Roundtable Discussion

The Art and Science of Zebrafish in the Classroom— An Interview with Melanie Fields

Stephen C. Ekker,¹ Lara D. Hutson,² and Melanie Fields³

Lara D. Hutson: We're here with Melanie Fields, who has done extensive work with zebrafish among secondary-school students. I'd just like to briefly introduce myself. I'm an assistant professor at Williams College in Williamstown, Massachusetts. I study zebrafish neural development, although it turns out that the gene family on which I work is involved in the human degenerative disease known as Charcot-Marie-Tooth disease. It's a neuromuscular disease and involves the degeneration of motor axons. We're making zebrafish models of it to examine the nongenetic factors that contribute to progression of the disease.

Melanie, can you tell us a bit about yourself?

Melanie Fields: I teach at the Sidwell Friends School in Washington, DC, which is a Quaker school.

Lara D. Hutson: Do you have any children of your own?

Melanie Fields: I have three children, ages 26, 21, and 17. My 26-year-old is partly responsible for my interest in zebrafish, because he went to the University of Oregon. I took a sabbatical that gave me a chance to visit with him and learn about zebrafish.

Lara D. Hutson: Do you have any hobbies?

Melanie Fields: I have quite a few hobbies. Our whole family—myself, my children, and my husband—loves to go rock climbing and backpacking, canoeing, and kayaking. Every year, during spring break at Sidwell, we take some students with us to the West Coast and other locales to go climbing and backpacking.

Lara D. Hutson: Can you tell us a bit about the school, and what you teach and at what grade level?

Melanie Fields: Sidwell Friends is a Quaker school, which means that it does things according to processes established

by the Quakers, who are known formally as the Society of Friends. Its grades run from pre-K through 12, and it has about 1100 students. In the upper school, which is where I teach, there are about 460 students, and I teach what I call "all flavors of biology." That includes honors classes; introductory biology for 9th- and 10th-grade students; advanced placement (AP) biology for 11th- and 12th-grade students; a neuroscience research course, where we work on zebrafish and other organisms; and a marine biology course, which I teach for 11th- and 12th-graders.

Lara D. Hutson: So you have very broad expertise, and you have recently begun using zebrafish in your teaching laboratories. You mentioned neuroscience, but are there other laboratories in which you use the fish?

Melanie Fields: Students in our freshman biology class have to do an independent research project, and I usually try and steer them into something involving zebrafish because I can then hook them into coming back to our elective neuroscience course as juniors and seniors. I have a number of students who are just beginning to do projects with zebrafish, and nine of my students recently went to the Society for Neuroscience meeting in Washington, DC, where they presented a poster on the Teaching of Neuroscience based on four outstanding projects they did in that field. These kids were in 9th grade when they did this, and they're now in 10th grade.

We also have a fairly jam-packed schedule in our AP biology class, in which we use zebrafish for studying the fertilization and development of eggs. We have a new fin-regeneration project in our neuroscience class, which originated in the biology class, in which we hope to study neural mass and development using zebrafish. We'll do that as part of our study of the nervous and neuromuscular systems.

Lara D. Hutson: It sounds like a lot of your laboratory study modules come from independent projects and student-initiated research.

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What proportion of your laboratories have come out of projects initiated by students? And has it been a rewarding experience, a frustrating experience, or a mixed bag?

Melanie Fields: It's rather like science at the career level. We had a visiting scientist, Fidel Ramon, of the Faculty of Medicine of the National Autonomous University of Mexico, who was attending the Society for Neuroscience meeting in Washington, DC, November 15–19, 2008, and some of our students told him that they hadn't yet been successful in their projects. Dr. Ramon replied by pointing out that "It usually doesn't work the first time, or the second time, or even the third time. You have to stay with it." The kids understood that.

They were blown away that a real scientist would come and spend a significant period of the day talking with them and asking them questions and giving them suggestions about how to improve their experiments, and they really felt engaged, welcomed, and respected.

In the end, it's extremely rewarding to finally take a project that kids have worked on and turn it into exercises that can be done as part of a regular high-school curriculum. That might involve 2 or 3 days of class time, and parts of it can be done in a 45- or 50-min schedule, or, for a double lab period, in a 90-min schedule. In our neuroscience class at Sidwell I've been teaching a particular program for about 16 years. Probably about 50% of the laboratories that I teach in our other classes come from projects that originated in that class, and we began using zebrafish in that class in 2000. Right now, we use zebrafish in about 10% of our laboratories. The goal for our advanced classes is to create projects that other teachers and students can use.

Lara D. Hutson: That's a great track record for getting student projects to work in the classroom. What would you call the most challenging thing about using zebrafish in the classroom? Have there been any really unexpected challenges?

Melanie Fields: One of the most challenging things has nothing to do with zebrafish, which are absolutely wonderful as teaching tools. But we built a brand-new upper school building several years ago, and the room in which we work with zebrafish is on the top floor and directly above the principal's office. So I went through several principals who floated away, until we finally got one who said, "Why don't we put drains in the floor?" and he replaced the floor of our room.

Lara D. Hutson: It sounds as if both you and the students have had some combination of frustration and reward. What do you think is the most rewarding thing about these projects for the students themselves?

Melanie Fields: I think I can safely get this answer right, because I ask the kids or try and hear them when they're talking among themselves and don't think I can hear what they're saying. I was recently with a few of the kids who are working with zebrafish, and who often come in on weekends because there's just not enough time in a regular class for some of their experiments, and I heard one of them say, "Well, when I heard I'd have to come in on Saturday or Sunday for a

class, I had second thoughts, but I really like it now." Another one answered, "Yeah, this is how we get something done. During a 45-min class we can barely get all the tanks clean and the embryos taken care of." So they take ownership of the projects on which they're working, and I think that's very valuable for them.

Lara D. Hutson: That's fantastic. Do you think that you have cultivated some young scientists who might not have gone in that direction otherwise?

Melanie Fields: I'm sure that I have, and there is one of whom I'm very proud. He was in my neuroscience class, and is now getting a Ph.D. in neuroscience, and presented a poster on his doctoral work at the Society for Neuroscience meeting and then went to see all three of the posters that our class at Sidwell presented at the meeting, where we present them in the educational poster sessions, and he spent an awful lot of time with the kids who were presenting them. He told them that ultimately, all of the work they were doing in our program was worthwhile.

Lara D. Hutson: Do you think that presentation at the neuroscience meeting has a significant impact on the students who do it?

Melanie Fields: I think it definitely does. We've also gone to the Biophysical Society meeting and attended the meeting of the American Society for Cell Biology in San Francisco, December 13–17, 2008. Attending that meeting provides a focus for us, because it takes place at the end of the semester, and that gives the students the feeling that they're working toward the particular goal of a possible presentation. I think biological science becomes very real to them when they go to a meeting and are recognized and appreciated and treated like genuine research scientists.

Lara D. Hutson: That's wonderful.

Melanie Fields: Recently, the Society for Neuroscience decided that it wasn't going to have a high-school program, and did not want to let high-school students attend its meetings, but we had three posters we needed to present, and we got our students into the meeting that year as guests of a couple of the exhibitors and research neuroscientists.

Lara D. Hutson: Is there anything you would do differently if you did it again?

Melanie Fields: I teach the neuroscience class at Sidwell in the fall semester. I used to also teach it in the second semester, but I don't do that any longer. I would like to continue teaching the neuroscience course during the second semester for continuity. I'm sure there are other things I would do differently as well. Sometimes it's a really hard push to get enough accomplished to have students produce responsible and legitimate presentations at a meeting.

Lara D. Hutson: I'm sure you're adapting your courses every year. Can you give us an example of something that you did during one semester that needed reworking for the

following semester or the following year, so that we can get a sense of the process by which you adapt these programs?

Melanie Fields: I can give you a couple of examples. One of the hardest things to do is to evaluate students, because we have no tests or quizzes. So I have them keep laboratory journals, and part of my process is to go through their journals and see how good they were at keeping regular daily records. But they're sometimes resistant to giving me their journals to look at, and it can be hard to spend the needed time to look them over carefully, because the kids sometimes want me to give back the journals right away.

What I've done for the past couple of years to solve that is to hold a journal club and have different students be discussion leaders, and give them guidelines for the discussions. I've also set criteria for grading their journal club presentations with an objective grading scale.

Lara D. Hutson: How do they do with laboratory reports?

Melanie Fields: I've gotten better at having them write true laboratory reports on the fin-regeneration experiment. They all had to write their own individual reports, which they never really did before, and I think that worked well.

One of the most valuable things is to have students realize that when we first do an experiment, I don't expect it to work; I expect it to flop. But I expect them to keep good enough records to permit us to figure out what specific aspect of the experiment we need to tweak to make it succeed, and how we have to tweak it. It's often hard to do that, but it keeps us from killing fish.

Lara D. Hutson: So you don't use heavy-handed oversight, and you let the kids take ownership of the experimentation process and responsibility for it.

Melanie Fields: Yes. I try to do that as much as possible. Sometimes they'll get angry at me and say, "Well, if you knew that was going to happen, why didn't you tell me?" I tell them that when they themselves find out, we will both know what to do.

Lara D. Hutson: So you must constantly be striking a balance between guiding the students and letting them take ownership of their work. Is that a real balancing act, or does it come naturally to you in your years of teaching?

Melanie Fields: It pretty much comes naturally to me. I often have to bite my tongue to keep quiet, but that's actually how I like to teach all of my classes. I've found that it helps the students to remember a point the next time they come across it. A student is more likely to remember, "Oh, I didn't pay attention to the control last time, but I have to do that because the control proves the results of my experiment."

Lara D. Hutson: Did you originally know that you were going to become a teacher, or did you decide that later in life, and what factors went into your decision?

Melanie Fields: When I went to college, I was determined to be an obstetrician/gynecologist. But as I went through

college, I first became a math major and then, in my last year, I decided to go into biology, which turned out to be a smart move. As I was graduating and preparing my résumé and applying to Colgate-Palmolive for work on the night shift as a technician, I looked at my résumé and saw that I had 8 years of volunteer teaching. I realized that I was doing that without pay, so that it must have been the thing that I wanted to do. So when I graduated from college, I went back and entered a teaching program.

Lara D. Hutson: Do you have any advice for someone who is thinking about going into teaching?

Melanie Fields: Be humble, and try and bring as much as possible out of your students by hearing what they say, and not what you have to say.

Lara D. Hutson: That sounds like good advice, and we could probably all benefit from it. What advice would you give a teacher who has no background in working with zebrafish but who would be interested in applying some of the techniques we discussed in the classroom?

Melanie Fields: I would start with something simple. There are biological supply companies from which one can order fish tanks and fish, and who will send a box of everything you need for a breeding experiment, so that you can study embryology.

I'd also recommend taking advantage of anybody who is nearby and who is a zebrafish researcher, because I've found the people in the zebrafish community to be universally friendly and willing to do just about anything to help teachers and students.

Lara D. Hutson: Are there particular people in the Washington, DC, area to whom you have gone for expertise or equipment or reagents?

Melanie Fields: Yes, Shawn Burgess of the National Institutes of Health (NIH) has been of great assistance to us. Eric Glasgow at Georgetown University Medical Center, Marty Halpern at Carnegie, and Ajay Chitnis at the NIH have also been very helpful.

Judith Eisen's lab at the University of Oregon has been outstanding in sending me reagents and answering questions rapidly by e-mail. Chuck Kimmel, who is Professor Emeritus of Biology at Oregon, enjoys communicating back and forth with the kids by e-mail, and the zebrafish course at the Marine Biological Laboratory (MBL) at Woods Hole has let me sit in on sessions there. They've been pleasant and extremely helpful.

Lara D. Hutson: At the beginning of our discussion, you mentioned that you had taken a sabbatical to be with your son, who was attending the University of Oregon. Can you reflect on that experience? Did it make a big difference in your being able to set up your zebrafish study program at Sidwell?

Melanie Fields: My oldest son went to the University of Oregon as an undergraduate, and when he left to go to Oregon he had been at Sidwell for about 8 years, and had been the

person taking care of my fish there. When he graduated I realized that I needed help. At that point I was using weakly electric fish, which cost about \$11 to \$19 apiece. I looked into the possibility of using zebrafish and saw that they cost only 99 cents apiece, and suddenly, as a Quaker would say, "A way opened."

So I went searching on the Internet and by coincidence found out that the University of Oregon was a Mecca for learning about zebrafish. When I thought about taking a sabbatical, I sent my son an e-mail asking what he'd think if I took a sabbatical out there with him. I got an e-mail reply in which I could read the feeling and that said, "That's nice, Mom." About 2 hours later I got another one that said, "Will you cook?"

Lara D. Hutson: How about laundry?

Melanie Fields: That might have been the next question, but I went, and stayed in the house of a graduate student who was taking off for a few months, and attended classes. My son would come over from his own apartment and visit. I also had my father with me, who was 90 years old. So it was a fun experience to go back to college with my son and my 90-year-old father as company. Judith Eisen, who is the Director of the Institute of Neuroscience at the University of Oregon and works extensively with zebrafish, gave me laboratory bench space to work on, and would have let me do anything that I wanted to do, but I told her that all I wanted to do was follow her graduate student, Sarah Hutchinson, around.

Basically I just did what they needed. If the fish had to be fed, I fed them, and if they needed fish to be bred, I bred them. They taught me how to remove chorions, how to do injections into zebrafish, and how to use various microscopes. It was a wonderful experience.

Lara D. Hutson: Then you went back and used it in your classroom? I was quite astonished to see that you could actually do studies of *in vitro* fertilization with zebrafish in the classroom. Were they successful?

Melanie Fields: Not really, but I still think it's a valuable thing for them to see. The other thing that I think I'm doing is creating little zebrafish researchers, because I tell them that if they select a university that has a zebrafish facility, they've got a job, because the fish need constant care. I try and teach them the different techniques for zebrafish care, so that if they go to work in a zebrafish facility, they can be more useful than the average entering student.

One of the kids I taught at Sidwell had his fish breed successfully, and was taking the embryos out on the table, when he looked up and said, "I always wanted to have a pet fish. Now I have 600."

Lara D. Hutson: Are you familiar with the Institutional Animal Care and Use Committee (IACUC) protocols for animal care, and does your school require anything like that, or do you see it coming in the future?

Melanie Fields: Our institution doesn't require that. But I do have the students look over a protocol like the NIH guidelines

for animal care, and the guidelines used at the MBL, which are a little bit easier. We use these to develop our own guidelines for animal care, which the students write up themselves.

Lara D. Hutson: I think that's a great experience for anybody who will ever continue to work with zebrafish or any living thing.

Melanie Fields: I feel the same. But for a while we were studying insect communication, and I found out that kids don't seem to be very concerned about care if they deal with invertebrates. Our kids looked at the matter and found legal opinions to the effect that invertebrates don't experience pain, but they are concerned about whether or not they're hurting fish. And we try to have an ethics and science section in each of the poster presentations that we do.

Lara D. Hutson: How do you integrate the work you're doing in the laboratory with what you're teaching in the classroom?

Melanie Fields: I try to take ideas from the neuroscience class and bring them into the other courses. But the students are the best ambassadors, and what actually happens is that throughout the day, students from the neuroscience class come into the bio lab that I teach, and they work there on the zebrafish throughout the day. On the first day that the fish produced eggs the kids were all excited, and we stopped what we were doing in the freshman bio class and took out our dissecting microscopes and looked at the eggs. At that point they were about at the one-cell stage. But the next day the kids got to see them when they were pigmented and looking a little bit more like fish.

So the older kids will come in and do their work, and sometimes when they're in there the students working in the laboratory will stop and ask them what they're doing.

Lara D. Hutson: Do you have any broad reflections on your overall experience in teaching biology, on zebrafish, or on the current state of education?

Melanie Fields: Well, this past summer I participated in a workshop on marine science at the University of Maryland's Solomon's Island research station in Chesapeake Bay. They've started a program in which they bring teachers in for 8 weeks during the summer and have them engage in research projects. What they're trying to do is have science teachers realize that one can't always use preestablished laboratory programs, and that the value of a real science experience and the exposure to science research is in realizing that failure can be a good experience. Their purpose is to make teachers aware that if you don't get the results you expect to get, you haven't failed, but rather that you need to tweak your experiment.

One thing I would like to see more of in science classrooms is the concept that the only way you can really fail as a scientist is by not trying. That if you try and you're thinking and you're doing the best you can, then you're doing good science.

Lara D. Hutson: Do you think that is happening, or that educators are aware of it generally and are working in that direction?

Melanie Fields: I think they're aware of it, but that they're often constrained by expectations made of them. Many public schools, for example, have benchmarks that science teachers have to meet, and require that they cover certain areas and follow the guidelines established by the county or other school district, and can't teach other material because there isn't enough time for that. But many programs now have project-based learning or are moving increasingly toward that.

Recently, there was a very interesting young teacher that I met who came from Hong Kong with his 9th- and 10th-grade students. They had done brain-cell culture experiments, and he was using that to teach them about neuroscience and neuroscience techniques. That was pretty impressive.

Lara D. Hutson: So there are hidden gems waiting to be used in teaching, and places where people are taking advantage of those when they're given the freedom to do so. Do you think that a structural change needs to be made in our educational system that would allow more of that? It sounds like the problem may just be that teachers' hands are tied.

Melanie Fields: I think that many of the current evaluations of success in teaching are bad; for example, tests don't truly reveal how well students are learning, and if you're using them as your evaluative tools, your hands as a teacher become tied. Perhaps teachers themselves should develop the guidelines and restrictions on what should and shouldn't be taught.

One thing I really like, and which I've pushed for and taken advantage of, is the annual interaction that I have with college professors and bench research scientists. If I didn't get constant exposure to and input and feedback from them, I couldn't grow, and I would like to encourage each of the research societies to promote that, but I don't know how that would work from the research side.

Lara D. Hutson: Well, my next question is going to be about the role you see for colleges and universities in primary and secondary science education, especially in an economic climate in which many schools simply don't have the funding for laboratory programs. What role do colleges and universities have in precollege science education?

Melanie Fields: Certainly there are opportunities with outreach programs, even though they may call for efforts that go beyond many teachers' regular workloads. A lot of people, such as Steve Farber of the Carnegie Institution for Science, are heavily involved in outreach to schools that cannot afford the resources needed for a full science education program.

I think that's great, but I don't want to tell researchers or the research societies to "step up to the plate" in that it's their responsibility to come and talk to me, because both sides have that responsibility. I know of at least two instances—and I'm sure there are more—when scientists have tried to reach out to a school that their kid is attending or a school that's near their research facility, and the teachers didn't respond. I'd like to tell the scientists to keep trying, that they will eventually find somebody who will say "Yes," but that teachers are so often overwhelmed with duties and their time so restricted that

they sometimes just can't respond because they don't have the time.

I recently met a researcher at Smith College in Northampton, Massachusetts, who wants to open up his zebrafish facility to teachers and students at a nearby public school who could come in during the summer, and wants to help them bring their experiences back into the classroom. But he's not really getting a positive response from the public school that he's trying to work with because of the benchmarks that its teachers have to meet every year.

Lara D. Hutson: Is there any advice you could give to scientists who are interested in such outreach? Is there an approach that you think might work better? Might mere persistence pay off, or finding the right people to communicate with?

Melanie Fields: My personal experience is that it's best for them to go from school to school, and talk to fellow faculty members or to other professional colleagues whose own kids are in primary or secondary schools, and ask them for the names of really good secondary-school science teachers. And then try and interest those teachers in research programs for their schools.

I know that the Society for Neuroscience has changed its direction about secondary-school programs, and has established relationships with organizations like the National Association of Biology Teachers. I think there are many teachers who might be interested in having zebrafish researchers and other scientists give demonstrations at their teaching society meetings.

Lara D. Hutson: Having myself encountered the response that you just described, I know that it's fairly common and isn't so much the fault of the teachers as of their lack of time or the demands on their curriculum.

Melanie Fields: When I talked with Steve earlier, he mentioned the possibility of different researchers throughout the country making outreach programs happen by having people like yourself or Steve who would be available for teachers to contact.

Stephen C. Ekker: I think there is an informal network of researchers who'd like to do that, and I think that Lara and Jennifer Liang and Steve Farber and a number of other people working with zebrafish are doing this online. It's really up to the zebrafish community to decide what they would like to do with this. But I think it would be terrific if there were a canvass or review of the zebrafish community in terms of educational and other available resources, including websites and other contact information.

Lara D. Hutson: There is a website called Zebrafish in the Classroom that Jenny Liang and some of her students set up, which I think Steve is alluding to. A link to it was posted on the ZFIN site only a few months ago. It is not a comprehensive website, but is intended to provide practical information for setting up zebrafish studies from scratch. There is also a Zebrafish K-12 site that is also accessible from ZFIN. It's

conceivable that teachers could set up zebrafish studies on their own with the resources on these sites, but I think it might help to have some training sessions and courses, and to use the websites or wikis to supplement that in getting things set up in the classroom.

Lara D. Hutson: I'd like to sum up by saying that you've really undertaken quite a lot with your students, and have really done a fantastic job.

Stephen C. Ekker: I think we've all learned a lot from you, and I'm very impressed.

Melanie Fields: Thank you. I have really enjoyed talking with you. The rewarding part of teaching science is those "Aha" moments.

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