Teaching and learning in nanoscale science & engineering: What do K-16 students need to know?

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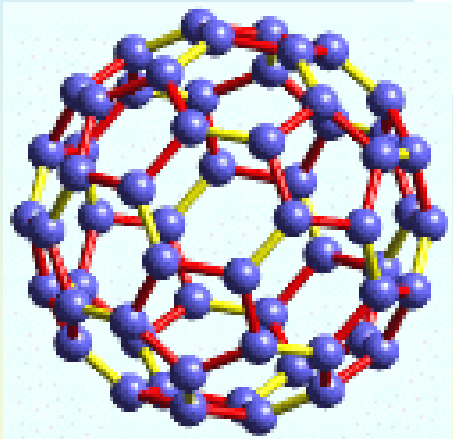


Overview

- *Social and ethical issues in nanoscale science & engineering research: a vehicle for promoting K-16 science education and increasing public scientific literacy*
- *Integrating NSE research into K-16 science education: possibilities and challenges*
- *Hersam nanoconcept inventory: initial findings*
- *What do K-16 students need to know?*

Societal implications of nanoscience and nanotechnology

Advances in nanoscience and nanotechnology promise to have major implications for health, wealth, and peace in the upcoming decades.

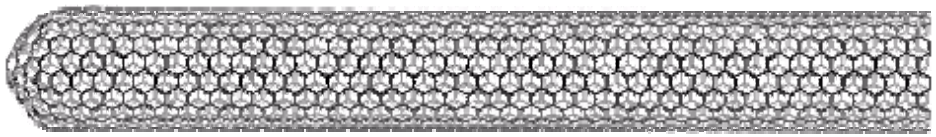
Knowledge in this field is growing worldwide, leading to fundamental scientific advances.

Expected breakthroughs include:

* ***Orders-of-magnitude increases in computer efficiency***
* ***Human organ restoration using engineered tissue***
* ***"Designer" materials created from directed assembly of atoms and molecules***
* ***The emergence of entirely new phenomena in chemistry and physics***

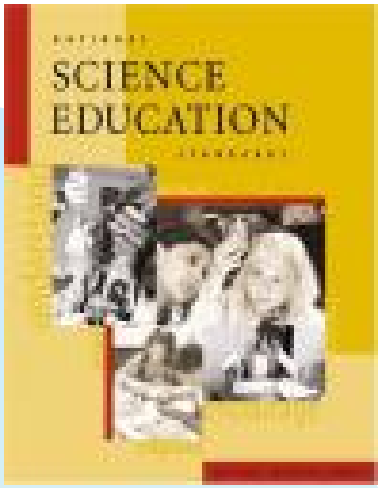
(National Nanotechnology Initiative (NNI), National Science Foundation, 2001)

Social and ethical issues in nanoscale science & engineering



THE ROYAL SOCIETY

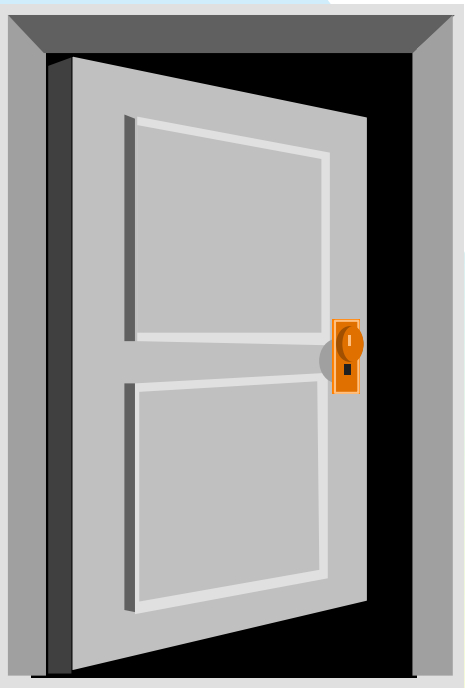
The Royal Academy of Engineering



Can these issues be addressed in K-12 science education?

- U.S. ***National Science Education Standards***
- AAAS Project 2061 ***Benchmarks for Scientific Literacy***
- Qualifications & Curriculum Authority, ***British National Curriculum***

Intended courses: SCE 4360/SCE 5362; Honors seminar, SCE 3930H



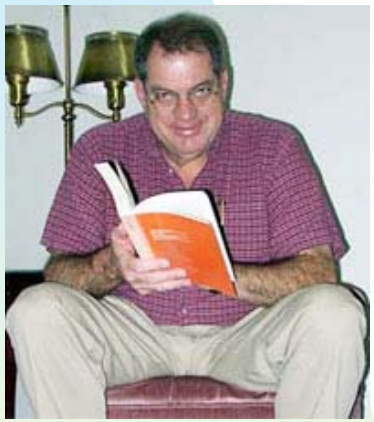
SCE 4360 … required undergraduate science methods class for prospective middle/high school science teachers in State of Florida (certification)

SCE 5362 … graduate version of above, also required for 6-12 certification in State of Florida

Honors seminar… interdisciplinary (with Philosophy), range of undergraduate students; first offering Spring 2006

University of Central Florida

PHI/SCE 3930H: Societal implications and ethical issues in *nanotechnology, biotechnology & information technology* research (Spring 2006/Spring 2007)



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College of Education

nano|ethics

Social and ethical issues in nanoscale science & engineering: Key questions

- *What are the "pros" and "cons" regarding nanotech research?*
- *Do scientists need to worry about ethics in the first place?*
- *What are the health & environmental issues at stake?*
- *What criticisms made against biotech might resurface for nanotech?*
- *Are we "playing God" by tinkering with nature? Is that bad?*

Overview of SCE/PHI 3930H (12-week semester)

- ***Week 1***: Science and "natural philosophy"; historical & conceptual development of atomic theory
- ***Week 2***: Review of basic concepts in biology, chemistry, physics
- ***Week 3***: Historical & conceptual development of nanoscience and nanotechnology
- ***Week 6***: Theories of technology
- ***Week 9***: Case studies of specific applications (UCF nano-researchers)
- ***Week 10***: Nanotech instrumentation/metrology

Historical overview: Early development of concepts and ethical issues in nanoscience

- Richard Feynman, "*There's Plenty of Room at the Bottom: An Invitation to Enter a New Field of Physics*", 1959.

- K. Eric Drexler, "*Engines of Creation: The Coming Era of Nanotechnology*", 1986.

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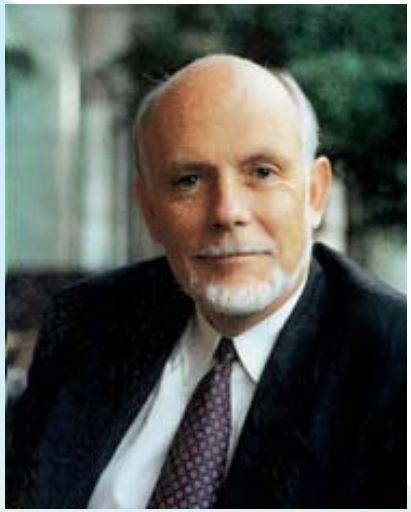
- K. Eric Drexler, "*Studying Nanotechnology*", 1988.

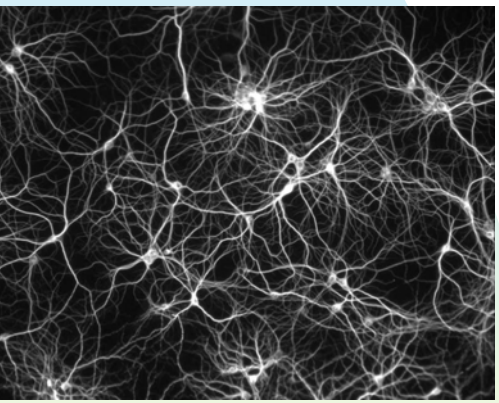


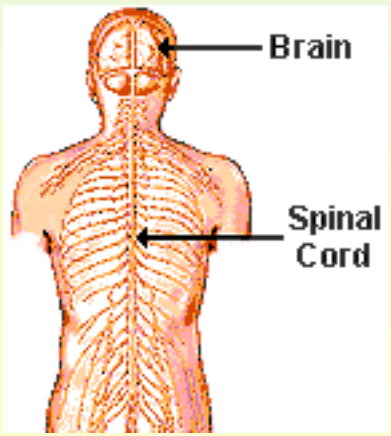
Major issues within the field

- "Top-down" *vs*. "bottom-up" approaches to nanofabrication (lithography, CVD, MBE, milling, etching, etc. *vs*. atom-by-atom or molecule-by-molecule or "self-directed assembly")
- *Chemical* principles vs. *engineering* principles ("fat fingers", "sticky fingers" vs. "mechanosynthesis")
- Avoiding public "backlash" experienced with other "disruptive" technologies, i.e. genetically modified organisms (GMOs)

Societal implications of nanoscience and nanotechnology: Sweeney's "Big Three"

* *National and global economics*
  Bayh-Dole Act (1980) in U.S.
* *Environmental sustainability*
  Largely unknown biotoxicity of nanomaterials
* *Education/workforce preparation*
  Future of K-16 science/engineering education





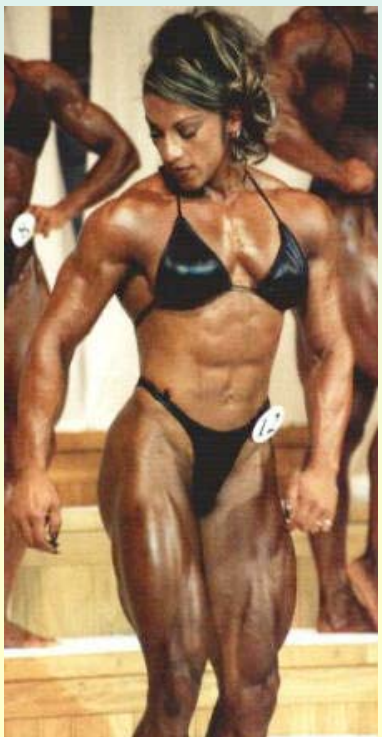
Nanofibres help nerves in brain regrow

- Researchers at *MIT*, US, *Hong Kong University* and *Fourth Military Medical University*, China, have used a nanofibre scaffold to help nerve cells regenerate in the brains of hamsters.

- Peptide nanofibre scaffold of ~10 nm in diameter; fibres form a network similar in scale to the surrounding matrix; solution of the peptides injected into the animals' brains; fibres self-assembled into a network in the void in the animal's brain caused by injury; technique restored at least some sight to ~75% of the animals.

- ***Technique being tested on spinal cord injuries; plans to launch trials in primates and eventually in humans; technique ultimately could help people who have suffered traumatic brain injuries, spinal cord injuries and stroke***.

- Ellis-Behnke *et al*, 2006, PNAS



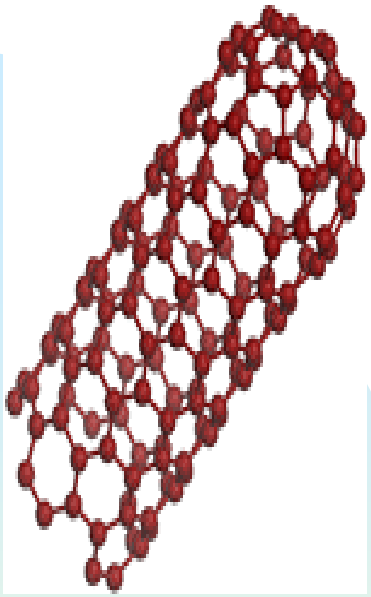
Artificial muscles based on nanotechnology

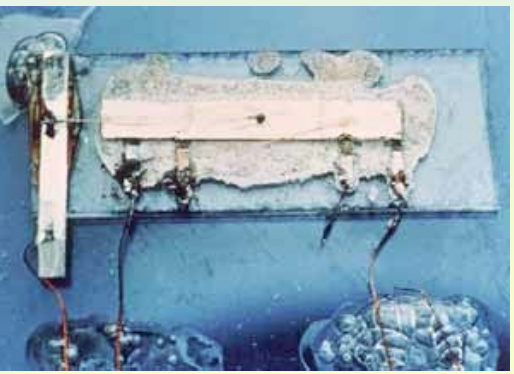
- Researchers at the *University of Texas at Dallas*, US, and *Pusan National University* in Korea have made two types of artificial muscle based on nanotechnology; **the muscles convert chemical energy to mechanical energy and could have applications in robotics.**

- Artificial muscles could have applications in robotics, freeing up robots from being tethered to heavy battery packs; possible applications with prosthetic limbs, smart sensors, dynamic Braille displays, and smart skins for aerospace vehicles.

- ***Ultimately, it may be possible to use artificial muscles in the human body, by replacing the metal catalyst with tethered enzymes that can exploit food-derived fuels***.

- Ebron *et al*, 2006, Science





Logic circuit on SWCNT

- Researchers at *IBM*, the *University of Florida* and *Columbia University*, all in the US, have created a logic circuit on a single-walled carbon nanotube. This is the first time that an *integrated circuit has been made on a single molecule*.

- Potential use of carbon nanotubes for terahertz applications, and greater computing/processing capabilities. Several social/ethical implications for privacy, warfare, human-machine interactions, biodiagnostics, etc.

- Chen *et al*, 2006, Science

Hersam nanoconcept inventory

- (1) **According to the majority of scientists, which of the following consequences of nanotechnology is deemed to be imminent?**
  - (a) Injectable nanobots that will fight individual viruses in the human body
  - (b) Human immortality enabled by manipulation of individual genes
  - (c) Self-replicating and autonomous nanoparticles
  - (d) All of the above
  - (e) None of the above

- (3) **Which of the following items is approximately one nanometer in size?**
  - (a) White blood cell
  - (b) HIV virus
  - (c) Diameter of a DNA molecule
  - (d) Hydrogen atom
  - (e) Proton

- (4) **The prefix “nano” means:**
  - (a) One-thousandth
  - (b) One-millionth
  - (c) One-billionth
  - (d) One-trillionth
  - (e) One-quadrillionth

Hersam nanoconcept inventory

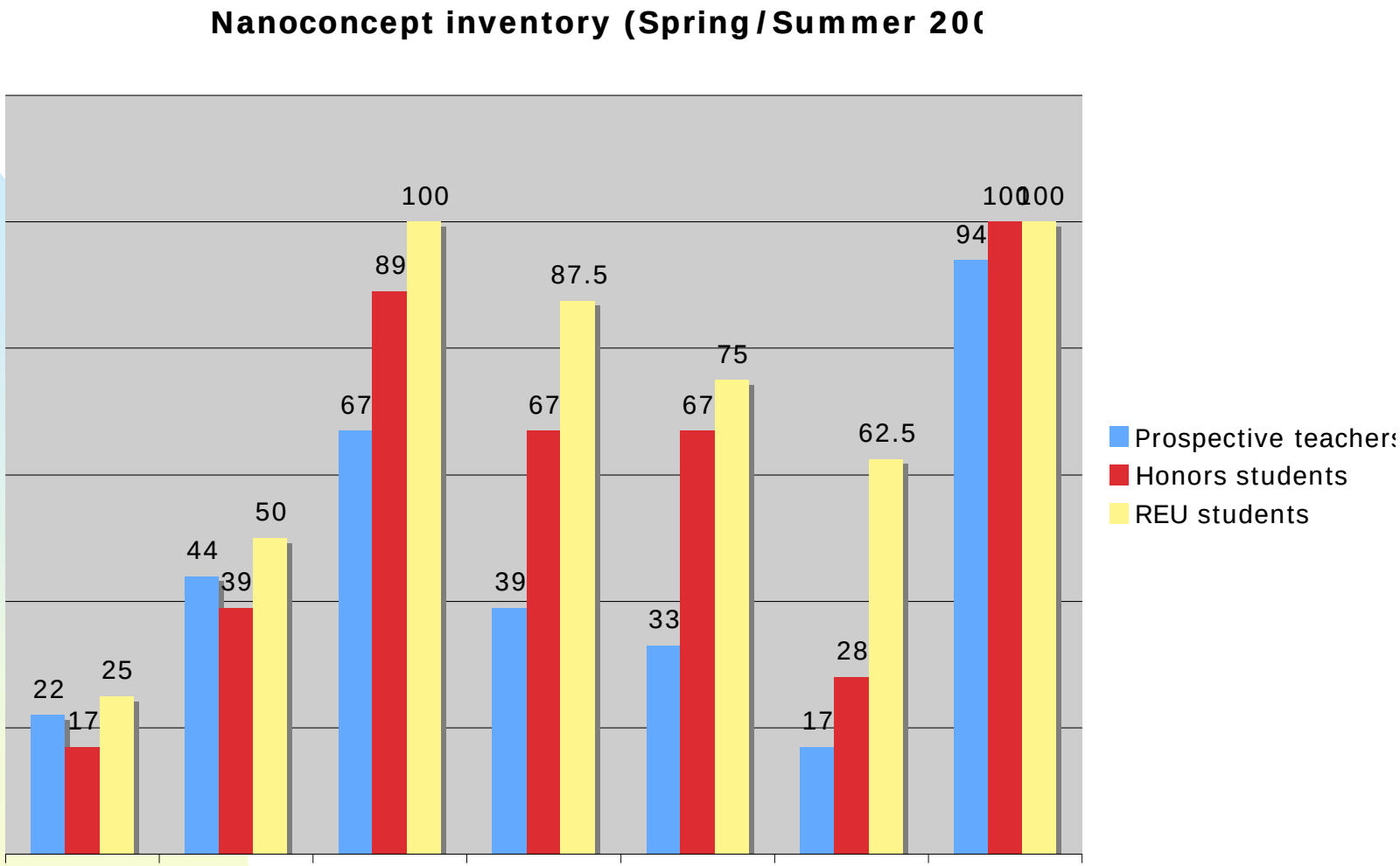
- (5) **The wavelength of visible light is approximately equal to:**
  - (a) 0.5 nanometers
  - (b) 5 nanometers
  - (c) 50 nanometers
  - (d) 500 nanometers
  - (e) 5000 nanometers

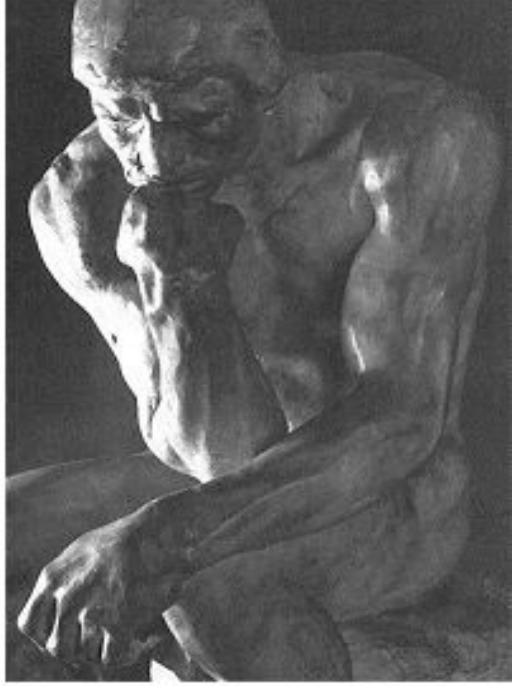
- (7) **As the volume of a spherical nanoparticle decreases, the ratio of surface atoms to total atoms:**
  - (a) Remains constant
  - (b) Increases
  - (c) Decreases
  - (d) Not enough information to conclude a trend
  - (e) None of the above

- (17) **The nanoscale electrical property of tunneling is:**
  - (a) Analogous to the sharing of electrons in a covalent bond
  - (b) The basis of the atomic resolution scanning tunneling microscope
  - (c) Contributing to increased power consumption in computer technology
  - (d) All of the above
  - (e) None of the above

Hersam nanoconcept inventory

- (20) **Nanotechnology is currently impacting which fields of science:**
  - (a) Physics
  - (b) Chemistry
  - (c) Biology
  - (d) Engineering
  - (e) All of the above


Nanoconcept inventory (Spring/Summer 200
22
17
25
44
39
50
67
89
100
39
67
87.5
33
67
75
17
28
62.5
94
100
100
Prospective teachers
Honors students
REU students

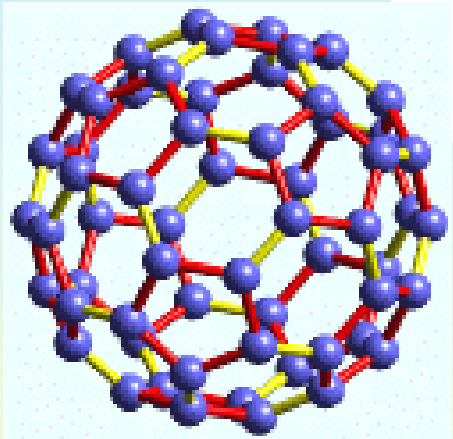


Initial thoughts: So … what do K-16 students need to know (NSE)?

- *What is hype/speculation and what is currently possible*
- *Scale and scaling effects ("metric problem")*
- *Fundamental quantum physical concepts ("cognitive problem"?)*
- *More explicit inter-relationships between the three "basic" sciences*

Challenges in K-12 science education

- *"[Science education] is looming as a bottleneck for the development of the field, and particularly for its implementation"* […] and *"education and training [in scientific concepts at the nanoscale] must be introduced at all levels, from kindergarten to continuing education, from scientists to non-technical audiences that may decide the use of technology and its funding"(*Roco, 2003)
- **What important concepts do elementary/secondary level students need to understand in nanoscale science and technology, *and who will determine this*?**
- **Will *all* students have access to science teachers who are adequately prepared in this content?**



International efforts in K-16 nanoscale science & engineering education

- Research in various areas of NSE is proceeding at a rapid pace … but scant knowledge base addressing "best practices" in K-16 NSE education
- An initial attempt over the past year to develop/compile a working knowledge base featuring in-depth accounts of recent international efforts in NSE education (edited book)
- *Integration of NSE in K-12 and undergraduate education*; *public NSE education*; *curriculum development and assessment*; *social/ethical issues*; *workforce preparation*, etc.

Sweeney & Seal (Eds.)., ***Nanoscale science & engineering education: Issues, trends & future directions***, forthcoming.

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What have we done so far?

- Sweeney, A. E., Seal, S. & Vaidyanathan, P. (2003). *The promise and perils of nanoscience and nanotechnology: Exploring emerging social and ethical issues.* Bulletin of Science, Technology & Society, 23(4), 236-245.
- Sweeney, A. E., Vaidyanathan, P. & Seal, S. (2006). *Undergraduate research and education in nanotechnology*. International Journal of Engineering Education, 22(1), 157-170.
- Sweeney, A. E. (2006). *Social and ethical dimensions of nanoscale science and engineering research.* Science & Engineering Ethics, 12(3), 435-464.
- Sweeney, A. E. (2006). *Teaching & learning in nanoscale science & engineering: A focus on social & ethical issues and K-16 science education*. Proceedings of the Materials Research Society, Vol. 931E (Spring 2006). Materials Research Society: Warrendale, PA. (Paper # 0931-KK03-05).
- Sweeney, A. E. & Seal, S. (Eds.) (forthcoming). *Nanoscale science and engineering education: Issues, trends and future directions.*
- Sweeney, A. E., Bowles, K. & Seal, S. (in preparation). *Nanoscale science and technology: Implications for science teacher education.*