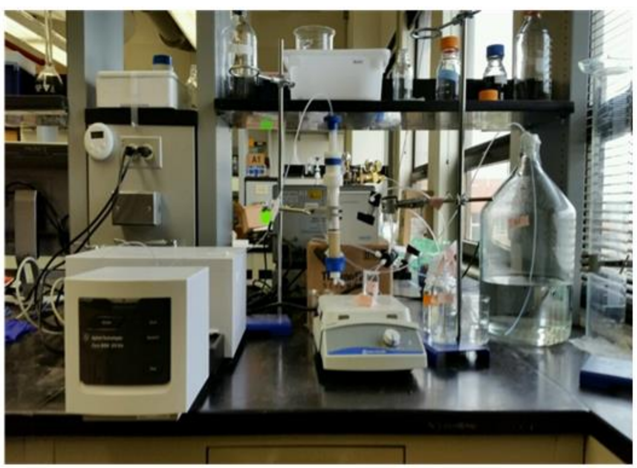
Lab 3
- Bacterial Toxicity
- 2 weeks

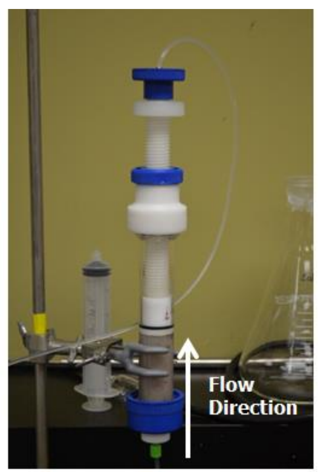
Lab 4
- Impact on Mechanical Properties of Biofilms
- 1 week

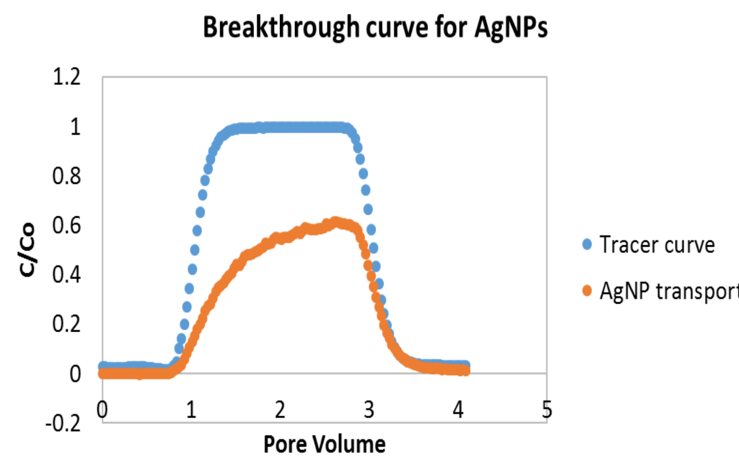
Hands-on Lab Activities



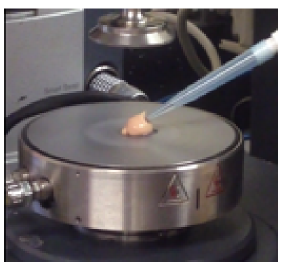


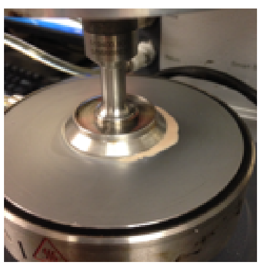






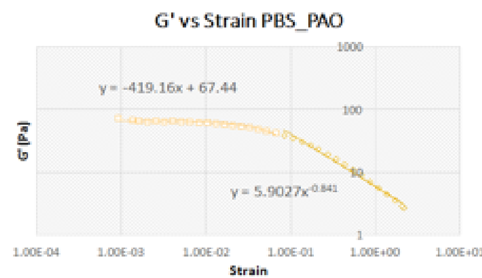
Hands-on Lab Activities





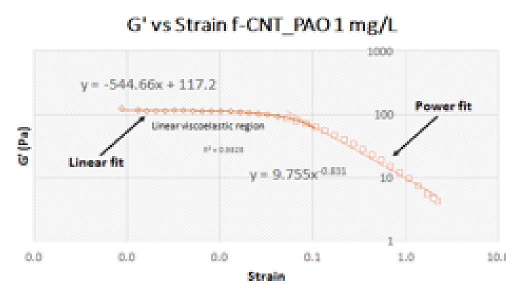
Grown biofilm was collected, mixed with CNT-PBS and placed on a rheometer for analysis of mechanical properties

Elastic modulus, yield strain, and yield stress PBS_PAO



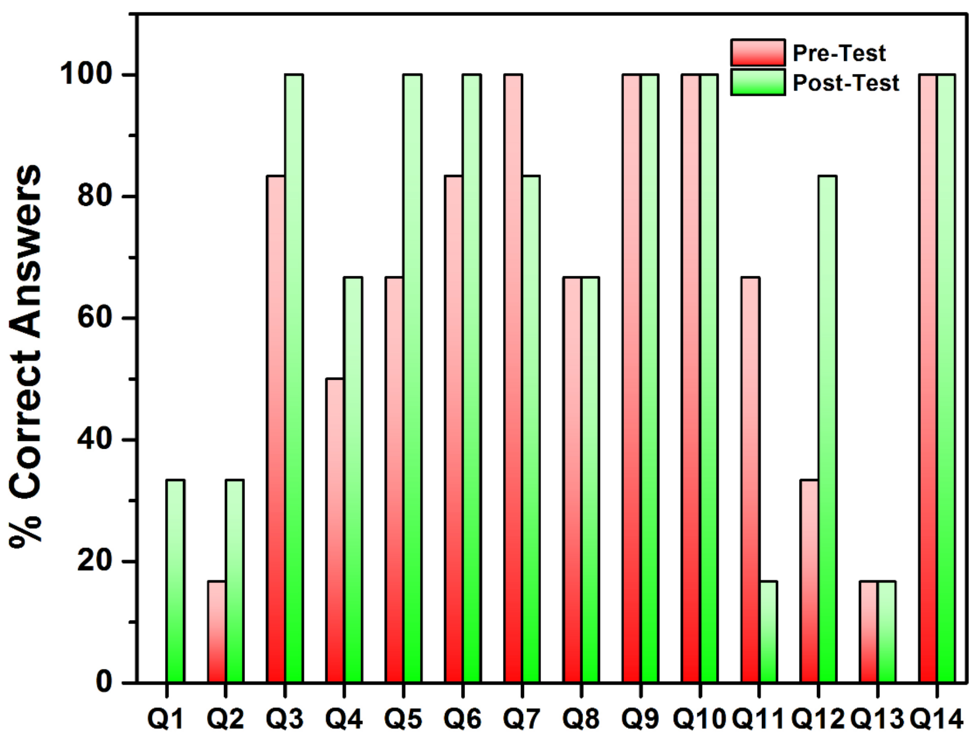
	Yield Strain	Yield Stress (Pa)	Elastic Modulus (Pa)
PBS_PAO	0.08249	3.283	45.09

Elastic modulus, yield strain, and yield stress f-CNT_PAO



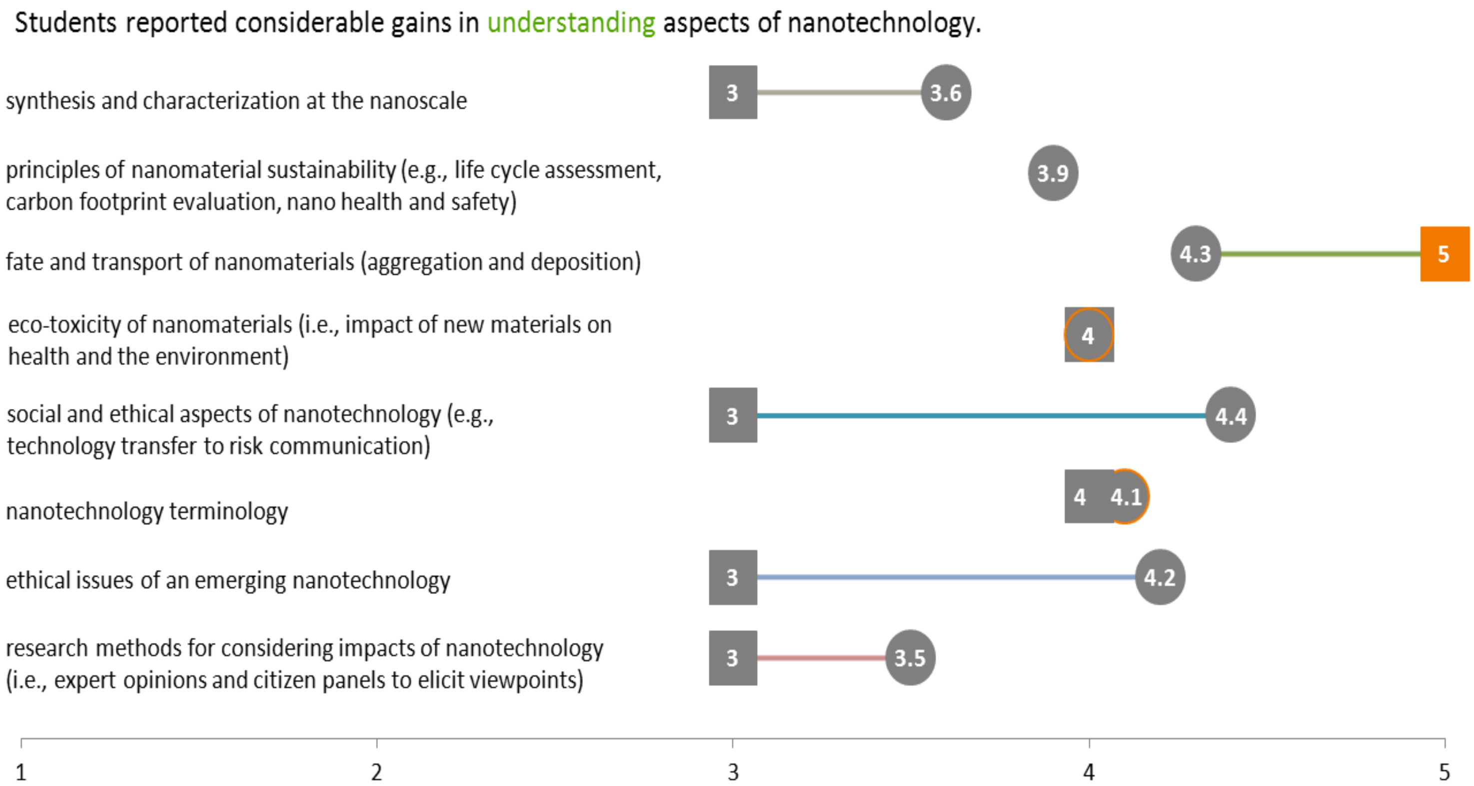
	Yield Strain	Yield Stress (Pa)	Elastic Modulus (Pa)
f-CNT_PAO	0.1068	64.26	77.54

Concept Inventory



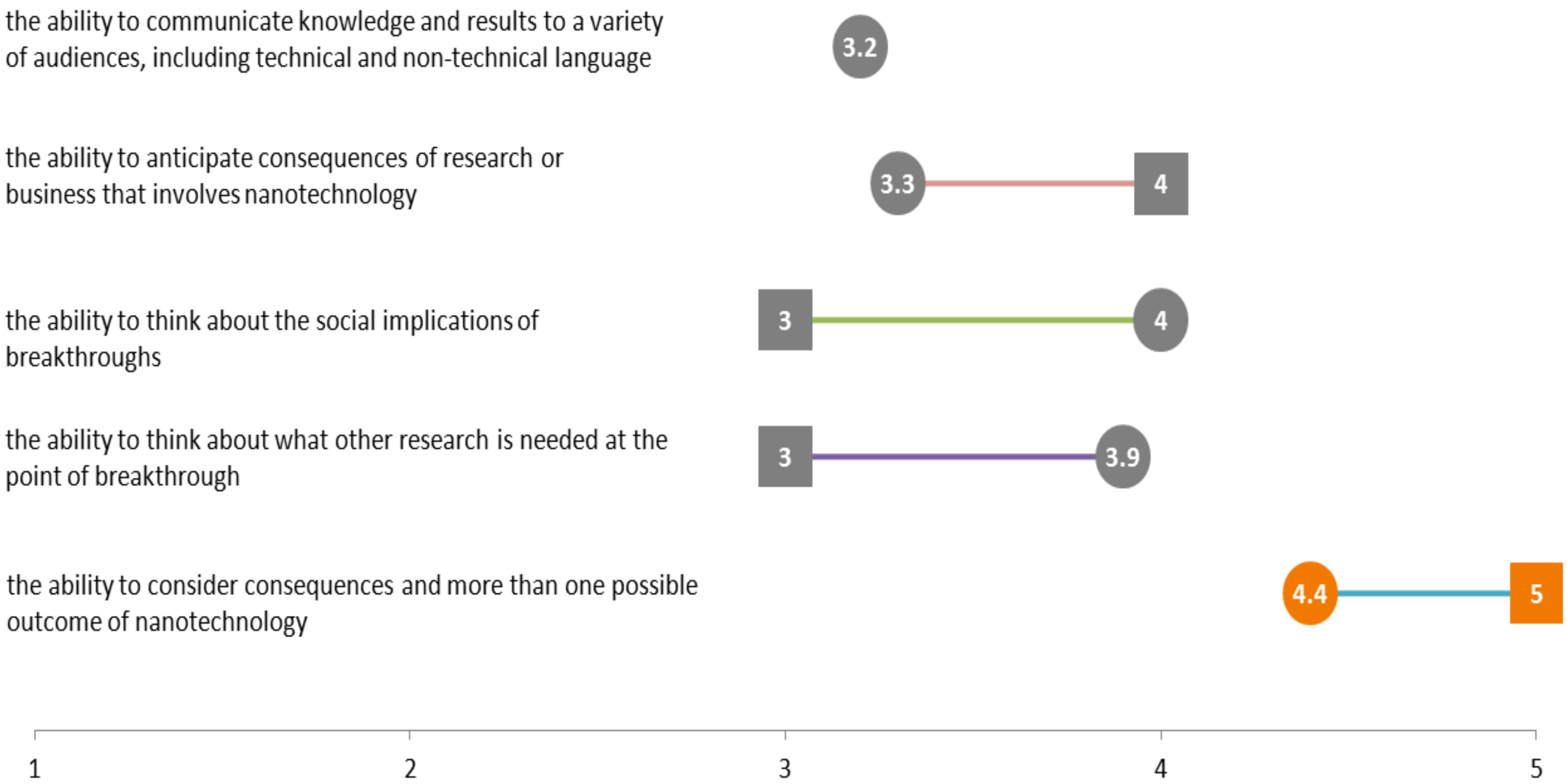
- Significant improvement in correct answers in the post-test

PI and Student Focus Groups: Concepts



PI and Student Focus Groups: Skills

Students gained skills in considering consequences and outcomes to a high degree.



Hands-on Activities in a Workshop at Oaxaca, Mexico

Summary

- PBL is an effective pedagogical technique for teaching nano-scale concepts
- PBL enhances core knowledge and critical thinking
- Focus on integration of social and ethical aspects of nanotechnology allows for better integration
- Hands-on laboratory course can supplement the core knowledge gained in a PBL course
- Activities developed are transferable to workshops, even in a different cultural setting

Acknowledgements

- National Science Foundation (NUE#1445960)





Nano Education Session Summary