Get the word out

Sharing progress in nanotechnology education is as important as developing the research programmes themselves, as **Kurt Winkelmann** explains.

Nanotechnology has progressed from an exploration of fundamental laboratory research to creating nano-enhanced consumer products and industrial processes. To develop a skilled workforce that meets the current and future needs of industry, our students must learn about nanotechnology. This education should begin early on in life, though ultimately school teachers are restricted to teach what is in their curriculum. It is therefore at university that the best opportunities for introducing nanotechnology present themselves. Several researchers and institutions are now developing nano-based experiments, courses and programmes. As they do so, it is important that they can share their outcomes so that all educators can benefit from those experiences. Owing to the inherent interdisciplinary nature of nanotechnology, dissemination of these results can be problematic. The *Journal of Nano Education* is one resource that enables this discussion and will hopefully lead to students learning nanotechnology throughout all levels of education.

The Florida Institute of Technology serves as one example of how to develop a successful nanotechnology curriculum that begins in the students' first year. We offer an introductory lab course to those who have completed a general chemistry lab course — this opens enrolment to more students than if it were a final year class in a single discipline. The course exposes students early in their college career to some of today's most cutting-edge science and technology. Students perform experiments that incorporate areas of different science, technology, engineering and mathematics (STEM) fields, but that may not fit within a lab course of a traditional discipline, such as building solar cells, synthesizing ferrofluids, collecting images of monolayers on graphite, or observing the change in properties as the dimensions of a material decrease from the bulk to the nanoscale. Education-grade instrumentation gives students an opportunity to gain hands-on skills operating a scanning tunnelling microscope and an atomic force microscope. Class activities include debates about the societal impacts and other non-technical but no less important aspects of nanotechnology. The course, which is taught jointly by the science and engineering faculties, aims at illustrating the interdisciplinary nature of nanotechnology and how the field affects us all.

An introductory laboratory curriculum must offer a variety of experiments that reflect nanotechnology research, which is constantly evolving and advancing. Ideas for these new experiments and activities can grow out of scientific research. By using more affordable starting materials, simpler instrumentation, and less extreme reaction conditions, research projects can become experiments for the teaching laboratory. Creating an experiment from a science or engineering project is by no means an easy process — experiments for the teaching laboratory must be affordable, safe, reproducible by inexperienced students and completed within one or two lab sessions. In addition, all activities must have an educational value; an educator must set learning objectives and find ways to accurately measure them. Students need to actually learn something, after all.

I urge scientists and engineers working in nanoscience to consider how they might adapt their research to create educational activities for new students. To this end, collaboration with a science education faculty member can be highly valuable. Immediate benefits include publications in education journals and a tangible 'broader impact' that makes future research proposals more attractive to funding agencies. Researchers also get to publicize their own work to a large number of students, broadening the pool of potential future research assistants. Research students can also be involved in the process. For them, the ability to explain scientific concepts to an audience of non-experts is also a valuable skill to develop and one that is necessary when teaching. They must reflect on the process of teaching and learning as they develop their lab experiment or demonstration, which will improve their skills as a future leader of their own research team.

As the growth of information in nanotechnology education gathers pace, it is important that there are ways of sharing the knowledge gained from successful practices. Most education journals, however, focus on a single STEM discipline so are not directly suited to such an interdisciplinary field as nanotechnology. The *Journal of Nano Education* addresses this issue. It is a peer-reviewed journal that began in 2010 and publishes several issues a year. Articles cover both the research and practice of nanotechnology education. Authors describe the implementation and assessment of nanotechnology curricula for a range of subjects and departments, or even college-wide. All levels of formal education, as well as faculty professional development and workforce training are featured. Contributions also show outreach activities and discuss how to improve scientific literacy and the public's understanding of nanoscale science and engineering. In most cases, articles highlight the practice of nanotechnology education with little attention paid to the guiding theoretical framework, although many education researchers do provide a thorough justification for their choice of pedagogical approach.

As college-level nanotechnology education becomes more widespread, the *Journal of Nano Education* will be a useful source of information for new and experienced faculty alike. Increasingly, the journal publishes contributions from authors across the world, reflecting the growing global interest in nanotechnology education as more countries invest in national programmes of nanotechnology research and development. It is stimulating to see how scientists and engineers with different backgrounds and from different countries are adapting their research to create new experiments and activities for the teaching laboratories and classrooms. Nanotechnology is now at the point where it has its own history of discoveries, it is time to use these to inspire the next generation. ❐

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