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Implementing a High School Interdisciplinary Course in Light and Electron Microscopy

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For the past eight years, the Bergen County Academies, a public magnet high school in northern New Jersey, has offered its students the opportunity to participate in a graduate-level research program. The school is equipped with various types of scientific instrumentation to fit the needs of its research labs and their respective fields of molecular and cell biology, genetics, biotechnology, chemistry and nanotechnology. Among these research labs is an electron microscopy facility featuring a scanning electron microscope (SEM), transmission electron microscope (TEM) and laser scanning confocal microscope.

Prior to the 2011-2012 school year, the primary function of the electron microscopy facility was to provide imaging and analysis capabilities to students who were conducting independent research. It was then decided that an elective in microscopy should be developed to increase the number of students utilizing the instruments. A curriculum for an "Introduction to Microscopy" elective was written and aligned with the New Jersey Core Curriculum Content Standards in science, technology, and English/writing and presentation. The trimester-long course began running in December 2011 and will be offered each trimester. Two sections of the elective are run concurrently, as the class size had to be limited to twelve students due to safety protocols and seating capacity of the lab. The course has a combination lecture/lab format to provide both traditional classroom instruction and hands-on exercises for the students to prepare samples and use the microscopes.

"Introduction to Microscopy" consists of three units: general microscopy theory, scanning electron microscopy and transmission electron microscopy. The general microscopy theory unit covers the theory and background material a student needs in order to understand how the instruments work, such as history of the microscope, atomic structure, the electromagnetic spectrum, resolution and parts of the microscope. The "parts of the microscope" lesson compares the components and systems of each instrument in parallel; for example, illumination source is first defined and then the source for each instrument is discussed. The SEM unit consists of sample preparation theory, beam-specimen interactions, secondary electron detection and image optimization. Students have hands-on exercises in preparing simple specimens and learning how to use to microscope to acquire quality images (Table 1). The TEM unit includes sample preparation, CCD cameras, simple alignment and fast Fourier transform. This unit also has hands-on exercises in which students prepare nanoparticles for TEM imaging and learn imaging techniques. Students are assessed on their knowledge in microscopy content areas, as well as the practical application of imaging techniques.

Microscopy is an inherently interdisciplinary field. Topics such as atomic structure, properties of the electron, electromagnetic spectrum, and sample preparation theory can all be classified as chemistry; resolution, diffraction, waves, lenses, wave-particle duality, electricity and magnetism fall under physics; and biological sample preparation principles, light microscopy stains and dyes, and cellular ultrastructure align with biology.

While microscopy may appear to be a very specialized course, the overarching concepts that are taught will be revisited by students in other science courses, both at the high school and college levels. In addition, students are exposed to advanced scientific technologies by using the electron microscopes, and a required lab report assignment enhances the students' technical writing and data analysis and presentation skills. By successfully completing this course, students are able to: explain the differences between and advantages/disadvantages of light and electron microscopy; independently operate the SEM and TEM; gather quality, meaningful data; communicate the results of a scientific investigation in written form; and understand the real-world applications of microscopy.

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Objective	Learners will apply their knowledge of sample preparation principles for the scanning electron microscope by preparing their own non-biological samples for SEM imaging.
Materials	Copies of protocol, SEM pins, Double-sided conductive carbon tape, Scissors, Swatch of "nano-structured" fabric, Forceps, Storage boxes, Gloves, Sputter coater
Activity	1. Facilitated classroom instruction aided by PowerPoint presentation 2. Hands-on laboratory exercise: preparing samples 3. Hands-on laboratory exercise: imaging samples
Procedure	1. Anticipatory set: students are given a handout with flow chart of sample preparation steps and must fill in boxes in correct order. 2. Teacher will review material from previous class on sample preparation theory. 3. Teacher and students will discuss flow chart and make necessary corrections to reinforce lesson. 4. Students will use knowledge from classroom instruction and printed copy of protocol to prepare "nano-structured" fabric for SEM imaging. 5. Students will use the SEM to image samples. 6. Teacher and students will evaluate quality of preparation for each sample.
Assessment/Closure	Quality of preparation will be determined by presence/absence of charging artifacts in SEM images.

Table 1: A sample 5-point lesson plan for the "SEM sample preparation" lesson in the "Introduction to Microscopy" elective.