A Partnership to Introduce Nanotechnology Research in High School Classrooms

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Abstract

Nanotechnology is an increasingly important field that will require a rapidly growing body of trained personnel for occupations in business and manufacturing as well as research and development. Reaching members of that prospective workforce with related educational activities before they have made decisions regarding post-secondary programs of study is one approach to insuring that these occupations will have adequate staffing. A partnership among a university, a leading medical technology corporation, and a high school has been established to develop, integrate, and pilot curriculum modules that will be taught in high school science classes and which incorporate themes related to a Nanoscale Interdisciplinary Research Team (NIRT) project. We will briefly describe the partnership arrangement among the organizations involved and the overall process for developing, implementing, and disseminating the curriculum materials. We will also present a more detailed consideration of the content of the modules and their integration into high school curricula.

Introduction

Nanotechnology is an increasingly important field as evidenced, in part, by the proliferation of subject-specific research journals and the number of patents awarded in a field that is still young.[1,2] The worldwide workforce necessary to support this growing field is estimated at 2 million by 2015, with the need for trained personnel expanding from R&D and education to manufacturing and services, business and other organizations.[3] While research in the field is rapidly advancing, very little progress has been made in bringing nanoscale science into school curricula and public awareness.[4] In fact, education is perceived to be one of the 'grand challenges' for the development of, and especially the implementation of, nanotechnology.[5]

In his opening address to the K-12 & Informal Nanoscale Science and Engineering Education (NSEE) Workshop, Dr. Mihail C. Roco, Senior Advisor at the National Science Foundation proposed several objectives for NSEE, including three that are being addressed by this project:

- Stronger collaboration between researchers and educators;
- Focusing on better preparation of teachers; and
- Partnering across institutions working on NSEE.[6]

The Center for Innovation in Engineering and Science Education (CIESE) at Stevens Institute of Technology (SIT) and a research group at SIT have partnered with Stryker Orthopaedics and the Academies at Englewood High School to develop, integrate, and pilot curriculum modules that will be taught in high school biology and chemistry classes and which incorporate themes related to a Nanoscale Interdisciplinary Research Team (NIRT) project at SIT. This partnership arose as

part of the outreach effort associated with a National Science Foundation (NSF) grant awarded to the research team. The conceptual foci of the modules, which will each include a laboratory activity, are both related to infection control and infection-controlling biomaterials, the themes of the parent NIRT project. In addition to content-specific objectives that are aligned with both the national and New Jersey science standards, the goals of the modules are to expose students to nanotechnology-based research; enhance/modernize biology and chemistry curricula; and demonstrate the societal relevance for basic science concepts.

Development and Dissemination Cycle

The module development team, led by staff at CIESE, consists of the primary investigators (PIs) of the SIT research team, a research collaborator from Stryker Orthopaedics, and two teachers from the Academies at Englewood High School. The development team is assisted by the PIs' undergraduate and graduate students and a high school student, recruited through Stevens' ongoing interaction with the American Chemical Society's (ACS) Project SEED program, a program that provides research opportunities for high-achieving students from under-served populations. The SIT students and high school student have contributed to the module development by providing technical assistance in the laboratory, reviewing lab protocols being developed, and providing feedback after performing some of the experiments.

The development and dissemination cycle for the modules is shown in Figure 1. We are currently in the first year of the cycle, with draft versions of the modules having been completed over the course of the summer. Six teachers, two of whom are the teacher developers, will pilot the

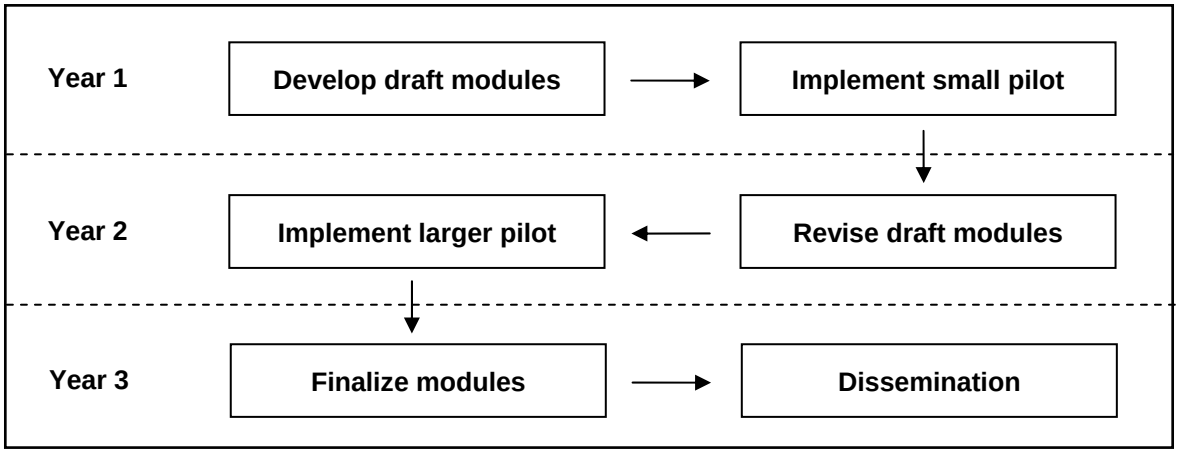

Figure 1: Schematic showing the development cycle for the NIRT curriculum modules for high school science classes.

modules in high school biology and chemistry classes during the 2008-09 academic year. Based on feedback from the pilot teachers and their students, the modules will be revised during the summer in year 2. Additional supporting materials will also be developed at the revision stage, including more extensive background information for teachers and video clips featuring the Stryker Orthopaedics collaborator.

After the modules are revised in year 2, a larger pilot study will be conducted with 20 teachers participating. Prospective teachers will be reached through an established CIESE teacher network. Teacher participants will be selected from all applicants based on a variety of teacher and school district characteristics. Specifically, every effort will be made to obtain participants from school districts across a wide range of the socioeconomic spectrum and representing racially and ethnically diverse communities. Once again, feedback will be sought from the participating teachers and their students after they have implemented the modules. Final revisions will be made after incorporating both teacher and student input.

After the modules have been finalized in year three of the project, they will be stored and featured on the CIESE website. These modules will be promoted and information regarding them will be disseminated at the New Jersey Science Teachers Convention, the National Science Teachers Association Regional Conference, ASEE, and other educational, engineering, and science conferences. Selected teachers will be asked to co-author journal articles about the modules and their experiences on the module development team. Additionally, the modules will be featured in ongoing teacher professional development sessions and educator conference information sessions led by CIESE staff.

Module Description

The modules that are being developed follow established CIESE models and are intended to be integrated logically and easily into general high school curricula in biology and chemistry. The general guidelines listed below were provided to the teachers developing the modules. The modules should:

- Expose a broad cross section of high-school students to nanotechnology-based research;
- Demonstrate the societal relevance of the research;
- Enhance and modernize topics taught within standard high school biology and chemistry courses;
- Be designed for easy implementation in general biology and general chemistry courses;
- Require no more than one week to implement;
- Contain a hands-on or laboratory activity;
- Address National Science Education Standards; and
- Be available for world-wide distribution via the established CIESE web site.

The content of the modules is related to infection control and infection-controlling biomaterials, the themes of the parent NIRT project, which aims to develop a surface coating that might be used on replacement joints, such as hip joints, that will allow human cells to adhere but will repel bacterial cells. The surface coating material that is the subject of the research is composed of nanosized hydrogels. The societal relevance of this research stems from the severity of the consequences experienced by hip implant patients when an infection occurs on the surface of the implanted joint that cannot be treated successfully with antibiotics because of the characteristics of the bacteria.

The biology module will focus on bacteria, including a comparison of their characteristics under different growing conditions and their ability to adhere to and grow on different surfaces. After students have the prerequisite background knowledge commonly required in high school biology

classes, including an understanding of cell organization (e.g., unicellular vs. multicellular and prokaryote vs. eukaryote) and basic bacterial cell morphology and arrangement (not included in the module), they will use a variety of resources, both video and print, to explore the topics of bacterial communication, biofilms, and infection control. Interleaved with this activity will be a multiday lab experiment that students will conduct as part of the module. The lab experiment involves culturing bacteria on glass slides, some of which they will pre-treat with a chemical solution. Students will discover that the bacteria adhere and grow well, forming a biofilm, only on the untreated slides.

A major focus of traditional labs involving bacteria is often the staining technique required to observe bacterial growth. In this module, the focus is shifted from laboratory techniques to biology and technology concepts because the bacterium selected for use in the experiment, *Vibrio fischeri*, is bioluminescent when it occurs in significant numbers in a biofilm. Bacterial growth will be able to be observed in a darkened room without staining. Under these circumstances, the lab experience can more easily be focused on concepts related to controlling bacterial growth rather than laboratory techniques. While this bacterium is not the cause of the infection in joint replacement procedures, it has many of the characteristics of the disease-causing bacterium but is not a human pathogen and can therefore be used in the classroom without concern for the students' safety.

Many standards from the National Science Education Standards (NSES) are addressed in this module including standards relating to life science, science as inquiry, and science and technology. The draft biology module incorporates the following standards from the NSES:

- Grades K-12
    - Unifying concepts
        - Systems, order, and organization
        - Change, constancy and measurement
- Grades 9-12:
    - Science as Inquiry
        - Ability to do scientific inquiry
        - Understandings about scientific inquiry
    - Life Science
        - Interdependence of organisms
        - Matter, energy, and organization in living systems
    - Science and Technology
        - Understandings about science and technology
    - History and Nature of Science
        - Science as a human endeavor
        - Nature of scientific knowledge
            - Engineering and technology

That the module addresses so many of the content standards while introducing students to cutting-edge research in nanotechnology is one of its assets. This module allows teachers some flexibility to emphasize selected content standards by tailoring it to their particular circumstances. The final version of the module will provide some suggestions as to how this can be accomplished.

Also, although not listed here, the relevant curriculum content standards for the state of New Jersey (NJCCCS) have also been identified for this module and will be included for the teachers. The NJ science standards are currently undergoing revision and will likely include a greater emphasis on engineering and technology, which will be addressed by both the biology and chemistry modules.

The chemistry module will take several commonly taught concepts at the high school level and incorporate hydrogels, the materials being explored by the NIRT research project for use on the surface of joint implants. This module consists of three laboratory activities and an Internet-based research activity all involving hydrogels. While the hydrogels used in the research activities are nanosized, the high school students will be experimenting with bulk hydrogels. The major connection between the high school module and the research work rests on the characteristics of hydrogels, including those that make them important materials for biotechnology.

The three lab activities are similar to those that are being done in many high school classrooms, but which have been adapted to incorporate hydrogels. The general concepts being explored by the activities are the properties of matter as related to its phase and molecular mass; chemical reactions; and organic chemistry. The fact that the research topic can be accessed from any of these curriculum areas, as shown in Figure 2, and that the lab experiments are similar to those already being done in many classrooms are two desirable attributes of the chemistry module. This also affords teachers the opportunity to introduce some engineering and technology aspects of chemistry while maintaining the flexibility to include as much or as little of the topic as is appropriate based on their student population, course curriculum, and time constraints.

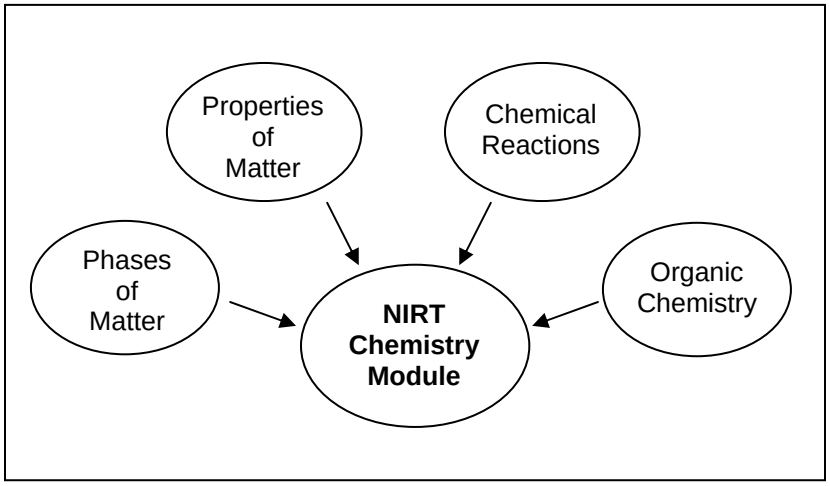

Figure 2: Diagram representing the connections and entry points from typical high school chemistry curriculum topics to the NIRT chemistry module.

As was the case with the biology module, this module addresses many of the national science standards, including:

- Grades K-12
    - Unifying concepts
        - Systems, order, and organization
        - Evidence, models, and explanations
        - Constancy, change, and measurement
- Grades 9-12:

- Science as Inquiry
  - Ability to do scientific inquiry
  - Understandings about scientific inquiry
- Physical Science
  - Structure and properties of matter
  - Chemical reactions
- Science and Technology
  - Understandings about science and technology
- History and Nature of Science
  - Science as a human endeavor
  - Nature of scientific knowledge
    - Engineering and technology

Conclusion

The tremendous current and future growth in the field of nanotechnology will require a workforce with knowledge and skills in this area for careers in business, manufacturing, and education, in addition to R&D. The approach we are taking to increase students' and teachers' awareness and knowledge of this field is to create curriculum modules that teachers can easily implement in their high school biology and chemistry classrooms that will introduce students to cutting-edge research in nanotechnology while addressing concepts that are already an integral part of the curricula in those courses. Our approach to this development effort has been to rely heavily upon the partnership that has been established among SIT, Stryker Orthopaedics, and The Academies at Englewood High School to create the modules. The success of this endeavor will be measured, in part, by the number of teachers and schools that implement all or part of the modules and will be reported in future publications.

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[5] Ibid. 3

[6] Ibid. 4