Building nanoliteracy in the university and beyond

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US universities are bridging the knowledge gap to better educate tomorrow's nanotechnology workforce.

Within the academic community, knowledge about nanotech is largely fragmented. Scientists and engineers, both students and faculty, may learn much about the technical aspects of nanotech, but little or nothing about its societal and ethical questions. And humanists and social scientists may know the societal and ethical issues, but they may be poorly informed about the underlying science. Considering that nanotech might instigate profound changes in medicine, electronics, materials science and other areas, it would be unfortunate if those within the academic community restricted themselves to narrow, disarticulated perspectives on nanotech.

Nurturing nanoliteracy

A recently formed research group at the University of South Carolina has the goal of nurturing a nanoliterate university community with programs drawing from the natural sciences, engineering, the humanities and the social sciences, and embracing all interested persons—including faculty, students, staff and neighbors—through coursework, scholarships, outreach, research, publications, symposia and conferences. Known as nanoScience & Technology Studies (^{n}STS)[1], the group defines nanoliteracy as a culture in which those interested in nanotech are reasonably informed about it (including scientific, humanist and policy features, and the spectrum of views on those topics), and are comfortable discussing it; members of the community are able to pursue their own interests in nanotech by learning more from various sources; members of the community are confident that they can use their knowledge to participate in shaping nanotech policy, even if they do not possess expert scientific credentials; and finally, considerations of the societal questions are integrated into discussions about technical change, so that the technology is not isolated from society.

If a university community truly possessed such nanoliteracy, then all who wanted to could participate constructively in discussions and decisions about nanotech policy. Humanists and social scientists, for example, would have realistic expectations of what nanotech can and cannot deliver, whereas scientists and engineers would understand other people's concerns about how nanotech will change our lives.

This raises the question of implications and interactions. Government agencies speak of researching the societal implications of a new technology, but 'implications' usually means that the technology arrives, it changes the society and then the change is understood after the fact. Instead of passively accepting this sequence, ^{n}STS programs enable one to understand nanotech now, before it causes major disruptions, so that people can advocate the more responsible kinds of changes. Thus we speak of societal interactions with nanotech: 'interactions' suggests that nanoliterate members of society make decisions about nanotech before technological change becomes a *fait accompli*[2].

^{n}STS programs

The three premier programs for nurturing nanoliteracy include coursework, scholarships and outreach. Courses include "Nanotechnology: Promises and Perils," an undergraduate seminar that serves as an introduction to social and ethical interactions with nanotech by placing nanotech in a framework of philosophies of technology; "Enhancing Humans," a course on the convergence of nanotech, biotech, information technology and cognitive science, which may lead to alterations in what we mean by 'human'; and "Nano Philosophy," a graduate seminar that challenges students regarding how nanoscale phenomena are represented, and what this implies about the process of scientific representation.

In addition, Spring 2005 saw the "Nano Semester," a repertoire of five undergraduate courses, enhanced with three plenary talks on societal interactions with nanotech, and concluding with student presentations and posters. The courses presented complementary perspectives from the humanities and social sciences, and included the previously described "Nanotechnology: Promises and Perils"; "Arguments in Science and Technology," which examined arguments about nanotech in light of the rhetoric of science and technology; "Visual Computing," which focused on art and technology with special attention to scientific visualization in nanotech; "Nanomedicine," with an emphasis on the social and ethical conditions that influence research results; and "Technological Sight: Seeing Nano through Instrumentation & Philosophy," wherein students investigated visualization through electron microscopy and other computer-based instrumentation, which led to questions about how we create these images and understand the structure of matter.

To the best of our knowledge, no other college or university has offered its students this kind of quality and diversity of coursework on societal interactions with nanotech. The Nano Semester also served as an incubator for developing future courses.

Each year, the ^{n}STS group supports nine or ten undergraduate students, called Nano Scholars, to work with faculty mentors to write or coauthor presentations and articles. In 2004–2005, three of the Nano Scholars created *News From the Bottom*, the first scholarly online nanotech journal written and edited by students[3]. This journal features work by

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undergraduate and graduate students on the epistemological, historical, ethical, legal, societal and technical aspects of nanotech and related technologies, and includes reviewers and authors from several universities, thereby nurturing national and international student dialog on nano-related issues. In short, the Nano Scholars program puts undergraduate students in a position to make their own contributions to societal interactions with nanotech, so that they are not limited to the experience of taking courses.

In 2004, *n*STS launched an outreach program, the South Carolina Citizens' School of Nanotechnology (SCCSN)[4], which brings experts and nonexperts together, in both formal and informal settings, to talk about the scientific, social and humanistic issues in nanotech. The speakers are faculty experts who are adept and comfortable in speaking with nonexperts, and participants are provided with a package of background articles to give them the knowledge and confidence to pose comments and questions to the speakers.

Outreach programs like this must be thoughtfully justified. Earlier discussions of 'civic scientific literacy' explored the hope that a democratic society would have a well-informed electorate for making decisions about science policy. Unfortunately, statistics indicate that levels of civic scientific literacy remain dreadfully low across three decades[5]. An alternative is to turn to the related ideas of stakeholder democracy and participatory democracy. Stakeholder democracy teaches that only a portion of the general population will be interested and active in a given issue: not everyone wants to identify himself or herself as a stakeholder. Participatory democracy consists of a series of empirical studies that show that nonexperts can acquire, comprehend and deploy the relevant scientific knowledge in order to have active and constructive roles in decisions about science policy[6,7]. The SCCSN is intended to serve those who see themselves as stakeholders in nanotech policy, by helping them develop the background and confidence to claim a role in processes of nanotech policy[8].

Participants in the South Carolina Citizens' School of Nanotechnology discuss nanomedicine with Dr. Robert Best, Columbia, SC, March 2006.

Other US institutions

There are undergraduate courses on societal interactions with nanotech at Rice University (Houston, TX), Arizona State University (Tempe, AZ), Lehigh University (Bethlehem, PA) and the University of Wisconsin (Madison, WI), to name a few. At Rice, the course is co-taught by a chemist and a cultural anthropologist, so that content from the sciences and the social sciences is balanced. Arizona State also employs several undergraduate interns who engage in research support. The same university also has a related graduate seminar which draws students from across the sciences and social sciences, and offers full-time support for graduate students and post-doctoral fellows. Wisconsin, too, supports graduate students and postdocs researching nanotech in society.

Regarding outreach, Rice has created the International Council on Nanotechnology (ICON), a multi-stakeholder forum where experts in academia, government, industry and nonprofits exchange information about nanotech's environmental health and safety issues, while working to maximize benefits to society. Arizona State and Wisconsin have launched science cafes in which nano-scientists engage the public by making brief, accessible presentations and fielding questions in an off-campus venue. The Wisconsin cafe was a result of the Madison Area Citizens Consensus Conference on Nanotechnology from April 2005. Lehigh has an outreach program called ImagiNations, which introduces nanotech to middle school students through the use of remote electron microscopy. Another project, the Lehigh Gap Environmental Revegetation Inquiry, has students investigate nanotech-enabled solutions to environmental problems and discuss the societal implications of using this technology.

The challenge of building nanoliteracy

Two problems are chronic and troublesome. First, there is insufficient dialog at the student level between the sciences and engineering, on the one hand, and the humanities and social sciences. At our university, faculty who are interested in nanotech already benefit greatly from cross-disciplinary interactions, but we would like to see science and engineering students take more humanities and social science courses on societal interactions with nanotech, and vice versa. There is, however, no incentive or reward for them to do so in terms of course credits for their degree requirements, which raises some delicate questions about the undergraduate curriculum.

Second, those who take advantage of our nanoliteracy activities represent an intensely curious but very small population. This may reflect the fact that nanotech has not achieved much sustained attention in the general population; it may also indicate that nanotech confronts a nonexpert with a very steep learning curve. One consequence of this situation is that several of our courses are taught regularly, but others, like the Nano Semester, need special arrangements to attract enough students to make the seminars viable.

At any rate, the work of building nanoliteracy is difficult and exciting. Many different careers and professions will be affected by nanotech, including both scientific and extra-scientific careers. Nanoliteracy will benefit both kinds of workforces as nanotech develops, as societal interactions arise, and as nonexperts claim their roles in nanotech policy.

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