Investigators
Dr. Zayd C. Leseman (PI)
Dr. Mani Hossein-Zadeh (co-PI)
Dr. Matthias W. Pleil (co-PI)
Dr. Claudia C. Luhrs (co-PI)

An Integrated Multidisciplinary Nanotechnology Undergraduate Education Program at the University of New Mexico

Funded by: Division of Engineering Education and Centers – Mary Poats Nanotechnology Undergraduate Education (NUE) in Engineering (Grant# EEC-1042062)

NEED **: "Educating undergraduate students at the University of New Mexico (UNM) and New Mexico (NM) STEM educators about the basic concepts, techniques, applications and the current state of Nanoscience and Nanotechnology (*NS&NT*), in order to produce an informed citizenry and competitive workforce in this emerging field"**

APPROACH : *Development of lecture/laboratory modules for undergraduate students (UG), courses devoted to NS&NT training STEM educators and involving the UG in NS&NT research.*

(1) Creating of a program in NS&NT for undergraduates at UNM and **NM STEM Educators.**
- Creation of 4 new courses dedicated to different aspects of Nanoscience and Nanotechnology (NS&NT).
- Including NS&NT modules in core courses in both the Mechanical and Electrical Engineering programs.
- Developing teaching modules for K-12 and the teaching of STEM Educators using undergraduate assistance.
- Including components of the NS & NT material in STEM Educator Workshops.

(2) Institutionalize NS&NT into the UNM-SOE curriculum.
- A concentration in NS&NT will be available to students who complete 3 NS&NT courses across the School of Engineering.
- Every year courses on NS&NT will be available to attract more students to this concentration.

(3) Fuse NS&NT education with research from the co-PI's NS&NT Research.
- Hiring undergraduate students to participate in research activities as research assistants.

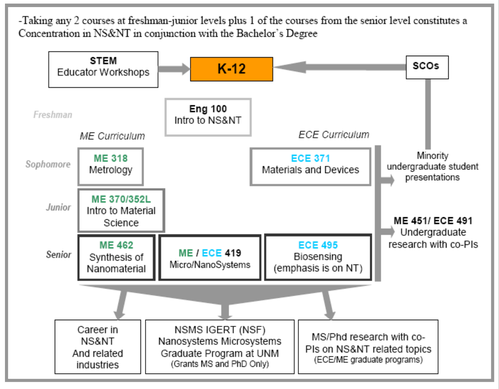
* Three junior faculty members and one research professor of engineering education from two engineering programs, Mechanical Engineering (ME) and Electrical & Computer Engineering (ECE), have employed their Collective effort to institutionalize NS&NT in UNM's School of Engineering:

-**Dr. *Zayd C. Leseman*** (Associate Professor of ME)
(*Research*: Physics of nano/micro-materials, adhesion of of micro/nanodevices, length scale effects in thin films, Phononic Crystals and alteration of the electrical, magnetic, and thermal properties.)

-**Dr *Mani Hossein-Zadeh*** (Assistant Professor of ECE)
(*Research*: High-Q optical microresonators, Nanophotonics, Microwave photonics and Photonic sensing)

-**Dr. *Matthias W. Pleil*** (Research Associate Professor of ME)
(Dr Pleil has 12 years experience in semiconductor manufacturing and is the Principal Investigator for the Southwest Center for Microsystems Education (SCME), faculty member at Central New Mexico Community College, and former Board Member to the ASK Academy,a New Mexico Charter School focused on STEM education.)

-**Dr. *Claudia C. Luhrs*** (Assistant Professor of ME)
(*Research*: Nanostructured materials, novel synthetic pathways for their preparation, characterization of their crystal structures, properties and reactivity, production of nanosized metal particles, nano-scale ceramic/metal and metal/carbon composites.)

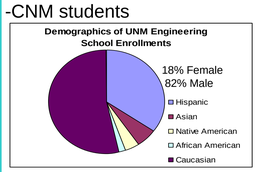


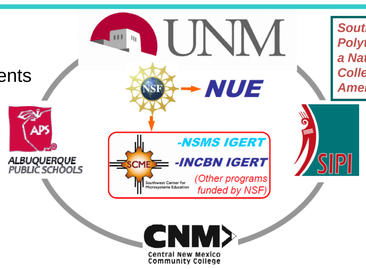
BENEFITS

- Training students that have a working knowledge of NS&NT and become valuable research assistants even as undergraduates.
- K-12 Shareable Content Objects (SCOs) will be developed and presented to high school teachers and students.
- Familiarizing New Mexico students with NS&NT without straining the curriculum of the two lead departments and financially burdening the students.
- Between the two leading departments of the project (ME and ECE) more than 328 undergraduate students will be exposed to the NS&NT material. Out of that number, 158 students are minorities (mostly Hispanic and Native Americans) and 44 are female students.
- Components of the NS&NT material developed will be presented at STEM Educator Workshops.

TARGET AUDIENCE

-UNM undergraduate students
-High school teachers and students
-STEM educators
-CNM students





Southwestern Indian Polytechnic Institute (SIPI) is a National Indian Community College for educating Native American students.

University of New Mexico is the home for three NSF funded programs/centers

-**NSMS IGERT**: The **N**ano**S**cience and **M**icro**S**ystems program highlights three technical thrusts; Informational Nanotechnology, Nano-Bio Interfaces and Complex Functional Systems (URL: http://nsms.unm.edu/igert/index.html).
-**SCME**: The **S**outhwest **C**enter for **Mi**crosystems **E**ducation offers professional development and educational materials to excite and engage secondary and post secondary students in the field of Microsystems (MEMS) technology (URL: http://scme-nm.org).
-**INCBN IGERT**: The vision of **I**ntegrating **N**anotechnology with **C**ell **B**iology and **N**euroscience is to develop a new cadre of interdisciplinary scholars with excellent research skills, prepared for challenges of the 21st century brought by the nanotechnology revolution (URL: http://www.chtm.unm.edu/incbnigert/).

DELIVERABLES

UNDERGRADUATE EDUCATION

COURSE Development and Improvement

- New nano material modules have been added to ME 519/419:"Micro and Nanosystems" (this course is cross listed in ECE and NSMS program)
- New nano material modules have been added to ME 260L:"Mechanical engineering design-II"
- For the first time NS&NT topics have been added to ECE-371:"Materials and Devices" (this is a core course in the ECE undergraduate program)
- "Introduction to modern biosensor technologies" has been created as a new special topics course ECE department. One third of the course material is focused on nano-mechanical, nano-electronic and nano-photonic biosensor technologies.
- New nano material modules have been added to ME 370:"Introduction to material science"

- Examples of term papers written by ECE undergraduate students who took the modified version of the "ECE-371: Materials and Devices" and the new "ECE 495/595: Introduction to Modern Biosensor Technologies":

-Nanofabrication: Nanoimprint technique
-Nano transistors based on carbon nanotube
-Carbon nanotube radio
-Application of Quantum dots in biomedical imaging
-EHS impacts of nanotechnology (nanotoxicology)
-Electrochemical Energy Storage Application of Carbon Nanotubes
-Nanoscience and nanotechnology in biology and medicine
-Nanoantenna:plasmonic and molecular spectroscopy
-Application of Quantum Dots in LED design
-Nanoantenna
-Nanowire transistor
-Application of graphene in digital logic memory design
-Nanowire based biosensors
-Carbon nanotube biosensors
-Micro and nano-mechanical biosensors
-Ion channel based biosensors
-Biosensing with nanochannel cantilever

Example of a success story!

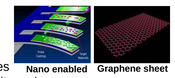
Juanita Trevino is an excellent example of the success from our program. Juanita, a recent graduate (BS) in the Mechanical Engineering Department at UNM, was a direct recipient of funds from the NUE Award. Not only did she take courses that had components added from funds from the NUE she also participated in NanoScience research in the laboratories of the co-PIs. In her research as an undergraduate she published a paper in the highly cited journal NanoLetters. Due to her positive experiences in our program she decided to begin her PhD studies in the NanoScience and MicroSystems (NSMS) program at UNM. Her PhD project is supported by her NSF Fellowship and ZL's NSF CAREER Award wherein she researches thermal transport at the nanoscale.

EFFORTS ON INSTITUNALIZATION OF NS&NT

PI *Leseman* has proposed NS&NT Certificates be issued by each department for students of courses that who have completed a pre-determined set cover NS&NT topics such as those being developed previously and currently by the co-PIs. The path to implementation begins at each department's undergraduate committee level with a proposal. ZL is developing the proposals for these certificates by corresponding with each department's committee. After each proposal is approved the Associate Dean for Academic studies in UNM's School of Engineering must sign off on the proposal and then it is instituted. ZL has already discussed this plan in great detail with Associate Dean Fleddermann and he has tentatively agreed to any such proposal. ZL has also attained tentative approval from the chairs of the different engineering departments. Once the undergraduate curriculum committees approve the proposals the department chairs and Associate Dean should sign it off on it in a reasonable amount of time. Implementation into the curriculum is anticipated for the Fall 2012 semester.

ENG 100: "Introduction to Nano Technology"

This course is offered for the first time in summer 2012 and is not only for undergraduate science, engineering and technology majors, but also K-12 educators and secondary students, in addition to anyone interested in learning about Nano. Students gain a broad understanding and a core set of vocabulary of the science and technology used in the creation and manufacturing of nano-enabled applications. As a web enhanced, hybrid course (part online, part face-to-face), it includes hands-on in class lab activities to engage student learning.
- Topics include a historical perspective of Nanotechnology, Micro/Nano applications, nano in nature, career pathways for the Micro/Nano technologist, and material properties at the nanoscale (optical, crystals, hydrophobicity, and surface to volume ratio, for example).
- No book is required, and all materials are provided online.



UNDERGRADUATE RESEARCH

Undergraduate students employed as research assistants during the first year of the project:

- Zayd Leseman's Group
1. Drew Landis (ME-UNM) Project title: " Design, fabrication and implementation of a Michelson Interferometer for ME-318"
2. Jason Walker (SIPI) Project title: "Fabrication of Nanoscale Thermal Transport Measurement Device"
3. Joshua Begay (SIPI) Project title: "6 Degree of Freedom NEMS Stage"
4. Calvin Silas (SIPI) Project title: "Stiction Failure of Nanodevice"
5. Denise Pinon (ChemE-UNM) Project title: "Release of Nanostructures with XeF_2"

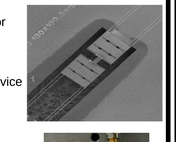
- Mani Hossein-Zadeh's Group
1. Mitchell Conner Malone (ECE-UNM): Project Title: "Biochemical sensor based on microwave resonance and carbon nantotubes".
2. Rene Zamora (ECE): Project title: "Nanoparticles detection with tapered optical fibers"

- Claudia Luhr's Group
1. Ricardo Martinez (ME). Project Title: "Alternative Methods for Graphene Synthesis".
2. Jaime Neeley (ME). Project Title: "Point of Zero Charge Measurements in Carbonaceous Electrode Materials".
3. Oren Raz (ME). Project Title: "Development of Capacitor Materials".
4. Phillips A Jones (ME). Project Title: "Growth of Carbon Fibers on Tungsten Sulfide"

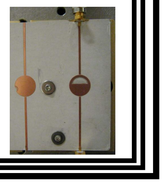
Student training: Two students have been trained to use X-ray diffractometer and received instruction regarding the fabrication of nanomaterials (Plasma aerosol, Wet chemistry, CVD and Expansion-reduction approach). One student was trained to use Scanning Electron Microscope and Transmission Electron Microscope and became an advance user of both instruments. One student was trained to use an advanced microwave simulation software (HFSS) and fabricate microwave boards. Other students have been trained to use various tools in the cleanroom as well as using LabView software.

- Interferometer setup designed and built by Drew Landis. The inset is the pattern produced by interfering the laser with itself off a 'flat' surface with He-Ne laser. Using the interference displacement and roughness can be measured down to 500 nm. This interferometer is currently used in ME-318.

- Freestanding SiNx platform fabricated for measurement of thermal conductivity of nanostructures. One of the projects that undergraduate student Jason Walker is working on. Jason has fabricated this device in UNM's MTTC cleanroom.



- Microdisk RF resonator fed by a microstripline to study the interaction between carbon nanotubes and microwave for sensing applications. The structure is designed and fabricated by the ECE undergraduate student Mitch Malone. Mitch became interested in the subject after taking the "Introduction to modern biosensning course" that has been developed as a result of this grant.



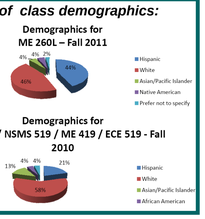
OUTCOMES

What we have learned:

Education
- Even with minimal background it is possible to introduce advanced topics in NS&NT. Especially fabrication and characterization techniques that do not require advanced mathematical background are easily understood and make the student very excited about the subject.
- Encouraging the undergraduate student to read research papers (in the context of class projects and term papers), helps the transition from relying on well defined textbook material to using scattered information on research papers as they get involved in research projects.
- Involving students in development of experimental setups for lab courses improves their self-confidence, design skills and in the meantime improves the course for the following semesters.
- Once the students are exposed to the application of the material they learn in the core course in NS&NT applications (as one of the emerging fields with significant national investment), they pay more attention to fundamental concepts.

- Research
- Undergraduate students can help in different aspects of the research projects with minimal training and background. Specifically for fabrication and characterization tasks they quickly learn the skills and in many cases they are more excited than graduate students.
- Due to lack of background and bias undergraduate students can think out of the box and be very creative.
- Involving undergraduate in research helps the graduate students to develop their mentoring and teaching skills and prepares them for academic positions.

Examples of class demographics:



Survey for ME370 (Introduction to material science)
> Questions:

Did the nanomaterials modules increase your awareness of:
1. **Basic definitions regarding nanomaterials**
2. **Methods used to generate nanomaterials**
3. **Characterization methods commonly employed to analyze nanomaterials**
4. **Applications of nanomaterials**
5. **Impact of nanotechnology in society**
6. **Future trends in nanotechnology**
7. **Are you planning to take other courses in nanotechnology within the ME Curriculum?**
8. **After taking ME370, would you now be interested in taking ME461-E (Theory, Fab, and Char of NEMS/MEM)**
9. **After taking ME370, would you now be interested to take ME462 (Nanomaterials preparation and characterization)?**

Question / Answer (1 lowest, 5 highest)

	5	4	3	2	1
1	14	17	3	0	0
2	12	15	5	1	0
3	8	16	7	2	0
4	11	15	8	0	0
5	8	15	20	0	0
6	6	14	12	1	0

	YES	NO
7	10	20
8	17	12
9	17	11

Survey for ECE-371 (Materials and Devices)
> Questions:

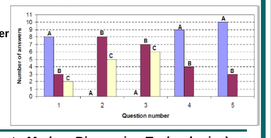
1-Your knowledge about nanoscience and nanotechnology (NS&NT) before taking ECE371: A) No knowledge B) Very limited knowledge C) Fairly good understanding of the field

2- Your knowledge about nanoscience and nanotechnology (NS&NT) after taking ECE371: A) Did not change B) Improved C) I learned a lot

3- Did you find the NS&NT topics covered in the class useful?
A) Not useful B) Useful C) Very useful

4- Did you continue reading more about NS&NT topics after the semester (internet, papers, books)?
A) Yes B) No

5- Will you consider a career in one of the NS&NT related disciplines?
A) Yes B) No



Survey for ECE-495 (introduction to Modern Biosensing Technologies)
> Questions:

1-The level of your knowledge about nanoscience and nanotechnology (NS&NT) in general: A) Has not changed B) Slightly improved C) I learned a lot

2- The level of your knowledge about application of nanoscience in biosensing: A) Has not changed B) Slightly improved C) I learned a lot

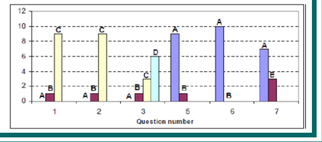
3- How many articles have you read about NS&NT based biosensing (internet, books, journals) during this semester?: A) None B) 1-5 C) 5-10 D) more than 10

4- Which one of these topics did you find more interesting? A)Nanofluidics B)Carbon nanotubes C)Nanowires D)Quantum dots E)Nanoparticles F)Nanomechanics

5- Will you consider taking more NS&NT related courses (ECE or other departments)? A) Yes B) No

6- Will you consider career opportunities in NS&NT? A) Yes B) No

7- Did you find any relation/connection between your research or ECE track and NS&NT? A) Yes B) No



- This material is based upon work supported by the National Science Foundation under Grant No. EEC-1042062.
- Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.