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JOHN DOLHUN: I've done these demos in front of live audiences. I remember one time I did one demo in front of alumni. I forget what it was, but it was a failure. And this one little kid-- he was only about four years old-- he raised his hand. He said, you win some and you lose some.

SARAH HANSEN: Today on *Chalk Radio,* we're talking about the course 5.310, Laboratory Chemistry. This is a course that not only teaches students about hands-on science, but also life. Because working in a lab is a lot like baking-- you can follow recipes, but your cake might still collapse.

I'm your host Sarah Hansen. In this episode, we're joined by two MIT educators who have helped shape this standout course. They'll tell us more about what it looks like to support students with various academic interests as they develop lab skills, overcome setbacks, and apply their studies to real-world problems like water quality.

JOHN DOLHUN: I'm John Dolhun, currently Director of the Undergraduate Chemistry Teaching Labs at MIT.

SARAH HEWETT: I'm Sarah Hewett and I am a technical instructor in the Chemistry Department at MIT.

SARAH HANSEN: For many of their students, 5.310 is the first time they step foot in a college level chemistry lab, and that can be a memorable experience.

JOHN DOLHUN: The first thing you would see are lines of student coat lockers. And that's the first thing that students encounter when they enter the lab. It's here where they would put their bags, and they store their lab coats and their goggles. And you would soon see walking out into the lab that it's divided into 12 bays. Each bay has 6 to 7 fume hoods and desk space for up to 14 students.

SARAH HANSEN: And lots and lots of windows-- something I may have read a bit too much into.

SARAH HEWETT: You can correct me. I always thought it was because in case there's an explosion, they want all the windows to blow out instead of the walls of the building.

JOHN DOLHUN: An-- [LAUGHS]

SARAH HANSEN: Maybe I'm wrong.

JOHN DOLHUN: --explosion. [LAUGHS]

SARAH HANSEN: John went on to explain that yes, you would see windows, but explosions, not so much. Anyway, let's get back to what you actually would see in this lab.

JOHN DOLHUN: We have some really neat instruments that the students can operate hands-on, exactly what the students would experience in industry-- Cary 60 UV-Vis spectrometers, state of the art density meters and refractometers, and one of the really exciting instruments is an inductively coupled plasma mass spectrometer. There are only two of these at MIT. And this instrument is used exclusively in 5.310, and the students actually use that to test their river samples to determine the concentration of 29 different elements down to the part per trillion level. So it's pretty exciting.

SARAH HANSEN: The river sample testing is part of what makes 5.310 unique. Students get to take their lab work right into Boston's own Charles River.

SARAH HEWETT: Yes. The most exciting experiment, I think, for most of the students is the Ellen Swallow Richards Lab. So the students actually go down to the river and take water samples. And then they get to analyze those samples back up in the lab for dissolved oxygen, phosphate concentration, and a bunch of other elements. So they get to learn a little bit about environmental chemistry, and analytical chemistry, and different techniques that we use for those types of analysis.

And the students really like that because it's very applicable to the Charles River and to the Boston environment. And they can see it and say, oh, wow, I'm actually doing something that's kind of useful and something that-- they always hear about how dirty the Charles River used to be, and they're actually kind of surprised when they do the lab now about how good the water quality is.

SARAH HANSEN: You may have caught that Sarah and John referred to this as the Ellen Swallow Richards Lab. It's a namesake with significant meaning.

JOHN DOLHUN: When I wrote this lab in 2010, I actually called it the Charles River Lab. The reason I wrote the lab was to introduce an environmental component into the 5.310 Laboratory Chemistry course. And sometime after I had wrote the lab, I actually was walking through the halls at MIT, and somehow I ended up in the lobby of Building 2. And I looked up and I saw this plaque and this photo of this woman on the wall. And I started reading it and it said, this was the first female student ever admitted to MIT who graduated in 1873.

It was Ellen Swallow Richards, who was an industrial safety engineer and environmental chemist. And it was really her work, I think, in 1887 which led to the first state water quality standards in the nation. And that was very significant, and that kind of moved me to rename the Charles River Lab the Ellen Swallow Richards Lab.

SARAH HANSEN: The groundwork laid by Ellen Swallow Richards has never been more important in a way that feels particularly relevant for my own community and likely for some of yours.

SARAH HEWETT: One of the local issues that has come up in the Cambridge area and around the country is the issue of PFAS, which are per- and polyfluoroalkyl substances, which are man made chemicals that have been around for less than 100 years. So they're relatively new, but they encompass things like Teflon and other chemicals like that that are involved in non-stick coatings for food and also in fire suppression technology because they're really flame resistant, and stain resistant, and stick resistant.

So now they're being detected in water supplies and in the food chain, and scientists are pretty worried about their impact on human health. And they're still not entirely sure what all of the impacts are, but there's been a lot of research recently into detecting these in the environment and trying to figure out what their impact is on health.

SARAH HANSEN: As you might imagine, most students aren't ready to go out into the field on Day 1 one of 5.310. The first step is learning how to be safe in the lab. And learning how to interact with chemicals and instruments in the lab can be daunting.

JOHN DOLHUN: They're coming in and they're afraid. Some of them have never, ever been in a wet lab before. You've got to make them feel really comfortable, even though they might be a fourth year student at MIT, graduating.

SARAH HEWETT: The really fun thing about 5.310 is that there isn't really a typical student. We get students from all types of majors that take the course. So it's a requirement for medical school and it's a requirement for the chemical engineering major, so we get a bunch of chemical engineers and some med school or pre-med students. But they all come from majors all across the Institute, which is really fun.

So even though a lot of them have not taken a chemistry lab maybe since high school or ever, they have a lot of science knowledge and knowledge of other things that is always kind of interesting. Sometimes after the lectures they'll come up and say, oh, this reminds me of something from my other class. And that's how I learn a lot, too, just from talking to them and hearing about their experiences.

They actually end up helping each other. So some of them who say, oh, I've worked in a biology lab, I might have more experience with pipetting can help students who maybe have not taken a lab class in many years.

SARAH HANSEN: For beginner and experienced chemistry students alike, 5.310's labs are a challenge. That means John and Sarah have thought carefully about what kinds of support their students might need.

JOHN DOLHUN: Many, many schools use a lab manual, and they use experiments that are very clearly published out. And the students go through maybe 12 experiments in a semester and they're very systematic in terms of the types of experiments that are there-- the traditional experiments. But with MIT, some of the experiments are multi-day, multifaceted experiments that are actually put together and can be quite challenging. A typical experiment could be 50 to 60 pages long.

In terms of helping them deal with frustration, I believe in divide and conquer. For example, one of the things that's very difficult, and challenging, and stressful might be writing up the lab report. That might take them 10 to 15 hours of time. So we teach them how to break this up to deal with small frustrations systematically. Do small parts of it early on and don't wait till the end to do the whole thing. It's kind of like them working on tiny anthills instead of a big mountain. And so, by forming these good habits, they'll soon be able to deal with mountain-sized frustration. I'm a product of MIT and it works for me.

SARAH HANSEN: In addition to building the perseverance chemistry requires, both students and instructors are also actively cultivating curiosity and making mistakes in the process.

JOHN DOLHUN: Students love diapers. And as soon as you pull a diaper out, that totally gets them relaxed and loosens them up. The polymer demo is all about sodium polyacrylamide, and that's the diaper polymer. That's the chemical in the diapers that absorbs the water at 800 times its weight. [LAUGHS]

When I do this demo, I usually call on a volunteer. And unbeknownst to the volunteer, I've already put some powder in the cup. And I start pouring water in a cup and I ask the volunteer to tell me when to stop. When they tell me to stop, I put a plastic cover on the cup, and turn it over, and then I put it on their head.

Usually I ask them to hold it so they can assume any responsibility for that water in the cup coming out. But usually, nothing comes out because the polymer has absorbed all the water, right? You get this beautiful globular polymer inside this cup. And you knock it out into a dish, and you can see it.

But I remember when I did this demo at one of the MIT parents' visiting weekends. And there were about 70 to 80 people in the audience, and I asked for a volunteer to come down. So he came down, but he didn't tell me soon enough to stop pouring the water in the cup. So I just kept going till he said stop, right?

So I covered the cup up very carefully, turned it over on this hard plastic, and I put it on his head. And the polymer and all the water, when I pulled the card out, it all came out and it messed up his hairdo. It was a gooey, gooey mess, and the audience just loved it. I mean, we had to clean him up with paper towels in front of everybody. So there's often unexpected fun in these live demos.

SARAH HEWETT: Yes. I think that's one of the fun parts about the lab, is that not everything works. It doesn't work always for demos. But even in the lab you can have two students follow the exact same procedure, and sometimes it just doesn't come out. Or they'll make one little error that they didn't even notice, and then it won't work.

And so that is definitely something that we deal with a lot in the lab-- dealing with that frustration and having the students say, well, trying to figure out what went wrong and how to fix it for next time. But that is a big part of what happens in the lab, and a big lesson I think that comes out that's very unrelated to chemistry but very important for life.

SARAH HANSEN: Another important aspect of this course is its emphasis on science communication.

JOHN DOLHUN: A few years ago, we looked at the course and we saw the necessity of writing and for the students to be able to communicate their work to a general audience of non-scientists. By working with writing, rhetoric, and professional communication instructors, students learn how to write and present the paper to a general audience.

SARAH HEWETT: We came up with a bunch of different topics that are related to water quality, and the Charles River, and all of the data that we gather for that lab. Students can choose which genre they would like to write. So some examples that we have are, there's a hospital memo about mercury levels in fish that we measure with our mercury analyzer. So they can use the data to make arguments about that. There are policy memos for the government talking about why it's important to limit phosphate concentration and pollution in the water. It challenges them to think about how to communicate science in these different ways.

And the writing instructors have been amazing in helping them learn how to write in these different styles. I never learned to write science from a writing perspective-- it was always just in my science classes from other scientists. And so I would recommend it to any other instructor to bring in writing help if you have it because it carries over to their lab reports, too, because they have all these skills of how to read their own work, and how to assess it for clarity, and all those things.

SARAH HANSEN: One thing about MIT faculty that we love is their commitment to sharing their teaching materials with everyone. I was curious what motivated Sarah and John to do this.

SARAH HEWETT: Sharing the course materials is a really helpful resource to other instructors because I know I've benefited from talking to people that I went to graduate school with about what they're doing, and going to conferences, and learning from other people. And so the more that we can share and make available these materials, the more it can help other instructors, and also to introduce more people to chemistry. If they have their one experience of a chemistry course, then maybe they can go online and see, hey, maybe this other place is taught in a different way that's way more interesting, or, I think that that's something that I might like to do. So I think it benefits everybody to be more open with what's going on.

JOHN DOLHUN: OpenCourseWare has such a good reputation in terms of people all over the world that actually turn to OpenCourseWare to open a course and actually learn the material from that course. I've had students-- freshman advisees-- who have come in who've learned everything that they know from OpenCourseWare. It's quite dramatic when you have a student come in and they literally can test out of every subject, but they've learned all of those subjects from watching OpenCourseWare.

SARAH HANSEN: Before we go, I also asked Sarah and John what they would like to ask you, our listeners, about teaching laboratory chemistry.

JOHN DOLHUN: Yeah. I think I'd be curious to know what demos some of the other educators do in their laboratory chemistry courses, and also what types of non-traditional labs they're running.

SARAH HEWETT: I think my favorite question to ask other lab instructors is, what is the purpose of teaching lab? So a lot of people have different answers to that, which is always kind of interesting. And then, also, another question that I've been thinking about is how to prepare students for what they're going to be doing next, whether it's going into industry, or academia, or pre-med. What can we do in the lab to help them with that, whether it's chemistry or related or not?

SARAH HANSEN: If you have insights to share, please get in touch with me the link in our show notes. I'll be sure to pass your ideas along to John, Sarah, and other listeners. If you're interested in learning more about laboratory chemistry or remixing Sarah and John's open educational resources in your own teaching, head on over to our MIT OpenCourseWare website.

Thank you so much for listening. Until next time, signing off. From near the Charles River, I'm your host Sarah Hansen from MIT OpenCourseWare.

Chalk Radio's producers include myself, Brett Paci and Dave Lishanksy. Scriptwriting assistance from Aubrey Calaway. Show notes for this episode were written by Peter Chipman. The 5.310 course site was built by Alicia Franke. We're funded by MIT Open Learning and supporters like you.

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