# Designs for learning

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## *Introduction*

A liberal education should help us to value deep intellectual passions and to become wise enough to share them humanely. In tapping the springs of our creativity, it should give us the courage and balance to join the conversation of great minds that is the history of our culture without apology and without aggression. Such an education is not primarily technical, although it values technical skill in its proper place. It is not education for a specific career, although its participants can justifiably anticipate very interesting careers. It is education of the entire person. People have histories and emotions as well as ideas and analytical skills. Entire people, not abstract minds, become students and teachers.

Here I discuss teaching and learning as an entire person reflecting on interactions with entire people. Teaching matters deeply both to the students who experience it and to the scholars who do it, for it endows the academic life with a type of meaning not available in research (which has other important rewards). The balance between teaching and research that makes an academic career satisfying can be greatly aided by situating that career within the broader context of a balanced life. Understanding how we learn about the important things in life thus has implications for how and what we teach. For that reason I have framed my conclusions with the experiences that have shaped my views. They help to explain how I reached these conclusions on making learning effective and teaching meaningful.

Good teaching is based on understanding how people learn: people learn best when they take ownership of and responsibility for their own education as active agents rather than passive recipients. And much of the nature and quality of the learning experience is

determined by the structures in which teaching and learning occur. Embodied in such structures are implicit messages that can have greater impact on personal development than the clarity and interest of the information transmitted. Much of what follows is thus about ownership, agency, and the implicit messages of learning structures.

**You need to know who you are and why you are doing what you are doing**

The implicit messages of my undergraduate education were not all helpful. When I entered graduate school in the fall of 1967, having graduated young from a prestigious university that prides itself on the quality of its undergraduate education, I was psychologically, if not intellectually, completely unprepared for the experience. Yale had coddled me (cf. Deresiewicz 2008). Frustrated by the hurdles that I would have to jump before starting my research, disillusioned by how little my fellow graduate students engaged with ideas, rapidly impatient and soon disoriented, I dropped out after two months and spent the next three years working in the computer services division of a medium-sized multinational corporation. During that time I learned to manage a team, to communicate with people from a broad range of backgrounds, to recover from failure, to take responsibility for my mistakes, to be determined and patient enough to see a project through to the end, and to see universities from outside, as one of many institutions in a society and one of many structures in which to learn: in short, to grow up. Those were not lessons I had absorbed from my undergraduate education, which had been conducted in misleading comfort and largely taught by professors who had never been outside the Ivory Tower.

Then, uncomfortable with the corporate value system, toughened by experience, and still enchanted by ideas, I returned to graduate school in 1970. I quickly earned a master's at Wisconsin, where I completed two major independent projects in addition to the master's research, then moved to the University of British Columbia for the PhD. (Between Wisconsin and UBC I married; sons followed in 1974 and 1976.) When I arrived at UBC in January of 1972, I was advised to have a chat with Peter Larkin, a professor of fisheries biology and a former Rhodes scholar who would later become the dean of the UBC graduate school. He had read what I had written in my independent projects at Wisconsin, and he had some advice for me. Do not, he said, listen to those

who will advise you to start a research project immediately. Instead, spend a year or so reading widely and thinking about what is important that has not yet been done. Only then, when you understand what you want to do and why it is important, should you begin your research. He was advising me to use about a quarter to a third of my time in my PhD program to identify and take ownership of the issues that would shape my research. He was also advising me not to let the direction of my research and my career be shaped by professors who gave me projects to work on, but to shape it myself. This stance resonated with what I had learned in the three years that I had worked in a corporation: take charge of your own life, take responsibility for your own ideas, and act upon them.

**Pushing the envelope … perhaps a bit too far?**

I took his remarks to heart and, with the approval of my faculty mentor, acted on them. UBC has a streamlined PhD curriculum with few required courses. One writes a proposal, gets it approved by an examination committee, does the research, writes the thesis, gets the degree, and gets on with life. The proposal is to be presented within 18 months of arrival. I dived into reading and thinking about what I might do and, after some over-ambitious first attempts, managed to come up with a package that I thought was both promising and practical. It consisted of a long introductory review of life history evolution that justified the design of three research projects, which I proposed to start in parallel to see which were feasible and then to drop two of them to concentrate on the one that worked best. The ideas that I was proposing to test were not very familiar to anyone on the faculty at UBC, but I thought I had done a good job in my proposal of describing why they were interesting and plausible.

I defended my proposal before a departmental committee late in the spring of 1973. Such committees were composed of the faculty mentor, four other members of the department, and an external member, in this case from cancer research in the medical school. The format was a 15-20 minute oral presentation followed by questions from the committee. When I finished my presentation, the fellow from cancer research went first, and he did not ask a question. He attacked, opening with, “This proposal is bad science

and bad philosophy. The optimality arguments suggest that evolution is moving towards some goal. That's teleological, and that's wrong. Defend yourself – if you can."

I got angry. I had spent 18 months reading, thinking, and writing, and I thought I had done it well. This professor misconstrued what I had written and presented, did not understand evolution, and was not challenging me constructively. He was attacking me in a way that could terminate my career in science before it could get started. We got into an intense argument that lasted about an hour. The other members of the committee looked on bemused as we went at it and finally asked a few friendly questions. Then they asked me to leave the room while they discussed my fate. I paced back and forth in the hall outside for 45 of the longer minutes of my life. At last the chair of the committee, Peter Hochachka, emerged to inform me that I had passed, barely, and that the decisive comment had come from Alf Acton, which I paraphrase as, "We cannot tell from this document and this examination whether he is a fool or a genius. I suggest we take the risk and pass him."

Evidently I had pushed the envelope about to its limits without realizing it.

Well, I am no genius, but the part of the proposal that had caused the problem, the long introduction to life history evolution, was revised and published in *The Quarterly Review of Biology* in 1976, its essential message intact. It established my reputation, has been cited more than 1900 times, and helped to create life history evolution as a major branch of evolutionary ecology. It exceeded the page limit of that journal by a considerable amount, and the publication fees were far beyond my graduate student's budget. My PhD committee at UBC, to their great credit, stepped in and paid the fee for me from their research funds. By early in the fall of 1973, pilot studies had shown that two of the three projects I had proposed were not feasible, and by January of 1974, when it was clear that the third was going to work, the spreading of risk across three pilot projects had also paid off. With valued support from all the members of my committee, I managed to finish my PhD thesis quickly and passed my defense in July of 1975. It had taken me five and half years to get my master's and PhD.

**Learning balance**

Our first son was born 8 months before I finished my PhD. I was not around much to help, for during that time I was working seventy to eighty hours per week as I pushed hard to finish the degree. When I got it, my wife sat me down and said, if I may paraphrase her, "I can understand why you needed to work so hard, but you have your degree now, we have one child, and we may have another. I want you to promise not to work nights or weekends: you need to be sharing the parenting, and your child needs a father. If you don't agree, I will divorce you." Straightforward. Cards on the table. Courageous. She frightened me to the core, for I love her deeply. I agreed to the promise; and I kept my word. For the next twenty years I did not work nights or weekends, and I spent thousands of delightful hours with our sons while they were growing up. She was very wise, and I am deeply grateful to her. Sometimes husbands need tough love.

The decision had major consequences for my behavior. When I was at work, I worked. And when I was with my family, I concentrated on them. The change in focus cleared and refreshed my mind so that when I went to work, I was efficient. Many think they must work long hours to be competitive; that is not necessarily true. One performs better when work is framed by a balanced life: *professio sano in vitam sanam*. Five to eight hours per day of clear thinking and concentrated work five days per week produces more impressive results than the coffee, chit-chat, and various displacement activities that often fill the time of many of those who think they are working seventy or eighty hours a week.

**Some modest advice**

Mostly on the basis of the introduction to my PhD proposal, I was nominated for and got a prestigious postdoctoral fellowship at Berkeley, where we arrived in June of 1975 and spent the next three years. The Friday before the first week of spring quarter in 1976 I was asked by a rather patriarchal, authoritarian senior professor to give the first session of the graduate seminar for which *he* was responsible. I recalled gratefully the freedom, the informality, and the support I had at UBC, and I was finding Berkeley to be more formal, more pompous, more full of itself, and a place that had created more hurdles for graduate students to jump. Feeling a bit mischievous, I agreed to do it on the

condition that I could talk about whatever I wanted, which was graduate education, and to his credit he agreed. After a discussion with my fellow postdoc, Ray Huey, I sat down and wrote *Some modest advice for graduate students* in about two hours. Ray added to it, and on Monday I presented it to the graduate students and professors in that seminar, adding a dash of theatre by acting like a busy professor, looking at my watch, and leaving in a rush without taking any questions. The performance created a minor local sensation. The text of the talk was copied and circulated widely, mostly within North America, for 10 years. I was then asked to publish it, which I did, with Ray's reply, in 1987 (Stearns and Huey, 1987). It became our most read and least cited piece of writing; you see both at http://faculty.washington.edu/hueyrb/prospective.php and (as of June 2008) on roughly 85 other web sites located on at least three continents.

My first stab at thinking about the concrete practice of education, *Modest advice* puts great emphasis on the psychological state of the student: its core message is self-reliance. Over the years I have received numerous emails from graduate students I had never met thanking me for having written it, often mentioning that they wished they had read it sooner. Its subtitles signal its message:

- Always Prepare for the Worst.
- Nobody cares about you.
- You Must Know Why Your Work is Important.
- Psychological Problems are the Biggest Barrier.
- Avoid Taking Lectures - They're Usually Inefficient.
- Write a Proposal and Get It Criticized.
- Manage Your Advisors.
- Types of Theses.
- Start Publishing Early.
- Don't Look Down on a Master's Thesis.
- Publish Regularly, But Not Too Much.

Thirty-two years on, I would like to add a bit to a piece that has, on the whole, worn well. The model for graduate work expressed in *Modest advice* is not for everyone.

When I got my first two PhD students in Basel, Switzerland, in 1984, I treated them as I thought I would want to be treated: I gave them *Modest advice* to read, and I asked them to come up with their own projects. One of them took to it like a duck to water, enjoyed it, and flourished in science: he is now a full professor at a major research university. The other came up with a great idea that suggested a pilot project involving a trip to a field site in Africa. I bought him a ticket and asked him to go down and do a feasibility study. On the last day we could get the money back for the ticket, he came into my office, handed me the ticket, and told me he would not make the trip because he could not bear the risk of failure. He then had a nervous breakdown, and when he emerged from treatment and returned to work, his personality had changed. He had become, as I perceived him, paranoid and obsessive.

He asked me to give him a project for the PhD, which I did, and proceeded to execute it with almost fanatical energy, producing a body of work that will probably never be replicated because no one else would be willing to work so hard and so precisely. He got the PhD, published several good papers from it, did a postdoc, got a starting faculty position in a medical school, then dropped out of academia to take a government job that involved statistics, at which he had become expert. When I had occasion to ask him whether I could show his wonderful PhD proposal (the one whose risk of failure he could not bear) to another student, he reluctantly told me yes, but he made clear that he blamed me for ruining his life by confronting him with unbearable expectations. The proposal later vanished from my files, which were accessible to my students in a public space. At that considerable cost, I learned that each PhD student requires a different approach. I do not think the experience refutes the general stance taken in *Modest advice,* but it did lead me to moderate it and to explore in a more careful and supportive way the implications that students perceive in my advice.

**Taking stock**

In 1986, using the freedom I had as a Swiss professor, I started to design several new structures – courses, workshops, field experiences, laboratories – in which effective learning could occur. The essence of the stance that guided those designs is that the goal of a teacher to help students become colleagues as fast as possible. A colleague is an

equal, an interested partner who takes responsibility for her own education, an independent agent. In an ideal world in which students showed up at universities as independent agents who knew what they wanted to do, articulated options, made choices, and accepted responsibility for those choices, all one would need is access to books and journals, an informal setting in which to discuss them, interested smart colleagues who took time to discuss, and, in the sciences, access to the materials and equipment needed to test ideas. In reality that won't work, for most students are not yet independent agents when they arrive. Their sense of agency needs development, and the issue I faced was this: how do we help them to transform themselves?

I pose the question that way because I see the primary job of a teacher as neither the transmission of information nor the development of technical skills, however necessary both may be, but as helping the student grow rapidly into the secure psychological stance of a self-confident adult mind that takes joy in the exploration of its own ideas and questions and responsibility for situating them objectively in the context of what others have thought and discovered. Just as a fencing instructor works hard on improving stance and footwork to provide a secure foundation for the student's more spectacular thrusting and parrying and a meditation instructor teaches focus on breathing to quiet the mind, we need to develop the mental confidence and balance of students as the secure foundation for the unfolding of their individual creativity. Once that is accomplished, all else comes more easily.

In what follows I describe the attempts I have made, and continue to make, to design structures within which students can learn to become colleagues rapidly. For some, it is a journey of many steps. For some, it is not easy. And for some it is a joy and a release.

## *Hard knocks*

One year of my stay at Berkeley was spent not as a postdoc but as a visiting faculty member. I taught marine ecology that fall and introductory biology that spring as a sabbatical replacement. Most of the students in the introductory biology course were pre-meds, and the course was huge: it filled a lecture hall that seated 350 people, and I was videotaped and replayed for another session at noon. In those days one used slides to

illustrate lectures. Before the course was half over I discovered that some of the pre-meds were stealing the slides before the noon showing to lower the grades of their colleagues and raise their own grades, which were curved. That behavior disgusted me.

Some of the professors at Berkeley were quite comfortable in their skins. Others were not, and in a very particular way. They knew they were at one of the best universities in the world, and they knew they were expected to be among the best in the world at what they did, but they suspected (or knew) that they were not, and the resulting insecurity occasionally created significant costs for those who had to interact with them. This aspect of the competitiveness and insecurity that is built into the funding and the reputations of the great research universities put me off.

(I have since learned that the issue is general. Berkeley is normal in that respect.)

Thus, when it came time to get a job and I had the choice of two offers, one from a great research university, Cornell, and one from a small, idealistic liberal arts college, Reed, I took the Reed offer, for I liked its emphasis on active student participation in learning, its academic culture was attractive, and I did not think its students would steal slides. I knew that I was stepping out of a mainstream research career, but Reed had a light teaching load, its biology department had a strong research tradition, and I felt that I should be able to continue to publish good work and to get a job at a research university later if I decided I wanted it. We arrived at Reed in August of 1978.

Many things happened at Reed. Some relate to teaching and learning, others to postgraduate education in the school of hard knocks. Both shaped my views.

I met some wonderful students, and some who were not so wonderful. Over five years I guided about 20 of them through their independent senior research projects, which were the capstone of the Reed curriculum. I collaborated with a brilliant physicist whose office was next to mine on some theory that advanced the field; such interactions across disciplines were easy because the college was small and faculty were more relaxed about their personal agendas than they are at research universities. I got an NSF grant for experimental work on life history evolution that produced important results. It proved possible to do significant research at Reed. My career took off, and in 1980 I started getting invitations to give talks in Europe – two or three per year.

That I was becoming internationally prominent in my field – and that I was brash – did not sit well with one of the larger frogs in the local small pond, my department chair, who had issues with my candor. To skip ahead for a moment to one of the hard knocks: he told me after four years that I could not get tenure at Reed because they did not have money for my position; I therefore applied for jobs and got a much better one as a full professor at a major research university in Basel, Switzerland; shortly after I left, Reed tenured the next two junior faculty in biology; and shortly after I arrived in Switzerland, in April of 1984, I had a heart attack, probably brought on by the stress of the move, by having to learn German, the language of instruction, and by the passing of my father, who had died three weeks before we moved.

The chair had lied to me to get rid of me, and I had paid a significant price. I would have been happy to stay at Reed, for I had friends on the faculty, and I liked the students and the culture of the college, but in retrospect, he did me a big favor: the position in Switzerland was superb, our 17 years in Switzerland became a high point of my life, and I again had the privilege – as I had during my three years in corporate life – of learning to recover from an apparent failure and turn it into an opportunity. That statement is both ironical and sincere: I had not died, and I was stronger.

Those experiences made deep impressions that affected my stance on hiring, on learning, and on teaching. I now do not trust people with positions of responsibility unless I can see that they have had the experience of recovering from some significant challenge that has set them back substantially. Needing to see evidence of resilience, I always ask questions about how people have dealt with challenges and failures when I interview them for jobs or for admission to graduate school. I believe that students develop best in the long term if they are exposed to real risks of failure. We do not prepare them well for what life will throw at them if we do not insist that they deal responsibly with the consequences of their choices. Those consequences include failing courses and, if enough courses are failed, being forced to leave school. If we are not willing to take such steps, we unleash upon the world an elite that feels it is entitled, because it knows best, to tell others what is best for them, when it in fact has very little notion of what life is really like for most of the people on the planet, who actually have to

deal daily with serious consequences. *We owe it to our students to grant them the privilege of learning from the opportunity to fail, and to fail in serious ways.*

## *Active, not passive. Collegial, not hierarchical.*

When I arrived in Basel, I encountered much more traditional teaching than I had experienced at Reed. The standard format was a large lecture in which students took notes that they later regurgitated in oral examinations. Professors were authority figures with high social status and were addressed with respect. I suddenly changed from Steve to Herr Professor Dr. Stearns and wondered who this stranger was that had become wrapped around my skin. Relationships started formally, and many never became informal even after many years of regular communication, for informality implied the commitments and responsibilities of a deeper sort of friendship and was not to be taken lightly. I learned German on the job and began lecturing in German six months after we arrived. It was initially not a pretty sight, but none of my students committed suicide, and for several years I produced and delivered lectures in German to large classes. Doing so rapidly improved my German, but it was not a satisfying way to teach, for I knew that I was not developing my students into colleagues: I was reinforcing the impression of hierarchy. They were down below taking notes, and I was up above telling them what was what.

When my German became good enough to allow me to say whatever I wanted without preparation, I decided to switch to teaching in small groups. I had the manpower to do so, for my position brought with it the power to appoint several assistant professors. The first course to be offered in a new format was an introduction to evolution, ecology, and behavior: “Evolution-Ökologie-Verhalten”, or EOV, which students encountered in the spring of their second year at university. We limited lectures to three overviews per semester and asked the students to prepare for three classes per week by reading about 30 pages per session. The texts we used were in English, for our approach to the subjects we were teaching had not yet been translated into German. For most of our students, English was their third or fourth language, and this course was often the first time they had to make serious use of it. We were asking them to work very hard.

We told them that they would not be allowed to enter the classroom unless they were prepared to discuss the reading, which we did in German. I justified that rule by exaggerating a key experience I had had at Reed, where I discovered in a seminar on the social implications of biology that the well prepared students would not let poorly prepared students into the room because they expected that everyone in the class would be able to explain any issue. Teaching was a responsibility shared by all. That was a fairly extreme stance even at Reed, but I portrayed it as normal to help justify it in Basel.

A typical session of EOV would go like this. I would walk into class, ask them what was important and what they had not understood in the reading, appoint a student to write the answers on the board, then step out for five minutes. When I returned, I would look at the two lists and add anything I thought they had missed. I then picked a topic, asked who had mentioned it, got them to explain why they thought it was important or what it was that they did not understand, then picked another student at random and asked that person whether they agreed with the explanation of the topic's importance or could explain what was not understood. We would continue until the lists were exhausted or until time ran out. In the course of a session every student could expect to be called on to explain something. If they started drifting off course or babbling misinformation, I would step in with a brief lecture – never for more than five or ten minutes – then let the discussion resume.

To build their confidence and accelerate the process of making them colleagues, I would often ask one of them to join me at the board while we constructed a diagram or broke an equation down into its parts. We would do it together, on the same level. At the start, it is always hard for students to do this: they feel very exposed. But as they learn that I support them and deal gently with any mistakes, many of them relax and come to enjoy it. A few never do.

We discovered that students who took this class did not have to prepare much for examinations, for they had essentially been in an oral examination for an entire semester. This was where I first began to suspect that there is a general principle involved in learning: *You remember best things you have explained while under constructive emotional stress*. Such a situation is generated by having to perform in front of others. Anyone who has taught knows that she first really understands the subject when she has

to teach it. By getting students to teach each other while I watched them and corrected their mistakes, I was giving them the same experience. I have come to think of *constructive emotional stress as having a role like a chemical fixative in developing a photo: it fixes in the brain the content of what is explained.* This is not something that happens when a student reads a book, even if they take notes on their reading. It can happen when they form small independent study groups and explain to each other the key points of what they have read.

We also asked the students to write a paper on a question they chose themselves and to base it on articles from the original scientific literature. We encouraged them to supplement our list of potential paper topics with ones they proposed. This was an unusual step within the Swiss university culture (and some others): we were asking second year students to think critically about original scientific work and to get comfortable dealing with knowledge as it is presented in research papers rather than texts. They could soon see that one paragraph of their text was based on many research papers, and that science is a process that deals with alternatives, some of which are not yet decided.

That course was taught from about 1988 until I left in 2000, and something similar to it continues to be taught in Basel. Eight of those who taught it with me and five of the students who took it are now tenured professors. They have all retained in their teaching elements of the EOV experience. The course was not only effective at recruiting students into science. Many of those who took it were destined for other careers, including high school teaching. Shortly before I left Basel in 2000 a teacher who had taken the course five or ten years earlier came up to me in the street – it was the first time I had seen her since she took the course – and told me that it was the best experience she had had at the university. The reputation of the course spread through Switzerland; it was one of the reasons that Basel became a magnet for biology students in the 1990's. My colleagues at the university told me that they could see that the course was working, for students who had taken it were more fun to work with: more active, more independent, more questioning.

In the context of an American liberal arts college, the course was not that unusual, with the possible exception of the strict requirement that students could not enter the

room unless they had done the reading and were prepared to explain it. In Central Europe, it was revolutionary. Its strengths stood out more clearly against that background.

### *Student questions are key*

A flashback: In summer of 1972 I spent two months taking a graduate field course in tropical biology in Costa Rica offered by the Organization for Tropical Studies (OTS), which is supported by a consortium of North, Central, and South American universities. The course consisted of a mixture of lectures and shorter and longer student research projects conducted at several field stations in a variety of habitats. On our first day in the field, we spent the morning walking through the rain forest looking at tremendous species diversity and fascinating morphologies and behaviors. We were then told to form small groups, write down the first fifty questions that came into our heads, and discuss the characteristics of a good question. It was a very stimulating exercise. The questions came out rapidly, practically as stream-of-consciousness, and covered a huge range of ideas: Why do tropical plants more often have leaves with pointed tips? How did leaf-cutter ants manage to domesticate their crop fungus? Why is species diversity so high in tropical rain forests? How can we measure competition among species in the field? Are the ants living on balsa trees helping them or hurting them? Some who played the 50 Questions Game discovered questions so fruitful that they have based their entire scientific careers on them.

However, the next day, the field projects that we began were not motivated by our questions: they had been designed and written by faculty from our course and from courses taught in previous years. Only after six weeks of testing other peoples' ideas were we allowed to design and execute our own two-week project.

I wanted the students in Switzerland to have a similar field experience, and my second innovation there was the design of the field course. After thinking about the OTS Fifty Questions Game, I decided to take the risk of working only with the students' questions. We would show them what was going on in the field to stimulate their thinking, ask them to write down and discuss their questions, then take their most suitable questions and help them to transform their questions into small-group projects with

testable hypotheses and detailed methods that they could then execute the next day. We asked them to perform proper statistical analysis on their data, present their results in brief oral reports that evening, and repeat the process for a week. After a week of being given the freedom to succeed or fail with their own ideas, they had learned a lot about the properties of a good question and a feasible project. We then asked them to design and execute an individual project that could be done within a week and to write it up in the format of a scientific paper. The most important ground rule that I established for this course was that *no faculty member or graduate assistant could give a student a question*. We could improve their questions by pointing out how they could be made more precise, more concrete, and more testable, but we were not allowed to feed them any.

At first we tried doing this as an afternoon exercise at a field site close to the university. It did not work well. The students were distracted by their other commitments, and the experience was not effective because it was broken up into short blocks of time, often too short for the biology to take place. We therefore decided to make it a two-week long block course at a remote site. In various years we took the students to Corsica, to the Camargue, to Sweden, to the Finnish Archipelago, to Hungary, and to the Swiss Alps, where we did biology 24/7.

A course based entirely on their own questions came as a revelation to many of the students. They realized that they could use their own curiosity to create knowledge, and that they could easily write down in thirty minutes more questions than they would be able to answer in a lifetime of research. *From having the freedom and privilege to learn from their own mistakes, they learned that it is not just all right to make mistakes – mistakes are essential, for science consists of making intelligent mistakes and learning from them as efficiently as possible*. By living alongside the faculty at remote sites where we did our own cooking and data analysis, and work often lasted late into the night as we hunched together over computer screens, they realized that we are all in this together, that they are larval colleagues, just like us only younger. *The implicit messages of the social setting are a very important part of the learning structure*.

During the 13 years that I taught the field course in Basel, it resulted in two original scientific papers, both from trips to Corsica and written by teaching fellows, and, more importantly, many students who were much better prepared to start their research for their

master's theses. The course continues to be taught in much the same format by former students who took it in Basel and are now professors at the University of Zurich.

When I moved to Yale in 2000, I did not have the manpower to take a large lecture course and break it up into discussion groups led by assistant professors as I could with EOV in Basel. Instead I now teach a large lecture course with sections led by graduate student teaching fellows, and I continue to struggle to find ways within the curricular structure of a major research university to provide the kind of learning experience I was able to give my students in Basel. One solution was inspired by the 50 Questions Game as it was used in the Basel field course, but there was a preliminary step.

That step was to make the introductory biology course, which I have now been teaching for seven years, writing-intensive. This means that students who take the course get a writing experience substantial enough to qualify as one of the two writing experiences required for their degree and that the graduate teaching fellows that lead sections are trained in teaching writing. The writing assignment was initially chosen from an updated list of potential themes framed as questions that I had started accumulating in Basel: things like, "Why forage in a group rather than individually?", "What are the causes and consequences of chaotic population dynamics?", "How will forests respond to global warming?", and "What are the evolutionary causes of altruism … cooperation … aging … menopause … menstruation?", to name a few.

The course is fairly large, with from 50 to 150 students, and it took a year or two to get the kinks out of teaching writing in the context of a large introductory science course. We now ask the students to write a 15-20 page review paper based only on original research articles, and to develop that paper in stages that allow them to clarify and express their logic: draft outline, revised outline, draft paper, peer feedback, first revision, feedback from teaching fellow, second revision, final draft. The process, which extends from early February to late April, is intended to drive home the points that you cannot write clearly until you have thought clearly, that writing clearly is a fulfilling craft, and that good writing is a key element of scientific communication: without it progress would slow because the social communication upon which science depends would be defective. Support from the Writing Center for writing and the Graduate School for teaching has been excellent. The graduate teaching fellows learn a lot about writing by teaching it,

something that will help them for the rest of their lives just as much as their instruction in writing helps their students. That's all good.

However, given my experience with the 50 Questions Game in Basel, I was not happy with the idea that we were providing the students a list of pre-cooked questions from which to pick the themes of their essays. We were denying them both the privilege of learning that they can use their curiosity to teach themselves and the opportunity to take a risk, to learn that they can take responsibility for a chunk of their own education. While I would like to take them all to Costa Rica for a walk in the rain forest, that is expensive, impractical, and could cause some ecological damage. So if the mountain would not come to Mohammed, Mohammad would have to go to the mountain. I went over to the Yale Center for Media Initiatives (CMI) and pitched them an idea: we would get images from BBC and National Geographic nature documentaries and turn them into streaming digital video that students could view on their laptops anywhere on campus. If we could not take the students to Nature, we would bring Nature to them. We would frame the images with an explanation of the 50 Questions Game, let them be stimulated by what they saw, from which we would strip all commentary, have them play the 50 Questions Game in section, share their questions with their colleagues, discuss the characteristics of a good question, and then have them write their paper on their best question.

The team at CMI liked the idea and looked into it. They reported back that National Geographic and the BBC would charge enormous fees - $20/second or more – for their material, and concluded that we could do it ourselves for less. We wrote a brief proposal, it was quickly approved, and we had funding for a ten-day expedition to the Galapagos to capture images of nature that would stimulate students to ask questions. We chose the Galapagos because the weather is usually good, the animals are tame, the dry habitat results in views that are usually unobstructed by vegetation, and the islands are legendary as a source of inspiration to Darwin. The CMI assembled a professional film crew, a yacht, and permission from the Ecuadorian authorities, and we spent 10 wonderful days roaming the archipelago filming and photographing everything we saw. The CMI team, led by Paul Lawrence and David Hirsch, then spent six months building the web site that now drives the Questions Exercise with which the writing assignment

begins. They did a beautiful job. You can view it at http://cmi2.yale.edu/galapagos/, and you can read about its development at http://cmi2.yale.edu/instructional_solutions/projects/galapagos/NMC_galapagos.pdf and in Hirsch et al. (2007).

Students taking such courses learn that with a good question and the resources of a university library, especially one that has comprehensive access to electronic journals, *you can teach yourself the state of the art about anything you can understand technically with a few months of reading and writing. You do not need a professor or teaching fellow to do so*, but letting one comment on your drafts helps to reduce error and accelerate learning.

Apropos the disposability of professors: I was once invited to give a lunchtime talk to the Rotary Club in Basel. This was in a town where one heard the line at parties, "In Bern one should aspire to be a general, in Zurich, a banker, but in Basel, a professor," and where it was widely known that in his last letter to Jakob Burkhardt, with a comment that helped to trigger his commitment to a mental institution, Friedrich Nietzsche had written, "I would rather be a Professor in Basel than God." I took as my theme the idea that professors are unnecessary. All one needs at a university is a good library, interested colleagues with whom to discuss ideas, and the means to test them. The audience chuckled at my talk, and one person said, "Yes, but we needed a professor to tell us that!"

### *The structure in which learning occurs can have greater impact than the information transmitted*

Another flashback that sets another scene: years ago, Silke Bernhard was asked by the pharmaceutical company for which she was then working, Schering, to develop a new kind of scientific conference. She came up with an extremely effective design, and when Schering lost interest after a few years, she pitched it to the Senate of the City of Berlin, which agreed to take it over. She named her baby the Dahlem Conferences, after the quarter of the city in which they took place. Silke passed on in 1993, but the Dahlem Conferences continue. They do not have the usual format in which speakers present their work and others listen and comment. Instead, twenty authors are identified who can write background papers that present relevant topics in a stimulating and provocative

fashion. These papers are circulated well in advance to the roughly 60 participants (including the authors), who are asked to prepare by reading them. This step is designed to get everyone on the same page before they arrive. The conference lasts a week. The participants form four discussion groups, each of which is charged on Monday with writing a report that summarizes the state of the field by Friday. The combination of advance preparation, concrete task, brilliant minds, and looming deadline elevates discussion to a high level and results in an experience that for many is exhilarating. The point was to have a good discussion; the problem was how to create a structure that would elicit it naturally; the solution was effective. The Dahlem Conferences have shaped many subsequent research agendas.

Having taken part in two Dahlem Conferences, in one of which I was on the organizing committee, and having used the format for another conference (Stearns 1999), I wanted my students to have similar experiences. It would not be possible to include the preliminary step of having papers written and circulated, for tasks of that magnitude do not fit readily or fairly into graduate programs, but it was possible to create a structure that used some of the same elements to accomplish a similar goal. In the process we discovered some unforeseen advantages.

I decided to call the structure a workshop in population biology. It would last a week, and it would take place at a remote location where we could work and have the potential to interact all day every day. I picked Guarda, a town in the Engadine that I had visited with my family on holiday in 1984. Like many towns in the Swiss Alps, there are apartments for rent; we usually rented apartments that would hold about 40 people, 6 of whom were faculty and their partners. Guarda is lovely – it won an annual award as most beautiful village in Europe – and the alpine meadows around it are in spectacular bloom in late June and early July. The location did not hurt.

After some experience, we settled on the following design: We arrived on Saturday afternoon. On Sunday morning, we met in plenary, the program for the week was explained, and each participant wrote down in headline format three topics she was interested in discussing. We sorted the participants by interest into groups of 4 or 5 and gave them the task of writing a research grant by Friday. They met regularly two hours

each morning and two hours each afternoon, and they were told that the faculty would be dropping into their discussions to observe and to help.

A key feature of the design was that some of the professors were world-famous scientists whom all the participants knew immediately by reputation. They were instructed that they were not allowed to give the students ideas; they could only improve ideas that the students had already had. We soon discovered that when some famous person was dropping in to hear what one had to say, the participants worked incredibly hard and made rapid progress. They rarely limited themselves to two two-hour sessions per day, often working long into the night.

Another design element turned out to be social contact. Between working sessions participants went for walks in the Alps with the famous visitors. Participants regularly came by the faculty apartment for drinks before dinner, and we asked each student apartment to invite each faculty couple to dinner once during the week. We also had after-dinner talks in which the visitors chatted informally about their latest ideas. And on Friday evening there was a farewell party to which everyone contributed food and drink. The impact of all this socializing on the students was enormous. They were mixing freely and chatting informally with heroes. Getting comfortable with heroes is a very good way to learn to be a colleague.

Please note that the definition of a hero is relative. The impact is greater if the person is world famous, but a positive effect can be achieved with anyone who is respected. That is why I try to eat lunch with my students after class whenever possible.

A third design element was the mix of participants. We started in the first year with masters and PhD students from Basel. After success had bred confidence and visiting faculty had enjoyed the experience and spread the word, we advertised the workshop and invited graduate students and postdocs from all over Europe. They applied in increasing numbers, and some even came from North America. Having a mix of master's students, PhD students, and postdocs gave different levels of experience in each of the discussion groups. The more experienced helped the less experienced, and those with better English helped those whose English was not yet fluent.

More than 600 participants have attended the Guarda workshops. They continue to be organized by Dieter Ebert and Sebastian Bonhoeffer (see http://www.evolution.unibas.ch/teaching/guarda/), and they have spawned similar experiences that continue each year in Vancouver, Paris and Lausanne. For many participants it has been a transformative experience, and *the key element in those transformations is social contact with intellectual heroes in the context of a clearly defined task carried out in a supportive local community within which the heroes are by their presence and attention valuing one's own ideas by contributing to their development and refinement.*

## *Harness competitiveness*

Not all the structures I tried worked out. This next one disappeared, but not, I think, because it was a bad idea in principle.

I called it the Computer Practical, but in fact it was a course in experimental design and statistics offered in a regular afternoon laboratory time slot. Students first received training in a computer language – at the time we were teaching Pascal – with emphasis on the ability to produce probability distributions and random numbers. They were then asked to come up with their own hypothesis and, having heard a lecture on the basic principles of experimental design, to write it down together with an experiment that they thought would test it. They then formed pairs, exchanged hypotheses and designs, and each student was asked to simulate the experiment proposed by her partner. In doing so, she was told she should exploit every logical flaw in the design and produce data that would reveal those flaws. Partners then exchanged data sets and were asked to analyze the data with statistical programs that they wrote themselves. This step limited the experimental designs to simple ones whose data could be appropriately interpreted with simple statistics.

The course was time consuming and demanding, and the students were much crueler to each other than Mother Nature ever is to a practicing scientist. Their natural competitiveness – which they expressed and accepted cheerfully – sharpened their learning. I would have continued to teach it, but administrative commitments intervened, and the person who took it over converted it into a more traditional course in biostatistics

that was less demanding to teach and less challenging to take. I would like to try it again someday.

### *Lectures can be transformed*

The lecture format will be with us for a long time because it is economically efficient and backed by tradition. Hiring enough staff to teach large introductory science courses in small groups is for most universities simply not possible. Therefore strategies to turn lectures from passive into active experiences are badly needed.

Eric Mazur, who teaches physics to premeds at Harvard, has come up with one good idea. Information is transmitted through reading, not through lecture. Students are required to complete the reading and take a quiz on the course web site the night before class. The quiz consists of three questions. The first is straightforward and asks about some concept from the reading. The second is harder, and some students may not be able to answer it, but it is graded on effort. If the students give it a good shot then they get full credit (even if it's wrong). The third asks, '"Is there anything specific you didn't understand - if not what did you find most interesting?" Eric uses that quiz to locate the issues that the students do not understand.

When students come to class the next day, he presents a question that expresses a high priority issue that is not well understood, asks the students to explain it to their neighbors (in a class of about 150), gives them five minutes or so to discuss it, then asks them to use Bluetooth clickers to vote on the multiple choice answers that he then puts up on the screen. This continues until class is over. Like the EOV method, Eric's strategy essentially puts the students into an oral examination that lasts all semester. They assimilate the material much better than they did when he gave them the exciting and more highly rated lectures that they absorbed passively (Crouch & Mazur 2001).

Eric checks the effectiveness of his teaching by giving a standardized physics concept test at the end of the semester. His students now perform much better on that test than they did when he gave traditional lectures.

I also interrupt lectures to ask students to explain key points to each other. It works well, and I plan to do more of it. The technology that Eric developed helps, but it is not necessary.

## *Applying the principles*

I am currently engaged in designing a new capstone undergraduate course at Yale on evolutionary medicine. It borrows these elements from another Yale capstone course, Studies in Grand Strategy: enrollment will be limited to 15 students; students must commit to the entire course, which begins in the spring semester of junior year, continues with a paid internship over the summer, and concludes in the fall semester of senior year. Class will meet once a week, late in the afternoon. There will be 3-4 lectures per semester on cutting edge research by famous scientists followed by extensive discussion and then dinner; close analysis of key papers from the current research literature; the fifty questions game followed by development of a research proposal on one's best question; the opportunity to pursue research in a summer internship; and instruction in how to write a scientific paper followed by the writing of such a paper in fall semester on the results of the summer project. Such a course is a structure in which students can express and value their own ideas while learning to be colleagues through social contact with heroes, one that harnesses natural competitiveness to constructive ends while emphasizing active learning over information transmission through lectures.

And that leads me to a final comment on how to design learning structures. The person who does the design must put enough of his or her own ideas into it that they are motivated to take ownership of it, feel proud of it, and stick with it long enough to get the kinks out and make it work. The structures I have described here are just one way to do it. I have presented them in the spirit of providing a few examples that appear to have worked and that suggest what might be general principles. There are a lot more structures out there waiting to be discovered. They are not hard to discover. All one has to do is decide that finding them is an issue that has priority.

## *Coda*

Why do I want to help my students become colleagues as fast as possible? Well, we each have only about 4-6 decades of mature rationality in which to create a valued life, and it goes by quickly. Value is not given to us. We create it by investing time, energy, and emotion into things we choose for ourselves. The sooner we start, and the more wisely we choose and invest, the more years we can have doing things that we value. I

want my students to lead valued and valuable lives, and they cannot begin to do so until they learn to take risks, make choices, and live with consequences.

It is also more fun to interact with colleagues. Students who are inspired and confident pose questions and challenge assumptions in ways that make me see fresh angles and new insights. It is only when they start teaching me that I know that I have started to succeed at teaching them.

What's wrong with lectures? A curriculum in which some stimulating lectures are artfully sprinkled is not a bad thing. But the lecture format is a structure with an implicit message: the lecturer transmits information that the student passively absorbs. The structure is hierarchical, and by promoting passivity it blocks the development of students as colleagues. For a young, creative, inquiring mind, too many lectures are boring and deadening, and the more creative and inquiring the mind, the smaller the number that qualifies as "too many." I therefore suggest that we concentrate on designing situations that support active learning rather than polishing our powerpoints for more efficient information transmission. The problem of transmission has essentially been solved: reading works. The real problem is retaining and using information, compared to which acquisition is trivial. So let's reduce, but not eliminate, the role of lectures. Doing so will often involve getting our own egos under control, particularly if we have invested decades in learning how to use lectures to earn applause and high marks on student evaluations.

Why care about teaching? After all, my university provides strong incentives to ignore it. If I write enough grants to receive a few, I can increase my income by 25% per year through summer salary, and my profession rewards original research papers more than successful students. I care because if I have a day in which I have seen a student's eyes light up on encountering an amazing idea, or in which I can see a student progress in thinking, writing, and speaking with clarity and grace, or in which a student grows in any other way because of something I have said, done, or arranged, I feel better that very night. While I suspect that emotion stems originally from parental feelings given to us by biology and generalized by culture, I have no proof of that. I do know that the more I have invested in teaching, the better it feels to do it: it has put value into my life. To teach is a privilege of the academy too often ignored in the research culture of the great

universities that produce the next generation of faculty. And if my experience is any guide, then an important part of the art of teaching is designing a structure that is effective for learning because it exploits the innate interests and motivations of students, then knowing when to shut up and get out of the way.

How can the research culture of the great universities be shifted to give professors incentives to create such structures? One long-term answer is clear: people who have encountered such experiences as students recreate them as professors. That is a bootstrap operation with a generational time scale, and it works. The short-term answers are not so clear. University administrations do provide resources to develop innovative learning structures, and that helps. But the deeper issue is the power of the massive research enterprise, which has become a major funding source for both individuals and universities and the principal source of reward and recognition in science, to shape and distort motivations.

It is curious that while more and more graduate schools are teaching graduate students how to be effective teaching assistants, few of them discuss how they can later become creative in their teaching as professors. And it is striking – if not surprising – that teaching is a secondary priority for many professors at research universities (with commendable exceptions). Graduate schools train their students primarily for research, and professors focus on research and publication. Nevertheless creative research has always depended on effective training. It is to balance those curious and striking facts that I have reflected here – as a professor of science at a major research university – on what three decades of trying ways to teach better have taught me about how to teach and why teaching is important. These issues should be integrated into graduate study in general. Perhaps we need Nobel prizes for teaching; we need some way to tap into the ego-fulfilling drives of bright faculty minds and capture some of their energy for teaching as well as research.

## *Summary of principles*

(1) If you are not encountering resistance, you are not changing things.

(2) Not taking risks is the biggest risk of all, for it yields an uninteresting life.

(3) Some moderation in risk-taking and resistance-induction is wise.

(4) A few years off between undergraduate and graduate education can improve the quality *and* accelerate the completion of a PhD project more than one might at first suspect.

(5) The aim of teaching intellectuals is to help them to become colleagues as rapidly as possible.

(6) We should value students' questions and require them to deal with the consequences of committing to their questions.

(7) We need to give students the freedom and privilege to learn from their own mistakes. They must learn that it is all right to make mistakes and not to fear them, for we all need practice in recovering from failure. Life is going to throw a lot of it at us.

(8) Just as a fencing instructor works hard on improving stance and footwork to provide a secure foundation, we need to develop mental confidence and balance for the unfolding of individual creativity. If that can be accomplished, all else follows more easily.

(9) We owe it to our students to grant them the privilege of learning from the opportunity to fail, and to fail in serious ways, including – for sufficient cause – having to leave university.

(10) The implicit messages of the social structure of a course are just as powerful in transforming students as intellectual content.

(11) You remember best the things you have explained while under constructive emotional stress, which has a role like that of a chemical fixative in developing a photo: it fixes in the brain the content of what is explained.

(12) Students can teach themselves the state of the art about anything they can understand technically with a few months of reading and writing. They do not need a professor or teaching fellow to do so, although having one around can be helpful.

(13) Social contact with intellectual heroes can be transformative, especially if it occurs in the context of a clearly defined task carried out in a supportive local

community within which the heroes are by their presence and attention valuing student ideas by contributing to their development and refinement.

(14) The art of teaching consists at least in part of designing a structure that is effective for learning because it exploits the innate interests and motivations of students, then knowing when to shut up and get out of the way.

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