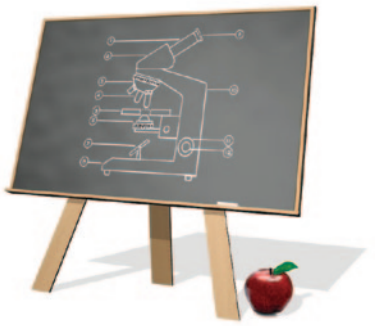
Augmenting Secondary Education with Advanced Microscopy



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Bergen County Academies

In his 2011 State of the Union address, President Barack Obama echoed the sentiments of this nation's leaders for the past twenty years when he stated, "Nations like China and India realized . . . they could compete in this new world. So they started educating their children earlier and longer, with greater emphasis on math and science. They're investing in research and new technologies. . . . Maintaining our leadership in research and technology is crucial to America's success. But if we want to win the future—if we want innovation to produce jobs in America and not overseas—then we also have to win the race to educate our kids." The Bergen County Academies (BCA) in Hackensack, NJ, is attempting to do just that: invest in research and technology at the high school level in order to expose students to real world opportunities and applications they will experience in the future.

BCA is a public magnet high school with an enrollment of approximately 1,100 students, featuring career-focused academies operating as a cohesive unit to provide a dynamic, specialized, student-centered environment. Transitioning in 1992 from traditional vocational education, BCA began with the Academy for the Advancement of Science and Technology. Students of this academy received an education heavily focused on the sciences and research. The success of the program led to six additional academies in the years that followed: Business and Finance, Culinary Arts and Hotel Administration, Engineering and Design Technology, Medical Science Technology, Telecommunications and Computer Science, and Visual and Performing Arts. Each of these academies provides students with a focused curriculum in its specialty area while also allowing students to explore and become involved in any and all programs offered at the school.

Over the past decade, highly motivated, dedicated, and visionary school administrators and faculty have believed in offering students a one-of-a-kind education expanding beyond the classroom and textbooks. This led to the development of the school's research programs in the areas of biotechnology, chemistry, nanotechnology, and stem cell research. To this end, a number of powerful technologies were acquired, including a flow cytometer, capillary gel electrophoresis DNA sequencer, RT-PCR, HPLC, GC-MS, probe station, FT-IR spectrometer, and cell culture facilities. BCA is also home to an electron microscopy suite known as the Nano-Structural Imaging Lab (NSIL), equipped with an SEM, TEM, and Laser Scanning Confocal Microscope (LSCM).

The mission of both the research programs and the NSIL is to expose students to scientific inquiry, research, and instrumentation and to provide transferable, firsthand experiences with the techniques, practices, and perspectives of professional scientists. By expanding the capabilities and context of secondary science education, it is expected that students will be better equipped for, and more likely to pursue leadership positions in, science, scientific research, and global-scale problem solving.

Development of the NSIL

Traditional light and fluorescent microscopy are core imaging technologies that were available to students from the inception of the research programs. When conceiving the NSIL, the district sought to expand imagining capabilities to the nano-scale. An advisory team was formed with researchers and facility managers from area research institutions and companies, including the City College of New York, Hunter College, and Polymath Interscience, LLC. A collaborative facility was envisioned that would afford science and engineering students the ability to synthesize, visualize, and characterize nano-scale structures, devices, and interactions.

The district sought and received funding from the Carl D. Perkins Vocational and Technical Grant to support the initial facility development, including the acquisition of an FEI Quanta 200 3D dual-beam FIB/SEM with low-vacuum imaging capabilities, as well as the associated sample preparation equipment and supplies. The system is supplemented with a peltier stage, an Oxford INCA EDX, and a platinum deposition system. Over the following year, the lab expanded its capabilities to include a TEM and an LSCM with support from the Bergen County Board of Chosen Freeholders. A JEOL 2100 with cryo capabilities and a Leica TCS SP5 (Figure 1) were added to the facility, along with systems for ultramicrotomy, carbon and metal evaporation, and cryo-plunge freezing.

In addition to imaging, these light and electron microscopes provide students the ability to create three-dimensional reconstructions. DualBeam™ Slice and View sections from the SEM and image stacks from the LSCM are reconstructed using Amira® software. Tomograms can be created using the TEM, with eTomo used for initial reconstruction, and can be further animated using Amira®. These 3-D techniques help students better understand and analyze the structure and function of their samples, such as nanoparticles or signaling pathways within a tissue sample.

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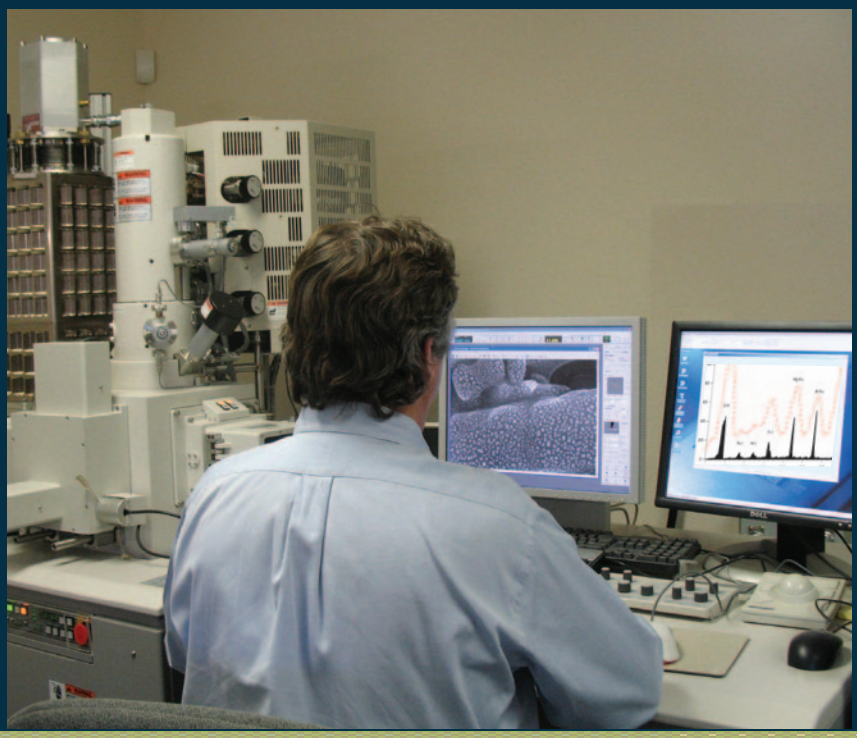

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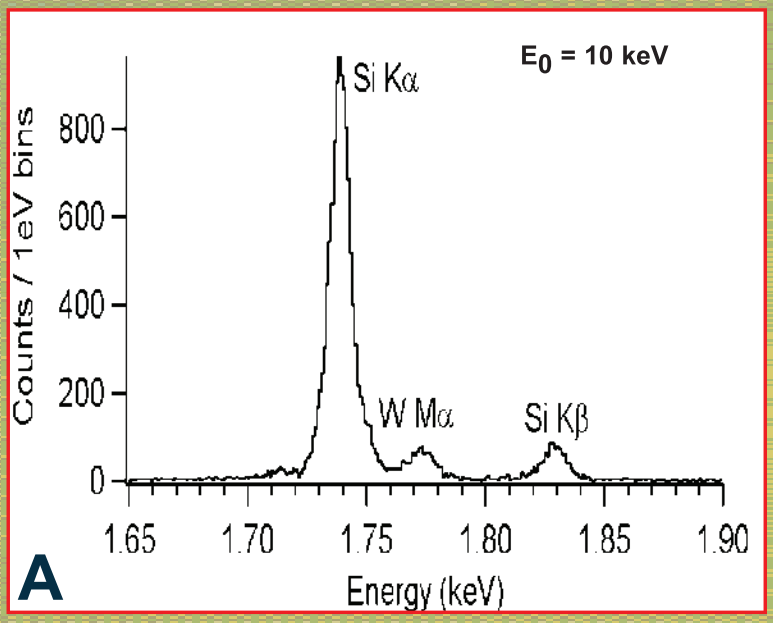

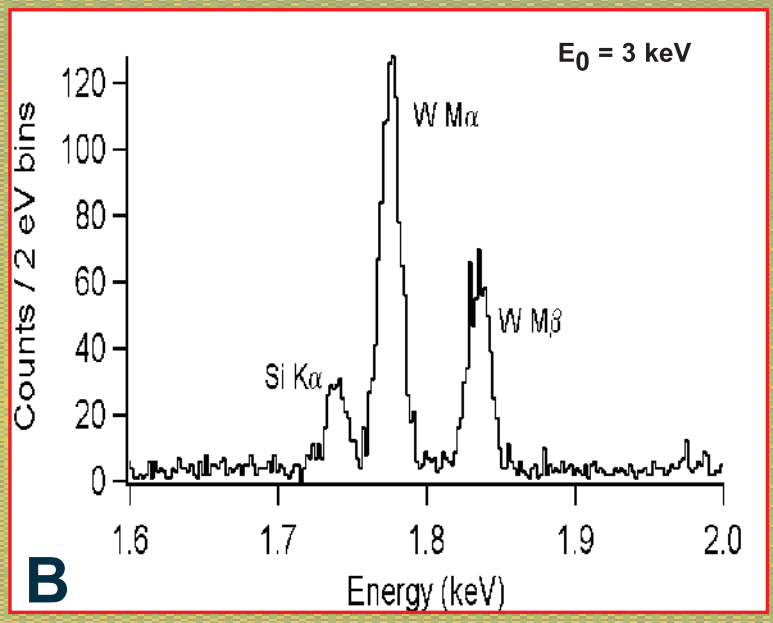

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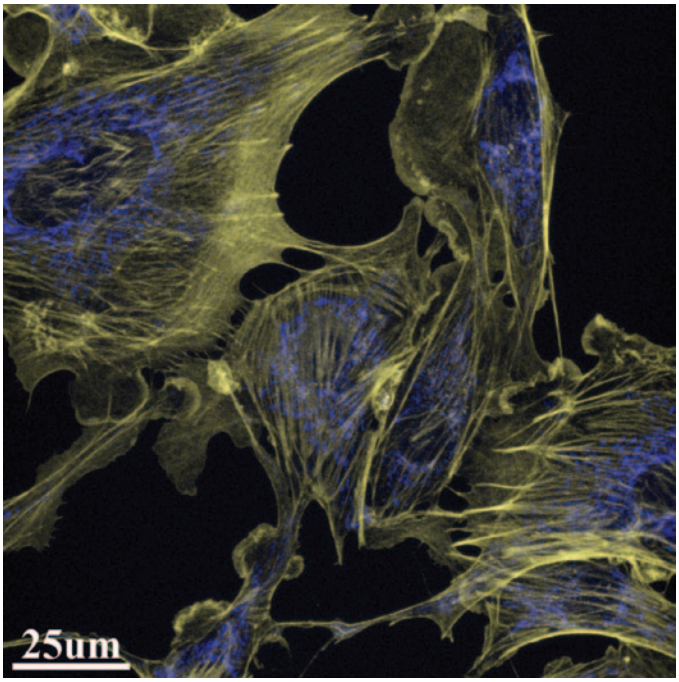

Figure 1: Student image of bovine pulmonary artery endothelial (BPAE) cells stained with MitoTracker® Red CMXRos and Alexa Fluor® 488 phallolidin taken on the laser scanning confocal microscope (LSCM).

The NSIL facility is staffed by members of the district's technology department and supported by faculty from the school's various research disciplines. This structure is unique and works in the best interest of the students because no one department or faculty member "owns" the equipment, which leads to a great deal of interdisciplinary research between biotechnology, stem cell research, chemistry, nanotechnology, and materials science.

Student Research in the NSIL

There are three main pathways for students to be involved with hands-on experiences in microscopy. The first is tied to the other research programs at the school. Students involved in research in the Stem Cell, Biotechnology, Nanotechnology, and Chemistry labs use the facility for an imaging or analysis component of the project they are carrying out (Figure 2). Students can use the LSCM, SEM, or TEM to image surface or interior structures of cells undergoing various treatments; confirm the presence, size, or shape of synthesized nanoparticles; determine the elemental makeup of a sample; or use the focused ion beam (FIB) to mill a pattern or uncover an underlying layer of a sample. For these students, microscopy may not be central to the research project, but it provides additional data to either support or counter their proposed hypotheses.

The second student pathway involves collaborative projects with an outside institution. A number of companies, hospitals, and universities have had researchers partner with BCA and the NSIL in order to have access to the technology the school has to offer. Currently, these researchers are able to have their samples prepared, imaged, and analyzed at no cost, on the conditions that a BCA student actively participates in the project and collects all of the data, is authored on any resulting publication, and is allowed to use the data they acquire in a science fair or

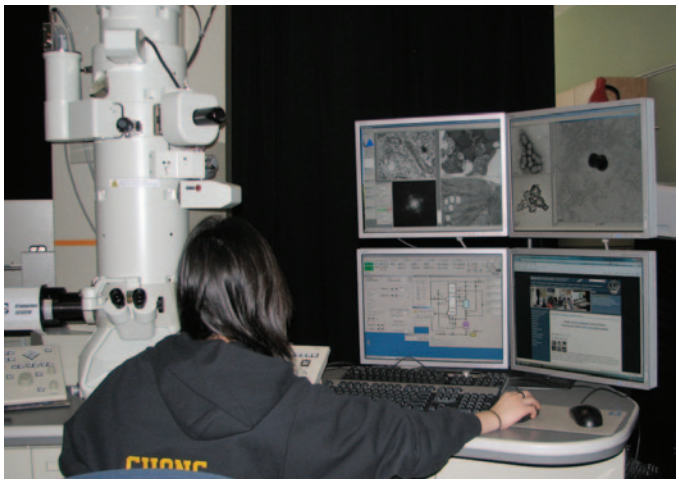

Figure 2: Independent research student from Bergen County Academies imaging nanoparticles on the TEM.

competition (Figure 3). While this benefits both parties, it allows students the opportunity to interact with the PI, exposes them to a current real-world research project, and shows them ways that they can apply the knowledge and research background they get at the school in future career paths.

The third pathway in the NSIL is an internship opportunity for students from other district programs. Seniors in the district must participate in an internship one day a week for the entire year. A select number of students are able to use the NSIL as their internship. During their time in the lab, the students learn theory and applications of each of the instruments, design a research project with a focus on microscopy, carry out the research project, and learn how to properly write a scientific paper and present their findings to peers (Figure 4).

In addition, the lab reaches out to the liberal arts faculty members of the school to try to find ways to get students outside of the research programs involved in short, meaningful

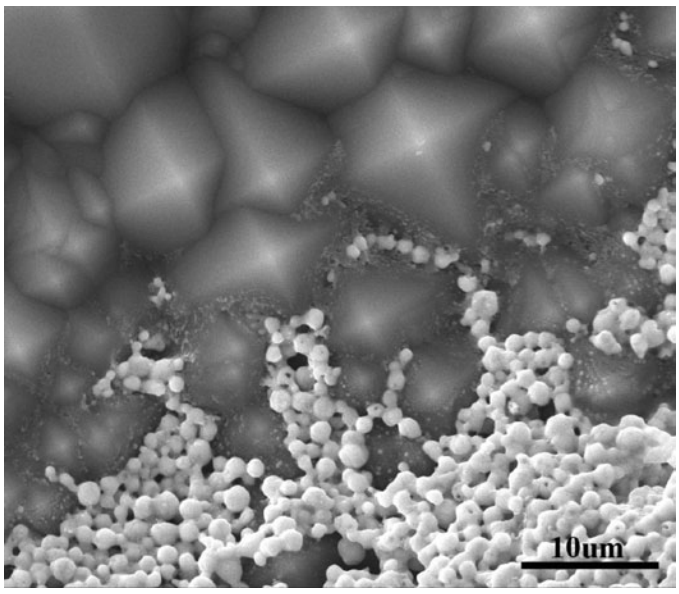

Figure 3: SEM micrograph of a silicon-silver interface on a photovoltaic device. This work was part of a student collaboration with researchers from a local company.

Figure 4: Andres Paez, former Nano-Structural Imaging Lab intern, and his research partner Namrata Ramani presenting their project at the 2010 Young Science Achievers Program (YSAP) culminating event held June 9, 2010, at the Liberty Science Center in Jersey City, NJ.

experiences in the lab (Figure 5). One example involved a comparison of bacterial growth on fresh versus spoiled lettuce by students in the culinary program. In another short course, students from the music ensembles examined the grooves on a vinyl record to visualize the small features which actually create the different sounds that are heard when the record is played. These short lessons are great for exposing a large number of students, who otherwise might not get involved in research, to the opportunities available to them.

Student Perspectives

Two students, a current senior and a recent graduate, were asked to comment about their experiences with the research program at BCA and the NSIL—especially how it made an impact on their lives and future career path. Won-Ik (Ryan) Lee is a current senior in the Academy for the Advancement of Science and Technology. His two research projects (one a collaboration and the other independent research out of the Stem Cell lab) have led to him presenting at the 2010 Material Research Society Fall Meeting [1], him presenting at the 2011 Stem Cells & Regenerative Medicine World Congress [2], and his abstract being accepted to the 2011 Gordon Conference on Stem Cells and Cancer [3]. In addition, he currently has a publication in review, and he has submitted an abstract to the 2011 Microscopy & Microanalysis conference.

Figure 5: Large group instruction for a freshmen biology class in the Nano-Structural Imaging Lab. Students were examining planaria as part of a lab project.

Andres Paez is a college freshman majoring in chemical engineering at Stevens Institute of Technology in Hoboken, NJ. Paez was an intern in the NSIL in 2009–2010, and his research in the lab led to an abstract publication in the 2010 Proceedings of Microscopy & Microanalysis [4], as well as an abstract submitted for the 2011 conference.

When asked about the research program at BCA, Lee said, "Research at BCA has changed the course of my life. I didn't come here thinking that I'd become so immersed in research. However, I have become so involved in both nanotechnology and stem cell research at BCA that I can't really see myself pursuing a career in any field other than scientific research." Lee ended by saying, "I've met students from across the country—whether from summer research programs, the National Chemistry Olympiad Study Camp, or even Model UN conferences—who do 'research' . . . no one does research like we do at BCA. Most other students seek internships in already existing lab groups and follow set procedures; BCA's student researchers independently develop their entire project, from formulating the research question and designing a plan to investigating the literature and conducting experiments. I believe this is what really makes our research program so special."

Paez was asked about his experience and if it opened any doors for him after graduation. He responded by saying, "The skills and techniques that I acquired in the NSIL have allowed me to have an immediate and significant advantage at the college level. Not only am I several steps ahead of my classmates in terms of thinking like a scientist, but I have been selected to work at one of the school's electron microscopy facilities to gain research experience, all because of my internship." He continued by saying, "For those pursuing a technical/engineering-type job during or after college, standing out from the rest of the crowd is what gives you an advantage. I am in a co-op program at my school, and there are over 200 students with an identical GPA and resume as me. However, those 200 students cannot say they have work published in scientific literature during high school. I can, and it definitely gives me an advantage."

The Future of the NSIL

With the NSIL only being open for three years, it is still too early to see how successful the program is at putting students on a path for research and science in college and as a career. Tracking students that move through the program will be vital in the years ahead. However, the short-term success of the facility speaks for itself.

The NSIL at BCA has grown not only in the number of students utilizing the facility, but also in terms of its output since it opened in 2008. As one benchmark for output, in 2009, two abstracts with two students as first authors were submitted and accepted to the Microscopy & Microanalysis conference [5, 6]. In 2010, that number rose to three abstracts with five students as first or second authors [4, 7, 8]. This year, nine abstracts with nine students as first or second authors were submitted to the conference. The increased number of submissions shows the

increased popularity of the research programs among students and the quality of ongoing projects at the school.

In its first three years, the NSIL has been primarily used as an imaging facility for students involved in independent or collaborative research at the school. The future of the program looks to maintain this structure while adding a curriculum component. The next stage is to make the facility even more accessible to students by developing elective courses that would introduce basic theory, research, and hands-on activities and exercises in microscopy to students who may or may not be on a science career path.

A final goal in the near future is to reach out to more local companies, universities, and hospitals in an effort to increase awareness of the program to the community of NJ/NY, while at the same time bringing in more collaborators with whom students can get involved in research.

As President Obama explained, "The first step in winning the future is encouraging American innovation. None of us can predict with certainty what the next big industry will be or where the new jobs will come from. . . . What we can do—what America does better than anyone else—is spark the creativity and imagination of our people." BCA and the staff of the NSIL believe that sparking creativity in the high school classroom will lead to a new generation of accomplished, motivated American scientists.

Note: The authors will be speaking about the NSIL at BCA in the *Microscopy in the Classroom* Symposium at Microscopy & Microanalysis 2011 in Nashville, TN. If you are attending the conference, feel free to attend the talk for more information.

Acknowledgments

The authors would like to thank the elected officials of Bergen County, NJ, and the administration, faculty, and staff of the Bergen County Technical Schools for their continued support of the research program.

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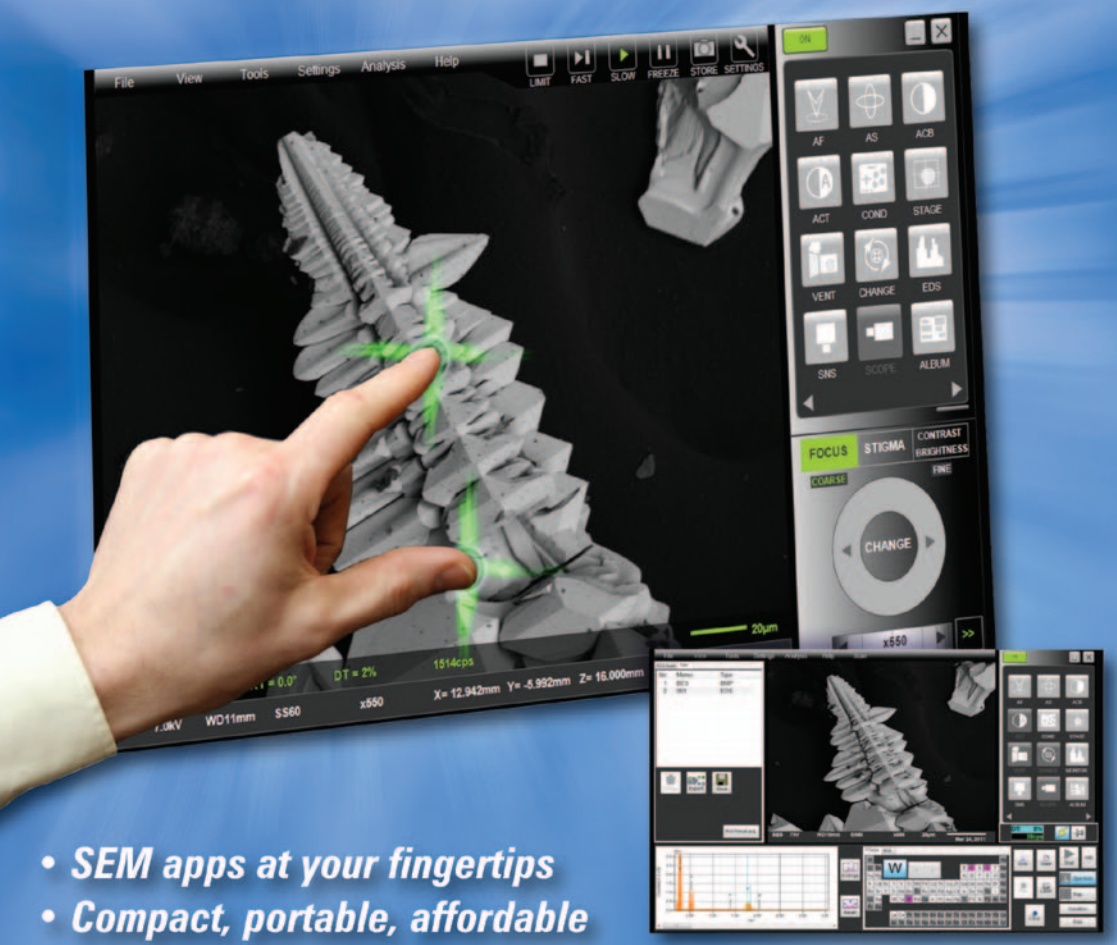

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