INTEGRATING STANDARDS EDUCATION INTO THE NANOMATERIALS ENGINEERING CURRICULUM

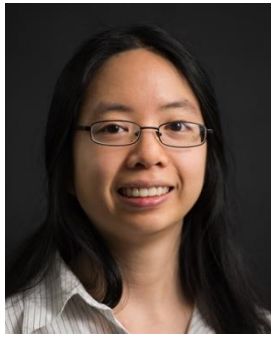
Stacey M. Louie[1] and Jiming Bao[2]
University of Houston
[1]Civil & Environmental Engineering
[2]Electrical & Computer Engineering

PROJECT OVERVIEW

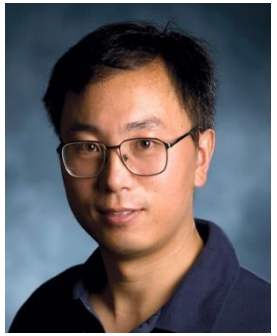
Incorporate standards education related to nanotechnology into two engineering courses at the University of Houston (UH)

- CIVE 7397 (Experimental Methods in Nanomaterials Engineering)
- ECE 5320/6307 (Nanomaterials and Solar Energy)

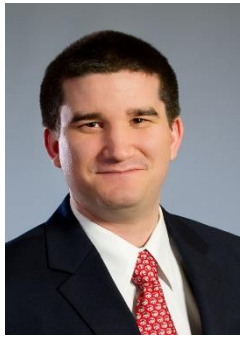
UH Personnel



Dr. Louie (PI)



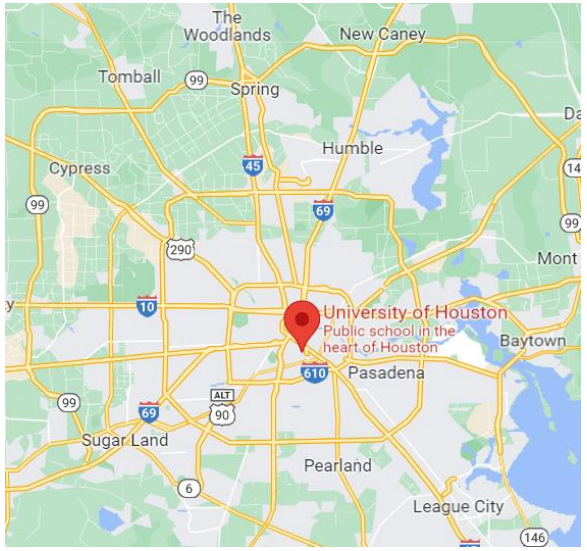
Dr. Bao (Co-PI)

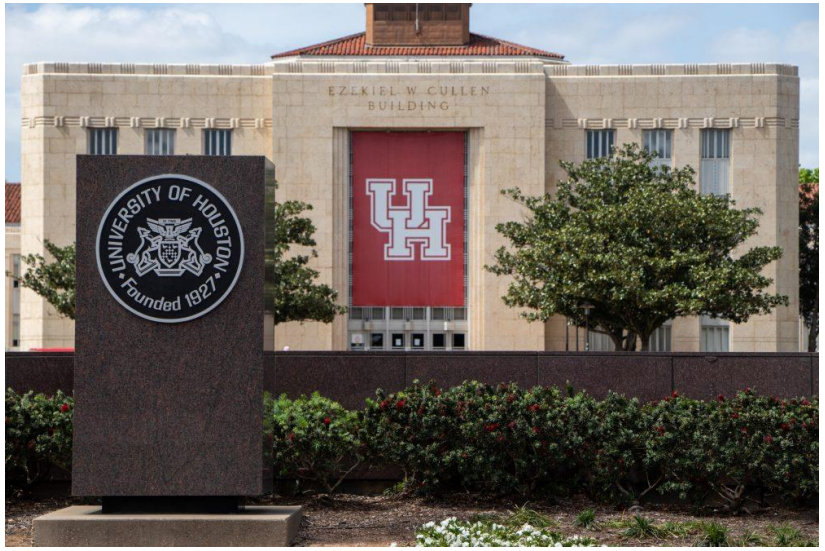


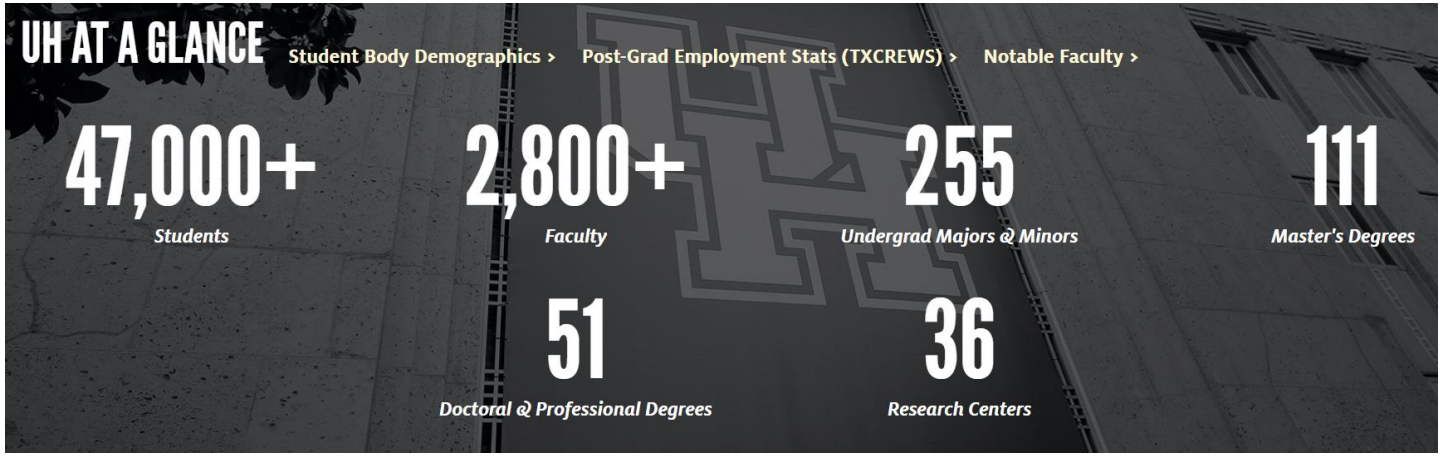
Dr. Kapral (Evaluator)

Disseminate educational modules through collaborations with partnering institutions (academic and industry)

UNIVERSITY OF HOUSTON







- Carnegie Tier One research university
- Student population:

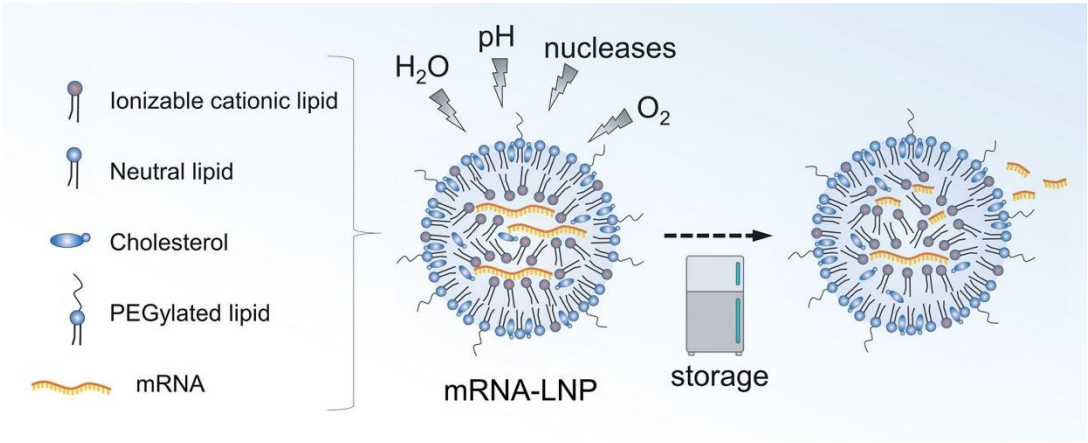
  ≈ 80% undergraduate,
  ≈ 20% graduate / professional
- Hispanic Serving Institution (> 30%)

CULLEN COLLEGE OF ENGINEERING

- Seven departments
  - Biomedical
  - Chemical & Biomolecular
  - Civil & Environmental
  - Electrical & Computer
  - Industrial
  - Mechanical
  - Petroleum
- Enrollment: 4,276
  - ≈ 70% undergraduate, ≈ 30% graduate
  - 30% Hispanic

NANOTECHNOLOGY EDUCATION

- Established research field (since the 1980s)
- Applications in research and industry are rapidly growing
  - Electronics/semiconductors
  - Nanomedicine (e.g., COVID vaccine)
  - Environment, health, & safety (EHS)
- Active standards development
  - ISO TC 229 – Nanotechnologies
  - ASTM Committee E56 – Nanotechnology
  - IEC TC 113 – Nanotechnology for electrotechnical products/systems



Schoenmaker et al., 2021, *Int. J. Pharmaceutics*, 601: 120586

NIST SSCD PROGRAM: TEACHING GOALS

- Develop an understanding of standards pertaining to vocabulary, classifications, and characterization related to nanomaterials
- Develop student skills and confidence in implementing and critically evaluating standard test methods
- Promote an appreciation for the value of standards and the standards development process

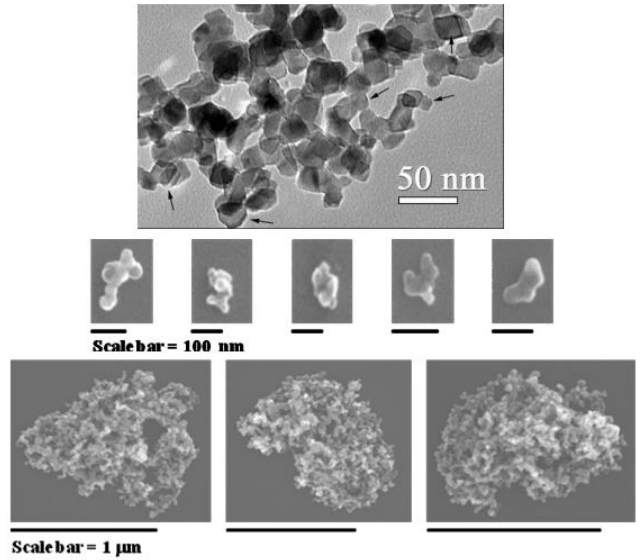
COURSE OVERVIEW

- **CIVE 7397** (Experimental Methods in Nanomaterials Engineering)
  - New lecture- and laboratory-based course on analytical methods
  - Graduate students in engineering
- **ECE 5320/6307** (Nanomaterials and Solar Energy)
  - Existing course (> 10 years), cross-listed with Materials and Chemical Engineering
  - Combined undergraduate and graduate students

CLASSROOM-BASED COURSE CONTENT

- **Course modules to introduce standards for nanotechnology**

Classroom-Based Educational Modules	Documentary Standards	Learning Objectives	Delivery and Evaluation Modes
(1) Standard Vocabulary and Definitions	• ISO/TS 80004-1:2015 • ASTM E2456-06	• Students develop familiarity in applying and implementing standard vocabulary	• In-class discussion and quizzes
(2) General Characterization and Reporting Requirements	• ASTM E3144-19 • ASTM E3206-19	• Students develop an understanding of the challenges in characterizing nanomaterials and the importance of standard test methods	• Hands-on laboratories with lab reports and discussion questions (see Aim 1.1.2)
(3) Importance of Standards for Nanotechnology Applications and EHS Assessment	• ASTM E3025-16 • IEC TS 62876-2-1:2018	• Students develop an appreciation of the real-world value of standards and the role of standards in competitiveness and innovation	• Case studies and pre-/post-surveys



NIST SRM 1898 Certificate of Analysis

Phornano Holding GMBH. Nano Gold, 2022, https://www.phornano.com/4ngold

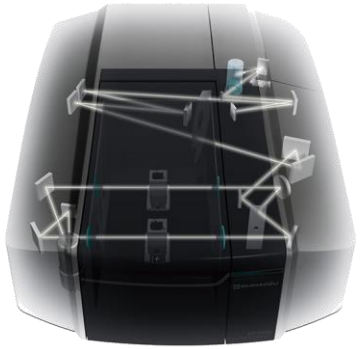
- **Demonstration activities**
  (Gold nanoparticle synthesis and behavior)
- **Standards development**
  (Guest lectures – NIST and industry scientists)

LABORATORY-BASED COURSE CONTENT

Implement and evaluate standards for nanomaterial characterization

- Four shared laboratories between CIVE/ECE courses
- One application-specific laboratory per class

UV-Vis Spectroscopy (ISO/TS 17466)



(Shimadzu, UV-2600i, https://www.shimadzu.com/an/products/molecular-spectroscopy/uv-vis/uv-vis-nir-spectroscopy/uv-2600i-uv-2700i/index.html)

Fourier Transform Infrared Spectroscopy (ISO/TS 14101)

(ThermoFisher Scientific, Nicolet™ iS™ 10 FTIR Spectrometer, https://www.thermofisher.com/order/catalog/product/IQLAADGAAGFAHDMAPC)

Dynamic Light Scattering (ASTM E3247)
Zeta Potential Measurement (ASTM E2865)

(Malvern Panalytical, ZetaSizer Nano ZS, https://www.malvernpanalytical.com/en/support/product-support/zetasizer-range/zetasizer-nano-range/zetasizer-nano-zs)

Field Flow Fractionation (FFF) (ISO/TS 21362)

Single Particle Inductively Coupled Plasma Mass Spectrometry (ISO/TS 19590)

Wyatt Technology, Eclipse AF4/DAWN HELEOS II / Thermo iCAP RQ ICP-MS
(Photo from UH Environmental Engineering laboratories)

EVALUATION AND DISSEMINATION PLAN

Evaluator: Dr. Andrew Kapral, UH Hewlett Packard Enterprise Data Science Institute

Spring 2023

- **External advisory board (EAB):** NIST, industry, academic collaborators
  - Review course content, provide guest lectures
- **Graded coursework and laboratory reports:** Instructors/TAs
- **Pre-post self report surveys:** Dr. Kapral
  - Student familiarity with standards
  - Student confidence (Likert scale) in understanding/implementing specific standards

Summer 2023 to 2024

- Share assessments with EAB for feedback on the process
- Distribute modules to other IHEs for evaluation
- Develop webinars and open educational resources (OER)

PROJECT TIMELINE

Milestone	Semester
PIs attend and present in NIST workshops	Fall 2022 — Fall 2023 or 2024
PIs develop courses and coordinate all staff/TAs	Fall 2022 — Fall 2023
Courses delivered and evaluated at UH	Spr 2023 — Spr 2024
EAB and collaborating IHEs evaluate course content, implement labs, and provide feedback	Spr/Su 2023 — Su 2024
Course outcomes shared at conferences	Fall 2023 / Spr 2024
Open course materials produced/disseminated	Spr 2024 / Su 2024
Final Summary Paper submitted to NIST	Su 2024