City College of New York
Nanoscale Undergraduate Education
Evaluation Report
2007-2008

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Executive Summary

Background

During the 2007-2008 school year, the CCNY-NUE project field tested its nanomaterials course (CHE 59808), the accompanying nanomaterials laboratory course (CHE 59806), and the "nano nuggets" module in ENGR 101. The nanomaterials lecture course and subsequent laboratory course were designed as a series of experiences intended to prepare students to conduct research with faculty. The nano nuggets modules was a short, 5-week experience intended to expose students to nanotechnology to increase interest and create a pipeline into more formal coursework. This report summarizes the impact of the course materials on teaching, learning, and student engagement.

Key Findings

Nano Nuggets (ENGR 101)

Nano nuggets was offered as a five-week module students could select within the ENGR 101 course. A total of 34 students across three different sections enrolled in the nano module.

The nano nuggets module was one of four modules that received favorable overall ratings. The nano module was rated as having effective pedagogy, materials, and equipment. The nano nuggets modules was also rated as "interesting" and "challenging". Overall, students rated the nano nuggets module as "worthwhile."

Nanomaterials Lecture Course (CHE 59808)

This introductory survey course was offered in the fall of 2007. Twelve students, mostly chemical engineering students, enrolled in the course.

Interest in Nanotechnology

All of the students' enrolled in the nanomaterials course expressed an interest in nanotechnology from the very beginning of the course, which did not wane over time. All of the students felt it was useful to learn about nanotechnology with most agreeing that “nanotechnology is the technology of the future.” Student’s interest in nanotechnology was also reflected in the fact that most were interested in doing undergraduate research in nanotechnology and would consider a career in nanotechnology.

Knowledge of Nanotechnology

In a pre- and post-assessment, students in the nanomaterials lecture course appeared to have a general knowledge of nanotechnology prior to enrolling in the course. By the end of the course, however, they demonstrated an increased understanding of knowledge specific to nanotechnology in the following areas:

- methods of synthesizing nanoparticles
- configurations of carbon nanotubes
- nanoparticles as additives in polymers
- self-assembly in nature
- examples of nanotechnology inventions
- examples of nanomaterials

Course Quality and Utility

Overall, students rated the nanomaterials lecture course as offering content, pedagogy, instructional materials, and support came together to provide an environment conducive to learning.

Students also reported that their knowledge of specific nanomaterials and nanotechnology concepts and principals, related skills, and understanding of ethical and contemporary issues related to nanotechnology had increased as a result of their participation in the nanomaterials course. Students confirmed what their pre/post assessments indicated in reporting that they are now:

- able to give examples of nanomaterials,
- able to explain terms generally used in nanoscience and nanotechnology,
- familiar with methods of synthesizing nanomaterials,
- familiar with macroscopic phenomena, and
- able to predict trends in mechanical properties of nanomaterials.

Nanomaterials Laboratory Course (CHE 59806)

This hands-on application course was offered in the spring of 2008. Ten students, mostly chemical engineering students, enrolled in the course. All of these students had completed the introductory nanomaterials lecture course.

Knowledge of Nanotechnology

Overall, the total scores for laboratory reports were high across the groups, averaging more than 80% of the possible 600 points per final report. The modules on which groups received the highest scores were:

- Module 3: Chemical Engineering – Imaging of Nanomaterials (mean = 94%)
- Module 2: Electrical Engineering / Physics – Optical Characteristics of Nanoparticles (mean = 91%)
- Module 5: Ethical and Societal Considerations for Nanomaterials (mean = 89%)

Groups still received more than 80% of the points on the other two modules:

- Module 1: Chemistry – Synthesis of Nanoparticles (mean = 85%)
- Module 4: Mechanical Engineering – Mechanical Properties of Nanoparticle Reinforced Composite Materials (mean = 81%)

From the beginning, students were able to write up the introduction and references sections. Over time, they also learned more about how to write the results, discussion, and conclusion section, as evidenced by instructor feedback and subsequent revisions.

Course Quality and Utility

Overall, students rated the laboratory course as offering content, pedagogy, and instructional and support that provided an environment conducive to learning. Students were less likely, however, to report that "the instructional materials were complete and helpful."

Students also reported that their knowledge of specific nanomaterials and nanotechnology concepts and principals, related skills, and understanding of ethical and contemporary issues related to nanotechnology increased as a result of their participation in the nanomaterials laboratory course. Specifically, students generally confirmed the acquisition of the skills demonstrated in their laboratory reports:

- synthesizing nanoparticles,
- operating a spectrometer,
- analyzing and interpreting optical data,
- operating an atomic force microscope,
- analyzing and interpreting stress-strain data, and
- a familiarity with ethical issues related to nanomaterials and their applications.

In addition, students reported an increased ability to make oral presentations and write laboratory reports.

Summary

In this first field test, the evaluation data provides evidence that the CCNY-NUE team was successful in developing and implementing nanotechnology coursework, laboratory experiences, and mini-“nano nuggets” modules that engage students and promote learning of knowledge and skills relevant to engineering and to nanotechnology. The CCNY-NUE team will conduct a second field test during the 2008-2009 school year.

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Overview

During the 2007-2008 school year, the CCNY-NUE project field tested its nanomaterials course (CHE 59808), the accompanying nanomaterials laboratory course (CHE 59806), and the “nano nuggets” module in ENGR 101. The nanomaterials lecture course and subsequent laboratory course were designed as a series of experiences intended to prepare students to conduct research with faculty. The nano nuggets modules was a short, 5-week experiences intended to expose students to nanotechnology to increase interest and create a pipeline into more formal coursework. This report summarizes the results of the field test.

Methods

In light of the intended outcomes from the CCNY-NUE experiences, the 2007-2008 field test gathered data on the impact of the nanomaterials lecture and laboratory courses on teaching and learning, and of both courses and the nano nuggets on student engagement. The evaluation included several data sources: a pre/post assessment of student learning in the nanomaterials course, laboratory reports, course evaluations for both the lecture and laboratory courses, and other feedback from students, teaching assistants, and faculty gathered via interviews, a focus group, and informal correspondence.

Course Goal Assessment

The purpose of the Course Goal Assessment was to (1) assess the change in students’ knowledge of nanotechnology and (2) interest in nanotechnology as a result of the nanomaterials lecture course (CHE59808). As such, the Course Goal Assessment was administered at the beginning and end of the nanomaterials course as an online survey. The Course Goal Assessment used in the field test included five questions to measure students’ general knowledge of nanotechnology, sixteen questions to measure specific knowledge of nanomaterials, five questions to assess students’ interest in nanotechnology, and three background/demographic questions.

Laboratory Reports

In the nanomaterials laboratory course (CHE 59806), students applied what they had learned in the nanomaterials lecture course through hands-on experiences. Students conducted four different experiments and a survey related to ethical and societal implications, and wrote a formal report of their group’s findings. The reports were graded equally on six components: (1) introduction, (2) experimental design, (3) results, (4) discussion, (5) conclusions, and (6) references. If the initial laboratory report was submitted on time, the group had the option of submitting a revised report based on feedback provided by the instructor. All such revisions had to be submitted before the end of the course; no revisions were allowed for the final laboratory on ethics.

Course Evaluations

Students enrolled in the nanomaterials lecture and laboratory courses completed an end-of-course evaluations. This evaluation, which is regularly administered in all engineering classes, asks for students' opinions about the quality and utility of the course. In addition to asking about the quality of the teaching and instructional materials, each course evaluation asks for feedback on the extent to which course objectives – specific to the course and for the engineering department – were met.

The course evaluation for the nanomaterials course included twelve questions related to the course quality (e.g., rating the materials, instructor) and thirteen questions related to the course objectives (i.e., did students feel they learned specific material) to which students were to respond on a scale of -3 (strongly disagree) to +3 (strongly agree). Similarly, the laboratory course included ten related to course quality, thirteen questions related to course objectives, and two related to interest. All evaluations were administered as a paper-and-pencil survey at the conclusion of each course.

Students who enrolled in the five-week nano nuggets module also completed a shorter end-of-course evaluation. Like the longer course evaluation, this one asked for students' opinions about the quality and utility of the course. The nano nuggets course evaluation included five questions related to quality, three related to interest, and one related to utility.

Other Data Sources

This year's evaluation also included additional feedback from students, teaching assistants, and faculty gathered via individual interviews, a focus group with students, and informal email correspondence between the instructor, students, and teaching assistants.

Key Findings

Nano Nuggets (ENGR 101)

Students enrolled in the ten-week ENGR 101 course explored different engineering topics through a one-hour lecture, two-hour laboratory format. Students could choose from five different modules that covered topics in electrical engineering, computer science, civil engineering, and nanoscale science. Students could either choose two, five-week modules or one, ten-week module. This year, a five-week nano module was included in the offerings. A total of 34 students across three different sections enrolled in the nano module. The other modules had enrollments as follows:

- Digital Clock (10 –week module): 36 students across 2 sections
- Aggregator (5-week module): 83 students across 5 sections
- Bridge (10-week module): 48 students across 3 sections
- Electrical Devices (10-week module): 10 students in 1 section

Course Evaluation

Students who enrolled in ENGR 101 completed an end-of-course evaluation for each module they selected. This survey gathered student opinions about the quality and utility of the module. Four of the five modules received passing marks: Nano, Aggregator, Bridge, and Electrical Device (the Digital Clock module received poor ratings on all items). Overall, students reported that across the four modules, the instructor explained the material clearly, that materials were easy to understand, activities could be completed during lab hours, that equipment worked properly, and that the available tools and supplies were adequate. When it came to rating the four modules on how interesting and challenging they were, all four received passing marks. Students also felt that the Nano, Aggregator, and Electrical Device modules were “worthwhile”.

Nanomaterials Course (CHE 59808)

Course Description

The nanomaterials lecture course was designed as a “survey course” that would introduce students to the key concepts, materials, and equipment that are most relevant to research on and using nanotechnology within the core fields of engineering (chemical, electrical, and mechanical).

The nanomaterials course included seven different modules. The modules covered (1) synthesis, (2) modeling, (3) linear and non-linear optics, (4) mechanical properties, (5) imaging, (6) applications, and (7) societal impact of nanomaterials. The course included both lecture and homework that required students to write short essays on topics such as nanowire synthesis, self-assembly, company portfolio, societal impact, and imaging technology in preparation for writing their ten-page term paper. In addition, students had to prepare models for carbon nanotubes and apply the modeling software they were introduced to in the course.

Participant Characteristics

A total of 12 students completed the nanomaterials lecture course. Almost all of the students were majoring in Chemical Engineering; one was majoring in Chemistry. Half of the students had heard about nanotechnology prior to enrolling in college, having been exposed to the topic in high school.

Interest in Nanotechnology

All of the students’ enrolled in the nanomaterials lecture course expressed an interest in nanotechnology from the very beginning of the course, which did not wane over time. All of the students felt it was useful to learn about nanotechnology with most agreeing that “nanotechnology is the technology of the future.” Student’s interest in nanotechnology was also reflected in the fact that most were interested in doing undergraduate research in nanotechnology and would consider a career in nanotechnology. At the start of the nanomaterials course, several students were even interested in writing an article for a campus publication or popular science journal on nanotechnology. By the end of the course, however, only two students were still interested in doing so. Given that students' interest in nanotechnology remained high throughout the course, this change in interest may reflect an increased understanding of the emerging and complex nature of the field and the challenges that might pose in writing an article for the general public.

Knowledge of Nanotechnology

The pre/post course assessment included both general and specific knowledge of nanotechnology. The general knowledge section included five questions about interdisciplinary nature of nanotechnology and where to go for related resources and funding. Although only half of the students said they had been exposed to nanotechnology in previous college courses, about two-thirds were able to answer the general knowledge questions correctly on the pre-test. There was no change from the pre- to the post-test, suggesting that students may have come in with this more general knowledge or that students for whom this was new information might not have felt it was as important as the more specific "science" knowledge they were gaining in the course.

The pre/post course assessment also included sixteen questions related to specific knowledge of nanoscale science as conveyed in the nanomaterials course. Overall, students demonstrated improved understanding on 6 of 16 questions (38%), no change in knowledge from pre- to post-test on 8 of 16 question (50%), and decreased understanding on 2 of 16 questions (12%). When there was no change in knowledge from pre- to post-test, about half of the students were able to demonstrate an understanding of this concept at the beginning of the course (i.e., on the pre-test).

The topics in which students demonstrated *increased* understanding included:

- methods of synthesizing nanoparticles (Q1)
- configurations of carbon nanotubes (Q2)
- nanoparticles as additives in polymers (Q5b)
- self-assembly in nature (Q7)
- examples of nanotechnology inventions (Q9c)
- examples of nanomaterials (Q9d)

The topics in which students demonstrated *no change* in understanding included:

- optical properties of nanoparticles (Q4a, Q4b)
- mechanical properties of nanoparticles (Q3a, Q5a, Q9a, Q9b)
- ethnical concerns and regulations (Q8a, Q8b)

The topics in which students demonstrated *decreased* understanding included:

- molecular properties that control the state of a material (Q3a)

- imaging of nanoparticles (Q6)

Course Evaluation

Overall, students reported that the nanomaterials course had the characteristics of a quality learning environment (see Table 1). Students agreed that the content, pedagogy, instructional materials, and support came together to provide an environment conducive to learning. More specifically, students felt that the expectations for learning were clear, the content was relevant, the instructional methods and materials supported learning, and feedback on their performance and support from the instructor were readily available. Student ratings of the helpfulness of the “textbook” in learning the course material were neutral, as no textbook was utilized. In lieu of a textbook, a set of handouts that included background materials was prepared and made available to students via PowerPoint presentations and an electronic Blackboard.

With regard to the course objectives, overall, students agreed that their knowledge of specific nanomaterials and nanotechnology concepts and principals, related skills, and understanding of ethical and contemporary issues related to nanotechnology increased as a result of their participation in the CHE 59808 nanomaterials course (see Table 2). Specifically, students generally confirmed what their pre/post assessments indicated in that they reported that they are:

- able to give examples of nanomaterials,
- able to explain terms generally used in nanoscience and nanotechnology,
- familiar with methods of synthesizing nanomaterials,
- familiar with macroscopic phenomena, and
- able to predict trends in mechanical properties of nanomaterials.

Students also reported that they were familiar with the operating and limitations of imaging devices, a sentiment that was not supported by the assessment results.

Other ratings suggest that the instructional materials course could be somewhat improved, particularly with regard to enhancing students’ understanding of professional and ethical responsibilities in the area and their ability to communicate effectively.

Table 1. Mean student ratings of course quality for nanomaterials course (CHE 59808) field test, fall 2007.

Course Quality	Mean[1]
1. The instructor made clear the important points I had to master for this course.	2.73
2. The syllabus was followed (if there was no syllabus, circle -3)	2.64
3. The instructor did ***not*** present the material in a way that made it clear what was to be learned and why.	-2.55
4. The relevance of this course to chemical and other areas of engineering was made clear.	2.45
5. The instructor was available during office hours, by e-mail, or other means of consultation.	2.91
6. The homework was helpful in learning the course material.	2.73
7. The instructor made good use of teaching media such as PowerPoint presentations and Blackboard.	2.73
8. The course content did ***not*** meet my expectations.	-2.55
9. The course material in both content and techniques was enhanced by well-chosen examples and illustrations.	2.55
10. Grading of homework and quizzes was done in a timely manner (courses only). Grading of reports was done in a timely manner (labs and design courses).	2.82
11. The instructor ***dis***couraged questions and class discussion.	-2.80
12. The textbook was ***not*** very helpful in learning the course material.	-0.60

Notes: [1] Ratings measured on a scale of -3 (strongly disagree) to +3 (strongly agree).
Source: ABET Course Feedback Survey, fall 2007.

Table 2. Mean student ratings of course and ABET objectives for nanomaterials course (CHE 59808) field test, fall 2007.

Course Objectives	**Mean[1]**
1. I am able to give examples of nanomaterials and rationalize why they are nanomaterials.	2.64
2. I can explain terms generally used in nanoscience and nanotechnology such as quantum dot, scanning probe, nanotubes, etc.	2.55
3. I am ***not*** familiar with synthetic routes to nanomaterials.	-2.55
4. I can qualitatively explain familiar macroscopic phenomena such as phase transitions, diffusion and wetting, in terms of molecular motion and interactions.	2.36
5. I am ***not*** able to predict trends in the mechanical properties of nanomaterials and nanocomposites as a function of the size of the nanomaterial.	-2.09
6. I am familiar with the operating principals and limitations of scanning and electron probe techniques.	2.09
ABET Objectives	
7. I have developed an ability to apply knowledge of mathematics, science and engineering.	2.00
8. I now have an improved understanding of professional and ethical responsibility.	1.64
9. My ability to communicate effectively has ***not*** been improved.	-1.73
10. The broad education I require necessary to understand the impact of engineering solutions in global and societal context has been extended.	2.18
11. I now have a better recognition of the need for, and an ability to engage in, life-long learning.	2.45
12. My knowledge of contemporary issues has ***not*** increased.	-2.09
13. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice has increased.	2.27

Notes: [1] Ratings measured on a scale of -3 (strongly disagree) to +3 (strongly agree).
Source: ABET Course Feedback Survey, fall 2007.

Nanomaterials Laboratory (CHE 59806)

Course Description

Designed to expose students to hands-on research so they are more prepared to work with faculty, the nanomaterials laboratory (CHE 59806) included five separate modules on nanotechnology that covered information from the seven modules presented in the nanomaterials lecture course (CHE 59808).

- Module 1: Chemistry – Synthesis of Nanoparticles
- Module 2: Electrical Engineering / Physics – Optical Characteristics of Nanoparticles
- Module 3: Chemical Engineering – Imaging of Nanomaterials
- Module 4: Mechanical Engineering – Mechanical Properties of Nanoparticle Reinforced Composite Materials
- Module 5: Ethical and Societal Considerations

The laboratory session associated with each module lasted approximately three weeks. Each laboratory module was led by a teaching assistant (TA) who was enrolled as a graduate student in the related program (i.e., a chemical engineering graduate student led the laboratory for this topic area). During the first week, the TAs conducted a demonstration laboratory to introduce students to the concepts, materials, procedures, and equipment. In some instances, the TAs reviewed key concepts from the nanomaterials course the previous semester as a refresher for students. To prepare for the experiment, students are expected to take additional notes to supplement their laboratory manual, to ask questions, and try out the equipment. Following the demonstration, students had one to two weeks to complete the experiments in their groups with support from the TA. In some instances, when the group was able to schedule their demonstration early in the first week, they were able to begin their experiment within two days. At times, the TAs needed to review portions of the demonstration. Because the laboratory experience was designed to give students real world experience, each group was given different pre-made samples to work with to encourage them to focus on their own experiment and not simply observe the results obtained by other groups. Finally, in the third week, student groups wrote their laboratory report.

Participant Characteristics

All of the students enrolled in the nanomaterials laboratory completed the nanomaterials lecture course. A total of ten students, divided into four groups of two or three, completed the spring 2008 laboratory course. Most were majoring in Chemical Engineering.

Laboratory Reports

Overall, the total scores for the laboratory reports were high across the groups, averaging more than 80% of the possible 600 points per final report. The modules on which groups received the highest scores were:

- Module 3: Chemical Engineering – Imaging of Nanomaterials (mean = 94%)
- Module 2: Electrical Engineering / Physics – Optical Characteristics of Nanoparticles (mean = 91%)
- Module 5: Ethical and Societal Considerations for Nanomaterials (mean = 89%)

Groups still received more than 80% of the points on the other two modules:

- Module 1: Chemistry – Synthesis of Nanoparticles (mean = 85%)
- Module 4: Mechanical Engineering – Mechanical Properties of Nanoparticle Reinforced Composite Materials (mean = 81%)

In looking at the scores for the six different sections within a report, students had an easier time writing up the introduction and references sections but were learning more about how to write the results, discussion, and conclusion section, as evidenced by instructor feedback and subsequent revisions. Three of the four teams opted to submit at least one revised report. All reports that were revised receiving higher scores, sometimes significantly higher.

Course Evaluation

Students who enrolled in CHE 59806 nanomaterials laboratory completed an end-of-course evaluation. This survey gathered student opinions about the quality and utility of the course, as well as their interest/engagement.

Overall, students reported that the nanomaterials laboratory had the characteristics of a quality learning environment (Table 3). Students agreed that the content, pedagogy, and instructional support came together to provide an environment conducive to learning chemical engineering through laboratory research. More specifically, students felt that the expectations for learning were clear, the experiments were relevant to the field, and feedback on their performance and support from the instructor and teaching assistant were readily available. Students were less likely, however, to report that “the instructional materials were complete and helpful.”

With regard to the course objectives, overall, students agreed that their knowledge of specific nanomaterials and nanotechnology concepts and principals, related skills, and understanding of ethical and contemporary issues related to nanotechnology increased as a result of their participation in the CHE 59806 nanomaterials laboratory course (see Table 4). Specifically, students generally confirmed the acquisition of the skills demonstrated in their laboratory reports:

- synthesizing nanoparticles,
- operating a spectrometer,
- analyzing and interpreting optical data,
- operating an atomic force microscope,
- analyzing and interpreting stress-strain data, and
- a familiarity with ethical issues related to nanomaterials and their applications.

In addition, students reported an increased ability to make oral presentations and write laboratory reports (see Table 3).

Table 3. Mean student ratings of course quality for nanomaterials laboratory (CHE 59806) field test, spring 2008.

Course Quality	Mean*
1. The instructor made clear the important points I had to master for this course.	2.50
2. The syllabus was followed (if there was no syllabus, circle -3)	2.75
3. The instructor and teaching assistants did ***not*** provide sufficient help in carrying out the experiments.	-2.63
4. The experiments increased my understanding of the practice of chemical engineering.	2.50
5. The instructor was available during office hours, by e-mail, or other means of consultation.	2.88
6. All of the experiments were boring.	-1.63
7. All of the experiments were interesting.	1.25
8. My ability to make oral presentations and write labs was improved.	2.00
9. Grading of lab reports was done in a timely manner.	2.50
10. The instructor ***dis***couraged questions and class discussion.	-2.43
11. The instructional materials were complete and helpful.	1.88

Notes: [1] Ratings measured on a scale of -3 (strongly disagree) to +3 (strongly agree).
Source: ABET Course Feedback Survey, spring 2007.

Table 4. Mean student ratings of course and ABET objectives for nanomaterials laboratory (CHE 59806) field test, spring 2008.

Course Objectives	Mean*
1. I am able to synthesize nanoparticles using chemical synthetic routes	2.75
2. I have learned how to operate a UV/vis spectrometer to follow the synthesis of nanoparticles.	2.38
3. I can analyze and interpret absorption/emission and fluorescence data.	2.50
4. I do ***not*** know how to operate an atomic force microscope.	-2.38
5. I am able to analyze and interpret stress-strain data.	2.63
6. I am familiar with ethical, environmental and health-related issues associated with nanomaterials and their application.	2.50
ABET Objectives	
7. I have developed an ability to apply knowledge of mathematics, science and engineering.	2.38
8. I now have the ability to design and conduct experiments, as well as to analyze and interpret data.	2.50
9. I have ***not*** acquired an ability to function on multidisciplinary teams.	-2.00
10. I now have an improved understanding of professional and ethical responsibility.	2.38
11. My ability to communicate effectively has ***not*** been improved.	-2.13
12. An ability to use the techniques, skills and modern engineering tools necessary for engineering practice has increased.	2.50

Notes: [1] Ratings measured on a scale of -3 (strongly disagree) to +3 (strongly agree).
Source: ABET Course Feedback Survey, spring 2007.

Student Engagement

Feedback regarding students' interest in and engagement with the laboratory experience came from the course evaluation and informal feedback from the teaching assistants and students to the course instructor.

Although sometimes late to lab, for the most part most TAs reported that students were engaged, prepared, and able to complete the labs within the allotted time. TAs did not indicate that students' tardiness significantly affected students' performance in the laboratory sessions.

While students did not rate all of the laboratory modules as interesting (see Table 3), when they did, they shared their excitement with the course instructor:

> *"[I] was extremely excited about the Module 2 [Optical Characteristics of Nanoparticles]. I learn [sic] so many things! The experiment did not came [sic] out perfect, but it made me know how the optical devices work in general."*
>
> *"[Module 3: Imaging of Nanoparticles] was enticing…I tend to get shivers down my spine when working with technologies that prove relationships or material properties that I read about in textbooks or learn in lecture. Nothing compares to hands-on learning."*
>
> *"The lab as fun, because computer got [sic] us nice images (should I say it was visual). Only drawback was that we never got the results that we expected. But on the other hand this is what research is about."*

Laboratory Experience

Students also provided informal feedback to the course instructor on the performance of TAs. Overall, students reported that the TAs provided clear and helpful information and guidance during the laboratory demonstrations of procedures and equipment, and during the actual experiments. TAs were characterized as "professional" and "knowledgeable".

Students offered some general suggestions for improvement that tended to reflect whether a TA implemented the laboratory only as outlined or whether the TA addressed needs that emerged during the sessions. For example, while some TAs reported that they recognized the need to review key concepts from the nanomaterials course and during the demonstration session, other TAs did not. In the latter instance, students were more likely to report that they wanted more information and the TA was more likely to say students needed to prepare more before coming to the laboratory.

Suggestions for improvement offered by students and TAs included the following.

Demonstration session:

- Show the laboratory set-up at the beginning to help *"visual learners"* relate the information to the actual equipment.
- Allow time for students to *"play"* with the equipment during the demonstration so there is *"less learning and tentativeness when it came time to do the actual experiments"*.

Experiments:

- Review basic concepts from the nanomaterials course and their importance from an application standpoint.

  "[I had to] 'teach more' in the lab than expected. Students seemed to know the basics, but needed to learn more about the specific properties and why they were important in the application."

- Ensure that all samples are prepared properly prior to the experiment.

  "Only one of three or four polycarbonate samples worked properly. Other samples fractured outside the gauge length or at the tips, which the jaws were holding, even when the velocity was low."

- Ensure that the number of samples to be observed is suitable for the equipment.

  "The program ran pretty slow when sample number increased. Sometimes this made observation and data taking extremely irritating."

- Allow more time for students to practice certain procedures, either during the demonstration or the experiment.

  "I found picking the cantilever and placing it above the laser head [difficult], guess with practice it will be easy."

  "Experimenters should be careful on fastening the jaws. If the grip is too tight, the sample breaks at the jaw. If it is a little bit too loose, the jaw loses its grip, especially when PDMS is the subject."

All of the TAs said that the time allotted for the laboratory demonstrations and sessions was adequate, averaging about 2-3 hours for key components, even with the additional time some spent reviewing basic concepts from the lecture course.

A Conversation with Students on the Nanomaterials Series

To better understand why students enrolled in the nanomaterials lecture and laboratory courses and their experiences throughout the series, the evaluator conducted a focus group with five students at the conclusion of the laboratory.

All of the students in the focus group were majoring in chemical engineering. Four of the five students had completed both the nanomaterials course and laboratory. This group of four included two seniors, one junior, and one sophomore. The other focus group participant was a graduate student who had only taken the nanomaterials course.

The focus group opened by asking students "Why did you want to take the nanomaterials lecture and laboratory courses?" to which students had this to say:

- *"to learn more about nanoscale science and technology" (3 students)*
- *"to learn how to write reports (knew professor gave good feedback)" (2 students)*
- *"I liked the professor" (1 student)*

- *"I wanted to get to know the professor to consider whether to pursue an opportunity to do research in her laboratory" (1 student)*

Students were then asked, "What from the nanomaterials course helped to prepare you the most for the laboratory (application) course?" Students in the group concurred that the nanomaterials course gave them an understanding of the core concepts they needed to know for the laboratory course. They also agreed that they wished the lecture course had included more to help them understand how these concepts related to the applications they would be dealing with in the laboratory.

When asked, "Now that you've been in the laboratory, what have you learned – knowledge and skills – that you didn't know coming into the applications course?" To this students responded that although the nanomaterials lecture course had provided an overview of equipment used in nanotechnology, students said that they needed the demonstration portion of the laboratory and the hands-on experience during the experiments to really understand how to use the equipment.

Students were also asked whether participation in the laboratory course helped them with other courses. Students commented that they could see the connections or overlap with other courses, saying that a process or concept in the laboratory would stand out as similar to what they had learned in another course.

Finally, when asked, "What advice would you give to the faculty to improve both the nanomaterials course and the laboratory?" students had this to say:

- Offer the nanomaterials course and laboratory earlier in students' academic careers.

  Students felt that the course and laboratory were valuable in that they introduced students both to nanotechnology and to other engineering fields. Such an introduction, students felt, could help students become clearer on what would be most appropriate for them as an undergraduate major, provide a clearer focus for their graduate work, and give them enough experience to know if they would like to research.[1]

- Offer the lecture course and laboratory concurrently.

  Students felt this would help them integrate the content, demonstration, and research experiences. In this manner, they suggested that the course, which would include lecture and demonstrations, would alternate with the laboratory sessions, which would also include a brief demonstration. This, they felt, would reduce the

[1] The course instructor commented that ideally, the course and laboratory would be offered in students' junior year. However, the junior year schedule is already filled with other requirements. Thus, another option would be to offer the course and laboratory during the sophomore year to prepare students to work with faculty on research projects during their junior and senior years.

amount of review required by students and teaching assistants during the laboratory course.

- Limit laboratory teams to two students.

  This last suggestion was a reflection of the difficulty groups had in scheduling their laboratory time when their group included three people.

Faculty Involvement

This year, the evaluator interviewed three faculty members who had been involved in the development of the modules to talk about their roles and how their involvement had influenced their own professional work. The previous year, the evaluator interviewed all but one of the faculty involved with the project. What follows is a summary of the key learnings from both sets of interviews.

- Two heads are better than one.

  Faculty members recognized that the involvement of different disciplines allowed them to offer specific insights into their content area and thus strengthen the overall project (e.g., advising the project to not use gold nanoparticles for mechanical engineering experiments because it is soft and conductive).

- Opportunity for professional learning.

  Faculty members also recognized this project as an opportunity for them to learn how to work with other faculty and community partners in a collaborative manner (e.g., working together to develop a module that integrates multiple disciplines; bringing in research and development representatives from industry who could speak about academic research in an inspiring manner). Faculty members also recognized that clear expectations for involvement, strong project leadership, and building on prior relationships supported the collaboration.

- Opportunity to enhance faculty research agendas.

  Faculty members felt these collaborative relationships provided an opportunity for them to be more multi-disciplinary in their own research (e.g., considering the possible applications of including nanoscale amounts of gold or other conductive materials in polymers, which are not conductive).

- Leveraging resources.

  Faculty members also recognized the opportunity to "leverage" resources in a manner that supported both this project and others in which they were involved (e.g., training high school teachers how to teach the new ENGR 101 nano nugget to build a pipeline to the college).

Summary

In this first field test, the evaluation data provides evidence that the CCNY-NUE team was successful in developing and implementing nanotechnology coursework, laboratory experiences, and mini-“nano nuggets” modules that engage students and promote learning of knowledge and skills relevant to engineering and to nanotechnology.

The CCNY-NUE team will conduct a second field test during the 2008-2009 school year.