A Formula for the New Microscopists

What began as a series of hands-on seminars have now evolved into perhaps one of the first applied microscopy baccalaureate programs of its kind in the U.S.

The microscope is probably the most common laboratory instrument in existence. Since the first compound microscope appeared in 1590, through the time of Anton von Leeuwenhoek and his discovery of bacteria and yeast using homemade lenses, and now the advent of fluorescent live-cell imaging and transmission electron images, that glimpse atomic structures thousands of microscopes have to led millions (or more) contributions to scientific understanding.

And yet, despite this rich history, almost no universities dedicate a major degree program to the discipline of microscopy.

Michael Whiteside, a molecular biology professor at Concord Univ. Chicago, has steered interested students to the College of Microscopy. In the fall, the new bachelor's degree program in microscopy he launched with The McCrone Group will officially begin accepting students. Image: The McCrone Group

Of course, any college degree program in a related science field—including chemistry, engineering, and microbiology—will put students in contact with light microscopes and, particularly in the case of graduate programs, even atomic force or electron microscopes. But try explaining that to Diana Wesoloski, a chemistry student in Illinois whose career ambition of working in a crime lab will frequently put her at the wheel of imaging equipment. As part of this goal she is taking specific microscopy-related courses in polarized light microscopy, trace analysis, and optical crystallography techniques to bolster her skills in support of her goal of obtaining a job in a crime lab.

The **Concordia Univ.** Chicago junior is benefiting from the early offerings of a new partnership, one which will prepare students for a career where the microscope is king. Officially accepting students for the fall 2009 semester, the bachelor's of science of science degree program in applied microscopy at Concordia Univ. is already catering to a few students who helped inspire the program in the first place.

Founded in 1864, Concordia Univ. is a small liberal arts-based Christian university with about 4,200 undergraduate and graduate students. The school is not known for its science curriculum, but it's instructors include a number of doctorate holders from some premier R&D institutions, including Rice Univ. and the Univ. of Illinois. It has also has been an active member in the Associated Colleges of the Chicago Area consortium, which helps organize cross-institution programs for students and faculty. It was during one of these seminars that Michael Whitesides, assistant professor of molecular biology at Concordia Univ. Chicago, Charles Zona, the dean of **The McCrone Group's College of Microscopy**, Westmount, Ill., and Jeff Jankowski, assistant professor of chemistry at North Central College, Napierville, Ill., had a brainstorm.

"We did a microscopy seminar during the last winter semester for a whole group of schools, with about 15 students in each group," says Zona, who has been dean since the College of Microscopy was launched by the Chicago-area microscopy consulting and equipment provider The McCrone Group in 2006. About 70 students in total participated, many of whom were students at Concordia Univ. Once a week, the instructors talked about core imaging topics, such as polarized light, scanning, transmission, and Raman imaging. The program covered 10 weeks, the second half of which focused on forensics. Participants were introduced to real-world methods for detecting weapons of mass destruction, analyzing art, and examining sensitive or valuable documents.

"It was very popular, one of the highest attended functions that people here could remember in a long time," says Zona. From there, he says, it evolved into the idea of offering a degree.

"There seemed to be a lot of interest there. That's kind of how the relationship evolved [with Concordia]," he continues. "We have taken on interns and graduates and such from the school, so there's been a long relationship."

The whole idea of a microscopy degree program wasn't new, says Whiteside. It's just that nobody had figured just how to package it for students. Other programs had existed years ago, he recalls, but most had died out.

"There was this perception that microscopes were more a tool than anything else. But the reality is that somebody still has to learn the equipment," says Whiteside, a longtime microscopist who was rarely able to demonstrate his skills to students because of his school's limited instrument resources . "It makes sense to make that into an academic degree again. I think there's a renaissance of sorts coming on."

The degree program concept was straightforward. Students would spend their first three years at Concordia Univ., learning basic science concepts in mathematics, chemistry and physics.

In the fourth year, Concordia students would go to the College of Microscopy to begin applying some of their knowledge in the laboratory setting. The fourth-year study program as it stands now amounts to 33 hours over two semesters and includes required courses in polarized light microscopy; scanning electron microscopy; transmission electron microscopy; infrared and Raman microspectroscopy; particle isolation and manipulation and optical crystallography techniques. Electives are available and students must earn grades of "B" or better in all coursework at Concordia and the College of Microscopy to earn the bachelor of science degree.

The course material is advanced. The first "Modern Polarized Light Microscopy" course, for example, covers principles of crossed polarized light with hands-on exercises determining isotropic vs anisotropic, birefringence using the Michel-Lévy Interference Color Chart, and qualitative and quantitative extinction positions. The "Transmission Electron Microscopy" covers multiple techniques, including electron diffraction spectroscopy and electron energy loss spectroscopy. In just six months the arrangements were made and a fully accredited degree was launched.

"I don't work a lot with universities," says Zona, but he reports the approval was completed relatively quickly. Most of the setup for the program was accomplished by Concordia and Whiteside, he says.

In addition to already having full arts and science curriculum in place at Concordia, the program's quick approval was probably aided by the reputation of the College of Microscopy, a 40,000 ft2 learning center that was completed in 2006 to fulfill a new mission for **The McCrone Group**, Westmont, Ill., a sales and consulting group that's been specializing in microscopy for more than 50 years. Founded by prominent Cornell Univ. microscopist Dr. Walter C. McCrone, the company is synonymous with advanced microscopy. The company has attracted top-level researchers, some of whom have analyzed the "Gospel of Judas" for authenticity and were directly involved in spacesuit development with NASA.

The group has succeeded in part thanks to demand for both its consulting expertise—through the **McCrone Associates**—and through its instrument sales business. Microscopy is a billion-dollar business and every major college campus has facilities housing electron microscopes and light microscopes.

"You need someone to manage these facilities, understanding for instance how a scanning electron microscope or transmission electronic microscope works," says Zona.

The mission of the School of Microscopy is to enhance the use of microscopy worldwide, and to raise the level of competency and scientific knowledge throughout the world with regard to microscopy. Donald A. Brooks, president and CEO of the The McCrone Group was more specific, saying it will: "prepare companies and the nation to solve difficult materials analysis problems."

A need for skilled microscopists

Microscopy Society of America figures show that 1,500 colleges and universities in the U.S. offer science and engineeering programs. Most of these degrees require the use of microscopes, yet the shortage of people qualified to perform rigorous research using light or electron microscopes is increasing.

The **National Academy of Sciences** earlier this year released a long-awaited report about the ways to improve forensic science in the U.S. As expected, the diagnosis was grim, and the report, titled "Strengthening forensic science in the United States: A path forward," warned of "shoddy scientific practices" and "poorly trained technicians", both of which could compromise results desperately needed by legal, federal, and private entities. The report also cited a "gross shortage of adequate training and continuing education of

practitioners."

The U.S. Dept. of Labor's 2008-2009 Occupational Outlook Handbook tends to corroborate this need, naming several microscopy-related professions among its list of the 30 fastest-growing professions between 2006 and 2016. Pharmacy technicians, for example, will number 91,000 workers and grow 32% while forensic science technicians, though anticipated to number just a few thousand nationwide, will grow 30.7% with most earning a bachelor's degree.

For the last 53 years, the McCrone Associates have been providing consulting services to private, federal and academic labs. Their experiences and expertise in subject matter ranging from materials analysis to crime scene forensices are now benefiting undergraduate students. Image: College of Microscopy

Bolstering this feeling of a microscopist shortage is the heady growth of technology fields that are absolutely dependent on high-level imaging data: cancer therapy, medical imaging, engineered nanomaterials, pharmaceuticals, and general nanotechnology.

Zona agrees about the definite shortage of microscopists, particularly in industrial settings.

"Any lab probably has microscopy available and it is probably the most under-utilized instrument available," says Zona. Often, he says, the skillset needed to properly align, calibrate, and properly use the instrument is lacking.

As technology improves and the level of materials expertise advances to near the atomic level and past the diffraction limit of light, the learning curve for effective materials analysis grows ever steeper. The coursework at the college is meant to go beyond that available in conventional collegiate settings. The emphasis shifts subtly from theory and approach to more concrete concerns such as analysis technique, data interpretation, and sample preparation. In the same way that the College of Microscopy answers specific questions for its clients, it will teach real-world situations to students: What is the crystal structure of this newly discovered ceramic? Who painted over this Rembrandt and when? Where did the anthrax powder originate from?

The college is able to communicate this level of expertise through the strength of its faculty instructors, who hail from walks of microscopy life, from the plastics industry to medicine. Typically they are employees of the 53-year-old McCrone Associates—known primarily for its chemical and particle analysis—and include Richard E. Bisbing, an executive vice president and director of services at McCrone Associates and an expert in analytical light microscopy and the forensics sciences with more than 35 years of experience; Elaine Schumacher, a senior research scientist at McCrone Associates with more than 25 years of experience in high-level electron, x-ray and spectroscopic imaging; and Joseph G. Barabe, director of scientific imaging and research microscopist for McCrone Associates, who specializes in art analysis and mentored under Dr. Walter C. McCrone, who himself trained thousands of microscopists worldwide.

"At one time, I counted up the experience level and came up with more than 400 years worth," says Zona.

Zona himself has decades of experience in microscopy. He joined the McCrone Group in 1995 after a career in materials analysis, teaching, and environmental microscopy. Involved in directing instrument sales for several years, he served as vice president of The McCrone Group until being named dean of the new college. One of his stated missions when he accepted the appointment was to help enhance the level of knowledge of the nation's microscopists in areas of increasing importance such as homeland security, forensics and criminal investigation, pharmaceuticals/biotechnology development, and electronic components.

"We promote lots of real-world experience, first from the instructor then from hands-on teaching using the latest technologies and latest available instruments, be it polarized light or electron microscopy," says Zona. At least 50% of the coursework is hands-on.

"Customers come to McCrone Associates and want problems solved," says Zona. But many of them also want to learn how to solve that problem themselves. The College of Microscopy gives them the chance to learn about the techniques used to solve that problem.

This, he says, will carry over into the degree program. At the College of Microscopy students will learn, for example, how to prepare samples in a cleanroom. It depends entirely on the microscope, but for Raman or FTIR imaging, for example, the sample slices must be very thin. Damage to the sample can compromise results.

"They need to show they can handle the delicate work," says Whiteside. "When I try to do sample prep here (at Concordia), it's hard. At the College of Microscopy they have the resources. That's a skillset right there, and lot of practice is need."

Then, of course, data must also be interpreted. Raman spectroscopic data requires different skills than data from polarized light microscopes. Yet another set of skills are required for reading electron microscope imagery.

In the fourth year, students begin to learn about forensic analysis. Trace evidence, analysis, body fluids, and identification become common classroom subjects.

"It definitely has more of a forensics flair to it that is applicable to industrial applications," says Zona. For example, students will perform fluorescence analysis in white powder. This involves hitting a sample with ultraviolet light, creating an identification tree for 16 common white powders, performing diagnostic tests, and going through an elimination process. In characterizing body fluids, students seek out spermatozoa and use fluorochromes to make particles visible to analysis.

An advantage in a competitive environment

The College of Microscopy was founded in 2006 in Westmont, Ill., to share knowledge about the many techniques and methods used by industry experts and instructors at The McCrone Group. In the first three years, applied microscopy students learn the fundamentals at Concordia Univ. They then begin hands-on work at the College of Microscopy. Image: College of Microscopy

In addition to sharing the skills and practices that increase the value of a microscopist's work, the college will pay dividends in other ways.

"Even taking some elective courses at the college will give a person who's looking for a job out there a leg up. Most chemistry programs cover something similar, but if you can put this on your resume with experience along with it, it can't hurt," says Zona.

In addition to gaining exposure to methods proven in industrial and federal lab settings, students also benefit from seeing other microscopists with far greater experience. Commingled with industrial students from outside—crime labs, pharmaceutical companies, Dept. of Homeland Security staffers—young microscopists quickly learn what it's like to work in industrial settings. Their expectations are quickly re-calibrated, allowing them to adjust more readily when they are ready to make the transition to results-based workplace.

As far as Whiteside can tell, the collaboration between a traditional college and an industrial group is entirely unique.

"When we started this we thought we were the only one in the world. Every time I dug deeper I found something," says Whiteside, who knows one other two-year college with a similar degree offering, as well as a four-year degree at Central Michigan Univ.

Whiteside, however, is not as concerned with paving a new path as he is with helping his students compete for employment after graduation.

"This is really the type of degree that helps them get a job," he says. From experience, he says, what students often study in college doesn't always indicate what they will do in their career. "When kids get degrees, they'll often get degrees in chemistry or biology then work in fields that are completely different than their training."

The important thing to remember here, he says, is "the fact that they are being trained in-house to be microscopists. If we train them to do that right off the bat, then they're already trained." They won't have to pick up that knowledge on the job.

At Concordia, the program is also offered as a minor, which allows business or marketing students who are interested in joining a science-related company the opportunity to learn about the technology behind their company's product. Additionally, technology-minded students could add a business minor to their applied microscopy degree program and find themselves with valuable corporate perspective when they begin their career at an instrument company like Olympus, Carl Zeiss, or Leica.

In the future, Whiteside would like to add biological imaging to the primarily chemical microscopy pursued at the College of Microscopy. For his part, Zona says he would like to eventually develop a Master's degree and more advanced courses in electron microscopy. For now, he'll be interested to see whether the program will take off as he thinks it might.

"There are other programs out there that share some similarities," says Zona. "But I went to the Univ. of Illinois Chicago and I have a degree in forensics science. From my experience, there's nothing else really dedicated to hands-on, real applications pertinent to the job market. It's great that students can get that kind of training."

Paul Livingstone

Nanotechnology Undergraduate Education

Today, there are about 20,000 trained nanotechnologists. But if an estimated 100 times that number of specialists will be needed in industry and science positions in the next six years, where will they come from?

NanoInk (Skokie, Ill.), a manufacturer of nanofabrication technology, has put in motion a curriculum-led nanotechnology project entitled the NanoProfessor Project. "Recent statements from the National Science Foundation indicate that upwards

of two million trained nanotechnologists will be needed globally by the year 2015," says Dean Hart, executive vice president of Commercial Operations, NanoInk. Today, there is little hands-on nanotechnology training at the high school, or even college, levels. With many of the trained nanotechnologist being at a PhD level, and even beyond, a future resource gap exists. Due to this resource gap "a strong need for a nanoscience education initiative that combines hands-on experience in nanotechnology with and experimental-based curriculum" was, according to Hart, the driving force behind the NanoProfessor NanoScience Education Program.

The NanoProfessor Project was established to educate students in small two- and four-year colleges. The program has already been implemented at Dakota County Technical College (Rosemount, Minn.) under the leadership of Deb Newberry, who, according to Hart, is "a pioneer committed to nanoscience education." Newberry is director of the Nanoscience Program at Dakota County Technical College and director of a newly funded NSF Regional Center for Nanotechnology Education called Nano-Link.

Through this project, students will have the opportunity to gain hands-on nanoscience experience in the fields of biology, chemistry, and physics. Hart explains, "At the heart of the NanoProfessor NanoScience Education Program is NanoInk's NLP 2000 Desktop NanoFabrication System (NLP 2000)." This tool is a desktop nanofabrication tool that allows users to build custom-engineered, nano-scale structures using NanoInk's Dip Pen Nanolithography (DPN) and other materials from metal nanoparticles to biomolecules.

The program was essentially built on the success of the NLP 2000. According to Hart, "Until the launch of the NLP 2000, hands-on experience in actually building nanoscale features was often relegated to only a few fortunate individuals who had access to costly and time-intensive equipment, such as e-beam lithographers, to make such structures." With the NLP 2000 tool, students or workers can have the needed cost effective, hands-on experience that could patch the current gap in resources.

So, why does nanotechnology have such an impact on our world today? "From the carbon black in tires that aid in automobile braking to avoid accidents, to titanium dioxide in sun screen that helps protect our bodies from the sun's harmful UV rays, nanotechnology is present in all walks of life," says Hart. Nanotechnology is helping to create a "green" environment for the world. Besides the manufacturing industry, nanotechnology also makes a strong appearance in life sciences in the fields of drug discovery and development, as well as other scientific disciplines (physics, chemistry, biology, materials science, and engineering). With nanotechnology having such an impact on the world and in science, the NanoProfessor NanoScience Education Program is intended to close the education gap for nanotechnologists and provide cost effective, hands-on experience.

—Lindsay Hock