THE UNIVERSITY OF RHODE ISLAND
COLLEGE OF ENGINEERING

NUE: Interdisciplinary Nano Tools Course at the University of Rhode Island (3 years summary)

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NUE: Interdisciplinary Nano Tools Course at the University of Rhode Island

- Motivation for Nano Tools
- Syllabus– A “tools-up” approach
- Assessment 3 years
- Conclusions
- Challenges

Nano Tools: Motivation

Nanotechnology education is critically needed to create a skilled domestic workforce to achieve and sustain this growth

Actual and estimated growth of nanotechnology
(NSF WTEC report "*Nanotechnology Research Directions for Societal Needs in* 2020)

	United States (*World*)	
	Primary workforce	Final products market
2000	25,000 (*60,000*)	$13 B (*$30 B*)
2008	150,000 (*400,000*)	$80 B (*$200 B*)
2000-2008	25%	
2015	800,000 (*2,000,000*)	$400 B (*$1,000 B*)
2020	2,000,000 (*6,000,000*)	$1,000 B (*$3,000 B*)

Nano Tools: Objectives

To develop nanotechnology competences and professional skills in undergraduate students within STEM majors at the University of Rhode Island by exposing them to state-of-the-art instruments commonly used in nanotechnology.

- To provide basic knowledge of the principles and operation of nanoscale instrumentations.
- To foster problem-based, peer-to-peer learning through research-oriented group proposal projects.
- To enhance students' technical communication skills through group presentations, journal-formatted project reports, and online learning and professional portfolios.
- To enhance student-faculty and faculty-faculty collaborations to create new research opportunities after the course.
- To expose students to societal, ethical, economic, environmental, and entrepreneurial/commercial implications of nanotechnology through topical seminars.

Nano Tools: ABET

Specific objective	ABET Outcome
Develop an interdisciplinary course that provides basic knowledge of the principles and operation of *Nano Tools*. • *Demonstrate a working understanding of inter-nanoparticle interactions that govern colloidal stability* • *Demonstrate an understanding of the principles and basic operation of the tools covered* • *Identify complimentary information that can be gained from the use of the tools for nanoparticle characterization*	*(a) an ability to apply knowledge of mathematics, science, and engineering* *(b) an ability to design and conduct experiments, as well as to analyze and interpret data* *(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*
Foster peer-to-peer learning through laboratories and problem-based research projects. • *Develop an experimental design that applies Nano Tools to solve an independent research project*	*(b) an ability to design and conduct experiments, as well as to analyze and interpret data, (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*
Enhance students' technical communication skills. • *Demonstrate an ability to self-directed learning, self-reflex of class material and a gain of nanotechnology competences toward professional development* • *Demonstrate an ability to communicate results to an interdisciplinary audience.*	*(g) an ability to communicate effectively* *h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*
Enhance student-faculty and faculty-faculty collaborations. • *Create new opportunities for collaboration and student training.*	*h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*

Nano Tools: Overview

Week	Instrument	Content	Focus
Week 1		Introduction to nanotechnology	
Weeks 2-3	 Dynamic light scattering (DLS)	Physical characterization of hard or soft nanoparticle dispersions	*How nanoparticle composition and dispersing medium determine inter-nanoparticle interactions and colloidal stability*
Week 4		Societal, ethical, and economic implications	
Weeks 5-7	 Transmission electron microscopy (TEM)  Scanning electron microscopy (SEM)	Physical and chemical characterization of hard or soft nanomaterials and nanoparticles Cryogenic studies of nanoparticle dispersions	*How direct imaging under dry or wet (cryogenic) can reveal microstructure and dispersibility* *How composition can be quantified and connected to microstructure*
Week 8		Environmental health and safety implications	
Weeks 9-10	 Atomic force microscopy (AFM)	Physical characterization of hard or soft nano-material surfaces	*How inter-nanoparticle interactions govern film deposition and morphology*
Week 11		Nanotechnology entrepreneurship and commercialization	

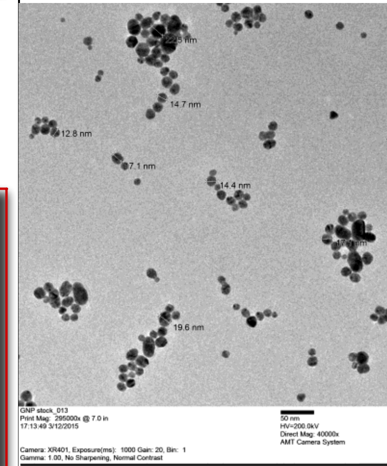
Weeks 4-10

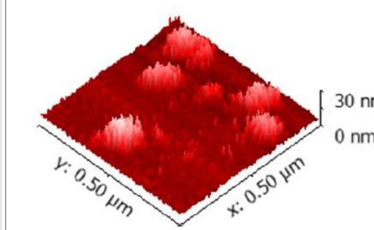
Interdisciplinary group proposal projects: Proposal planning, communication skills, and laboratory training with faculty mentors and their graduate students

Weeks 11-15

Proposal development, preliminary data, and presentations

Figure 1. An overview of the interdisciplinary URI *Nano Tools* course. Green boxes in weeks 4, 8, and 11 denote periods where the PIs and invited speakers will give topical lectures related to the broader impacts of nanotechnology. Black boxes denote periods where technical lecture and laboratory content will be provided on *Nano Tools*. Red boxes denote activities related to independent research proposal planning and development.

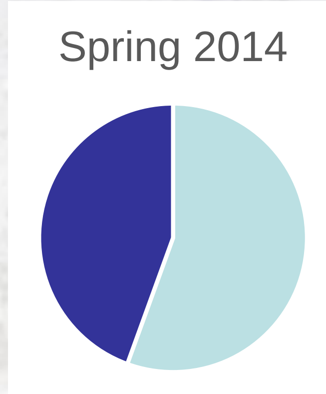


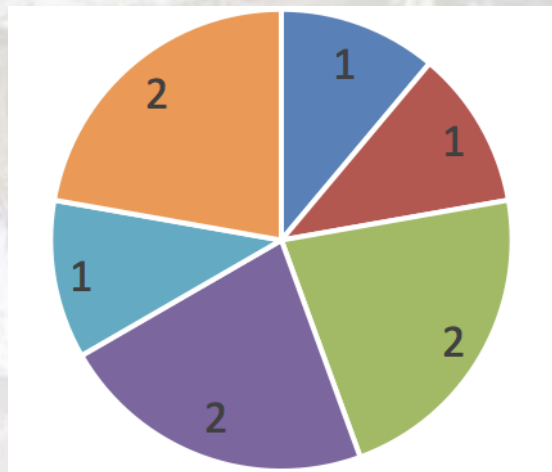


Nano Tools: Syllabus SP2014

- EGR450 Nano-tools is open to any science and engineering student that fulfill the math and physics requirements
- Three lecture instructors (Bothun, Bose and Craver) and one lab instructor (Khan)
- Three credits
  - 1.5 hrs lecture
  - 3 hrs laboratory session
- Lectures and Labs (10 weeks)
  - 2 Lecture: Introduction to nanotechnology
  - 2 Lectures: Interparticle interaction and DLS
  - 3 Lectures: Electron microscopy and TEM and SEM
  - 2 Lectures: AFM
  - 1 Lecture: EHS
- Team Projects
  - 4 weeks: Projects presentation (weekly updates and final presentation)

Nano Tools: Demographics





Physics | Chemistry | Chem. Eng. | Biomed. Eng. | Civil & Environ. Eng. | Elec. Eng.

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Nano Tools: Activities overview

Lectures	Labs	Products
Intro. Nano/DLS	Gold Nanoparticle synthesis DLS intro and use	Nanosuspension (used for the whole course) Histogram hydrodynamic diameter
TEM/SEM	TEM intro. and use SEM intro.	TEM: core particle distribution using software SEM: Image
AFM	AFM Introduction	AFM: Image
EHS	Group activity/Video	Essay

Nano Tools: Science communication

Activity with Journalist Students

- Students in our class were paired with a journalist student. Journalist student were required to prepare a science news piece.

Fighting Cancer in Little Ways

By Kelsey Maloney

KINGSTON – The Rhode Island Consortium for Nano-science and Nanotechnology was established in 2010 by Congress, which conjoined the University of Rhode Island and Brown University to perform research on this developing science. In an interview with Rachel Simon, a first year graduate student in electrical engineering at URI, she explains her work with nano-medicine and her research into the use of nano-particles to treat cancer.

"One of the huge problems with currently existing cancer treatments is that they've been working at the wrong scale," said Simon. "For example, with radiation, you have to expose healthy tissue as well as the tumor you're trying to kill. However, nanotechnology lets us get down to the actual cellular level to possibly only kill the tumor."

Simon and her student group have been working with data developed by faculty, which shows that cancer cells are absorbing these nano-particles successfully. Through their research so far, what has been shown is that by using grown cancer cells in the lab, then applying these nano-particles to them, the nano-particles can successfully pierce through the cell. Today, they have moved onto trying to figure out how to deliver this new treatment in the human body.

"So in real life, we have to be able to inject this into the bloodstream and make sure that the nano-particles will work well in human blood," said Simon. "We've started off by taking these nano-particles and breaking down human blood, which can be very complex because human blood has a number of components."

Simon explained how they are going through this process step by step. First, they have tried seeing how nano-particles interact with the salts dissolved in blood and the next step was protein, and so on. They will go through this process with every component in human blood.

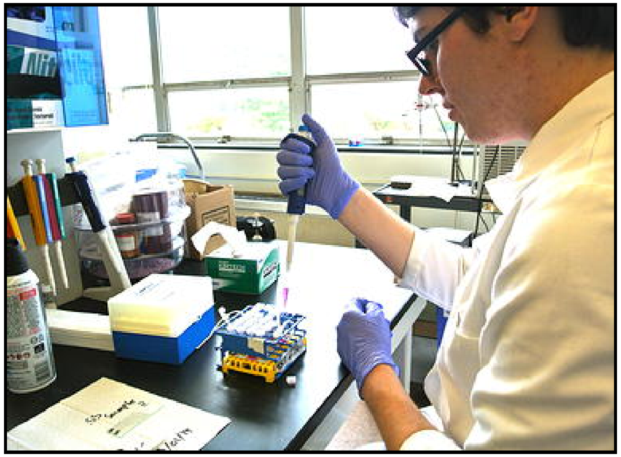


Photo credit by Kelsey Maloney

Simon and her group are using a number of nanotechnology instruments and tools to perform these tasks. One of them being a tool called Dynamic Light Scattering, which is a way of estimating the size of nano-particles. Another tool is called the Transmission Electron Microscope (TEM), which allows them to visualize the nano-particles.

"The TEM is a very impressive tool considering that these nano-particles are about a thousand times smaller than the width of a human hair," said Simon.

To Watch Video Click Here

Nano Tools: Assessment

- Summative Assessment:
  - Pre and post: content based and perception based questions
  - Scientific ability rubric modified from Rutgers University Physics and Astronomy Education Research (PAER) group and Wansom S. et al. (2009)*

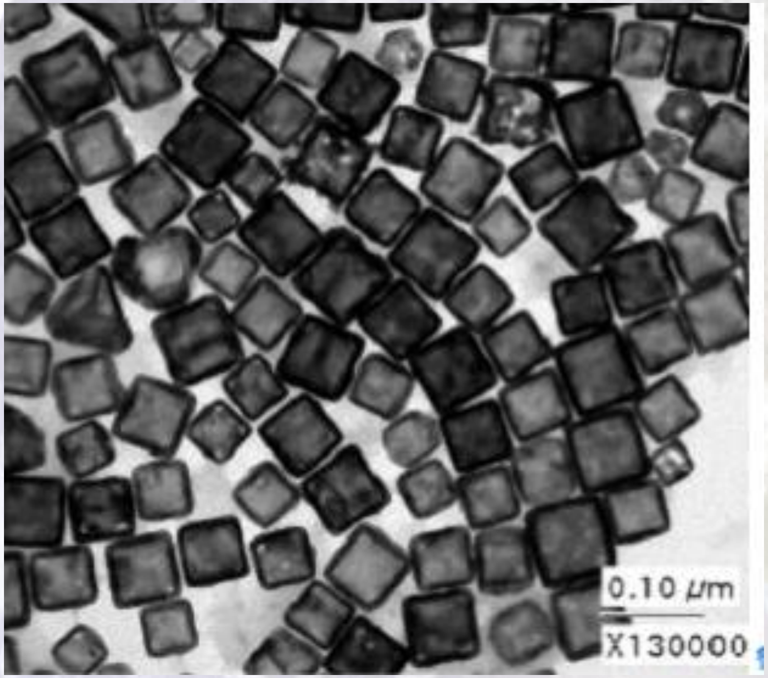
*Wansom, S., Mason, T.O., Hersam, M.C., Drane, D., Light, G., Cormia, R., Stevens, S., Bodner, G. (2009) A rubric for post-secondary degree programs in nanoscience and nanotechnology. International Journal of Engineering Education 25 (3), 615-627

Nano Tools: Summative Assessment Rubric

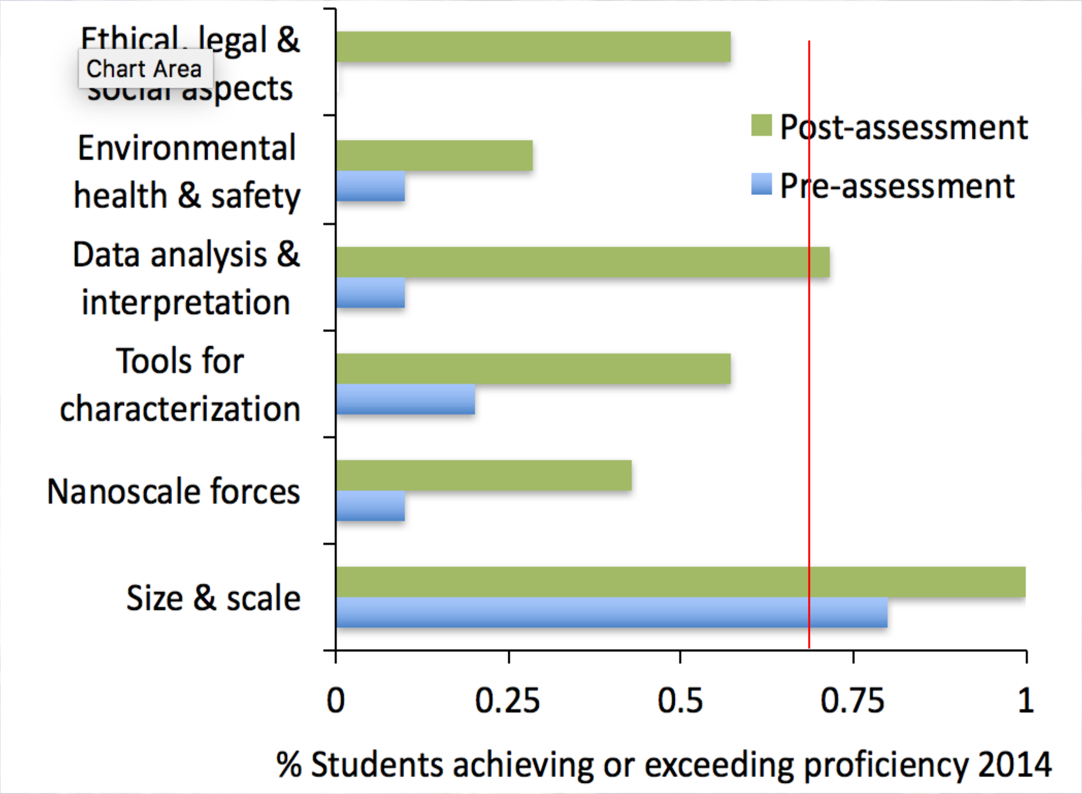
		Not yet proficient (1)	Developing proficiency (2)	Achieving proficiency (3)	Exceeding proficiency (4)
(G.1) Size & Scale	At the nanoscale, factors relating to size and scale (e.g., size, scale, scaling, shape, proportionality, dimensionality) help describe matter and predict its behavior. Students must be able to appreciate and compare the sizes of objects on all scales.	Not able to identity scale	An attempt is made to identify the scale of different materials, but several mistakes are made	A student properly identify most of the materials' sizes	Student successfully identify all of the materials' sizes
(G.2) Forces	Students must demonstrate a basic understanding of the DLVO theory and quantum mechanics	Not able to identity forces	Some force are identified correctly but some of explanations are incorrect	All of the forces identified are correct, but some are missing	All significant forces are identified and all explanations are correct
(A.1) Effect of nanoparticle composition and environmental conditions on interparticle forces	Students must be able to explain the effect of nanoparticle composition and the physicochemical characteristics of the bulk solution on the interparticles forces and therefore nanosuspension stability	Not able to explain interactions	Some interactions are identified correctly but some of explanations are incorrect	All of the interactions are identified correctly but few of explanations are incomplete or partially correct	All significant interactions are identify and all explanations are correct
(A.2) Tools & Instruments/ Characterization	Students must be able to identify the principles and basic operation of the different tools.	Not able to identify principle of tools	Some principles are described correctly but others are incorrect explained.	All of the principles are identified correctly but few of explanations of are incomplete or partially correct.	All principles are identified and all explanations are correct.
(A.3) Data analysis from tools	Students must be able to identify complimentary information that can be gained from the different tools	Not able to interpreter any data	Student is not able to interpreter the data outcomes of each tool	Student is able to interpreter most of data outcomes of each tool correctly	Student is able to interpreter correctly data outcomes from each tool
(G.3) Environmental Health and Safety	Students must demonstrate an understanding of the possible routes of exposure to nanoparticles, implications of physicochemical conditions and the difference between chronic and acute effect	Not able to identify EHS concepts	Some concepts are correctly but others are incorrectly explained.	All of the concepts are identified correctly but few of explanations of are incomplete or partially correct.	All principles are identified and all explanations are correct.
(G.4) Ethical, Legal and Social Aspects	Students must be able to articulate the ELS aspects large scale application of nanotechnologies.	Not able to explain ELS aspects	Some concepts are correctly but others are incorrectly explained.	All of the concepts are identified correctly but few of explanations of are incomplete or partially correct.	All principles are identified and all explanations are correct.

Nano Tools: Summative Assessment Examples Questions

6.- The figure below shows two images of different batches of gold nanoparticles. Can you identify the tool used? What type of quantitative and qualitative information can you obtain from it?. What type of information would you need to obtain a more reliable analysis of the image. [Objective A.iii]



Nano Tools: Summative Assessment

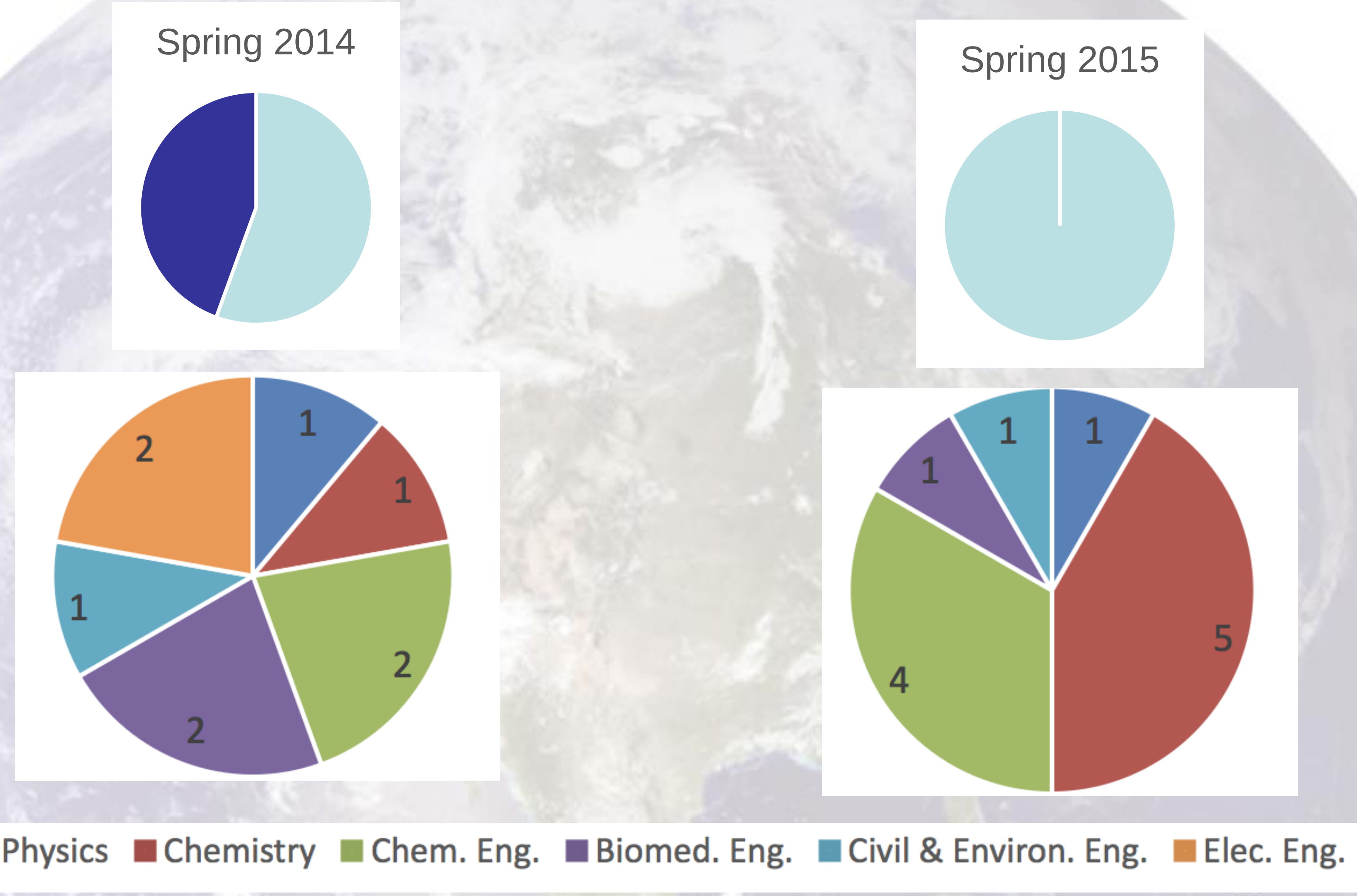


Our objective is up to 70% of proficiency in each area.

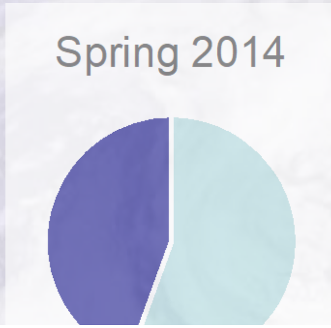
Nano Tools: Students comments

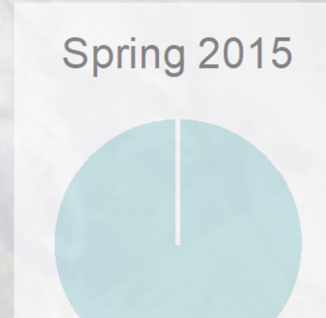
What was the most effective part of this course?	What are your suggestions for changes that would improve this course?	What do you consider to be the most important?
Learning tools (in class brief description) and using them. It gave us confidence.	Make the final project last all year. Use each instrument and write a status report then at the end of the year present all data gathered.	How images can be taken and what equipment to use depending on what information you want to collect.
Working with older students in the lab was a great learning experience.	Don't squeeze AFM and project into last few weeks together; make project semester long learning experience.	Hands on experience, basic lab chem, contaminants concerns, instrument operation.
Using each machines yourself and completing a research project in which you apply the skills you have learned.	Final project should have started earlier. More concise lessons, some felt repetitive and it seemed like that time could have been used to the project.	Being introduced to the nanoworld at all. This course made me think a lot about my future in terms of research or even a career.
Research project. Learned how to work better in groups, time management with respect to balancing research projects and other classes. Learn about mentors.	Maybe more basic chemistry first because I had chemistry classes in a while and forgot some things. A quick review could have been useful.	Developing skills to use the instrumentation and more importantly, analyzing and interpreting the results from the instrumentation.

Nano Tools: Demographics 2Y

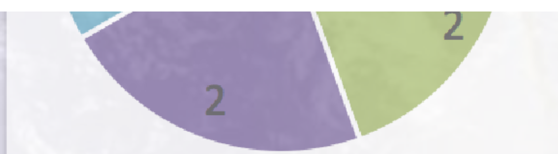


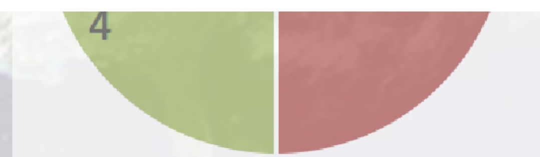
Nano Tools: Demographics



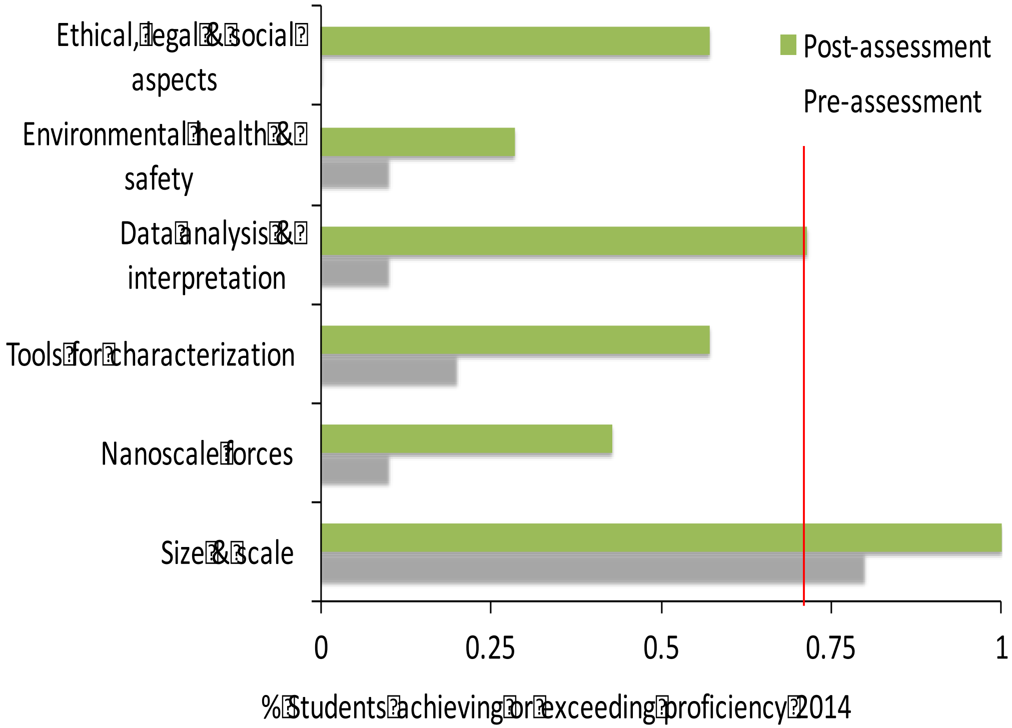


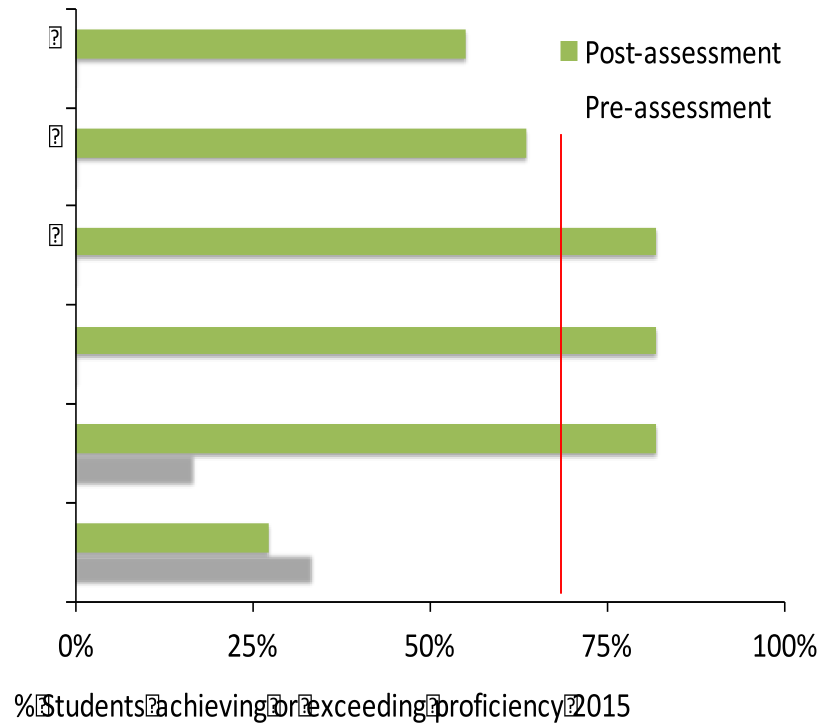
1) Provided **pre-laboratory videos** that covered basic operation.
2) **Utilized "pathway of light, electrons, or AFM tip"** to illustrate instrument principles and ability to determine nanoscale properties.
3) Eliminated SEM and **focused on DLS, TEM, and AFM**.
4) Provided **extra "out-of-class" time** on the instruments.
5) **Demonstrated data analysis** tools and **discussed interpretation** in class using student data.
6) Initiated **independent research projects with faculty mentors** near the beginning of the semester.





Nano Tools: Summative Assessment 2Y





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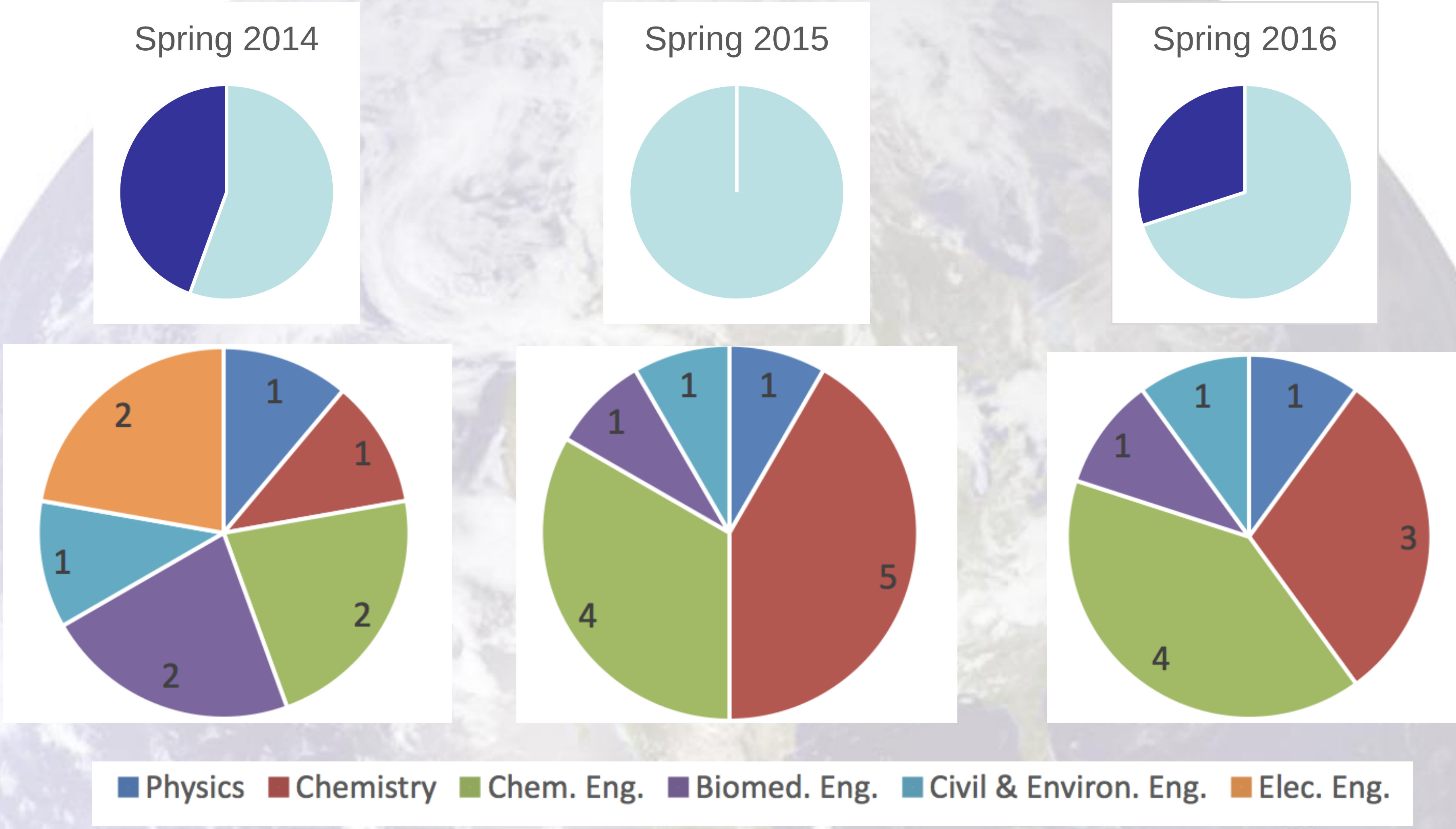
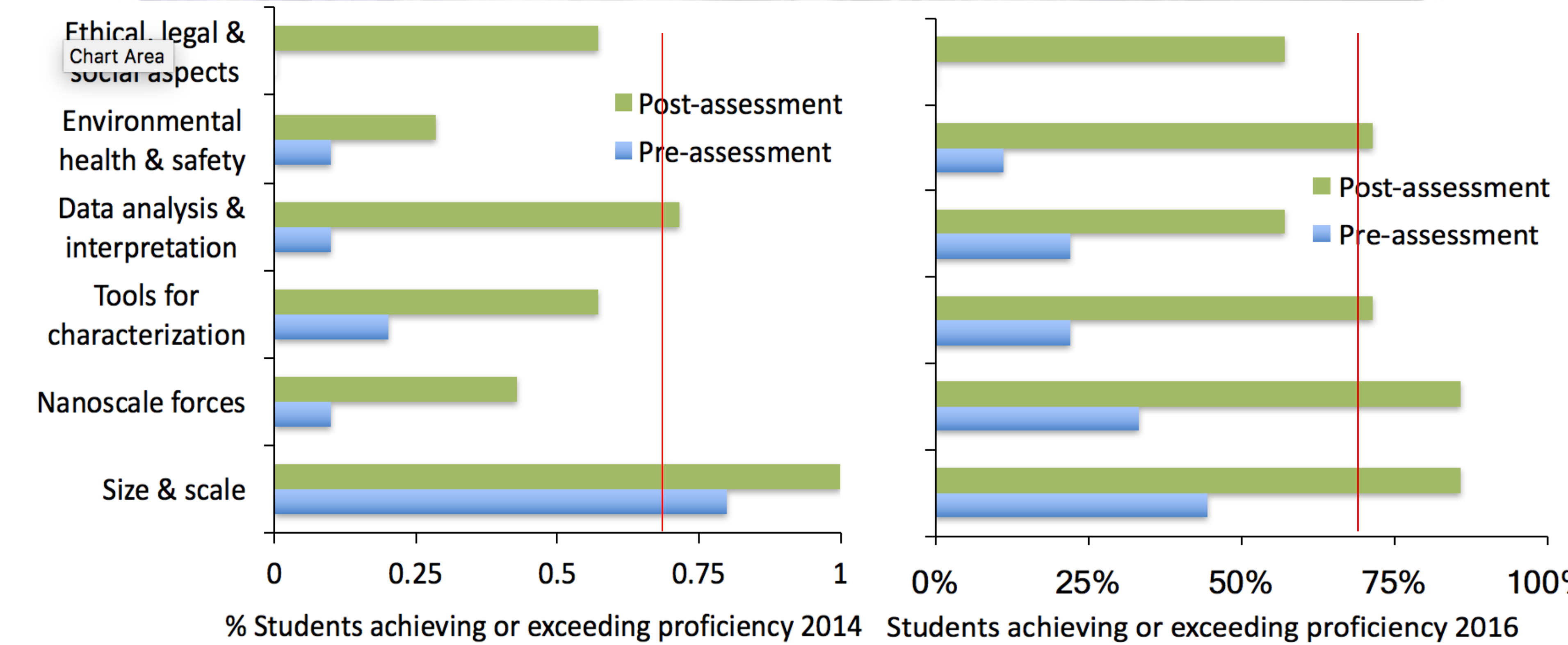
Nano Tools: Demographics 3 Y



Nano Tools: Summative Assessment



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Nano Tools: Conclusions

- **Starting with the tool**, students learn how nanoscale properties are determined through theory reinforced by experimentation.
- Discussing **complimentary results from different instruments** reinforces the fundamental basis for each technique and empowers students to make decisions on what properties to measure, how, and why.
- **Applying nano tools to mentored research projects** connects the instrumentation to applications and reinforces knowledge.

Nano Tools: Challenges

- Great experience for students and instructors, BUT time consuming and expensive.
- Students have varied backgrounds and laboratory experiences.
- Extensive hands-on work needed to be proficient using a “nano tool.”
- Mentors understand objectives of the course and align their projects accordingly.
- Internal support to sustain the course…

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Questions?

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