

1Reflections on an Interdisciplinary Life

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Dear Theodore, I appreciate your kind words. It's been a pleasure to know you and watch you grow into an outstanding and truly integrative philosopher and historian of science, which is what you aimed for 30 years ago, but is very difficult to actually achieve. I recall when I told my own advisor Howard Stein that I now had my first graduate student, named Theodore, from Greece, he cleverly asked me "well is he the gift of the gods?" to which I immediately applied "yes!" You were a gift and a pleasure to work with and set a very high standard for those who would follow.

I am deeply honored to be awarded this degree and I thank the university faculty and administration who made it possible. It's a great honor to receive from the cradle of Western philosophy and science. This degree is especially meaningful because I have had a relationship to the Department of History and Philosophy of Science since it was only an aspiration. In 1985 I received a letter in my capacity as series editor for the *Science and Philosophy* bookseries from two Greek researchers, Kostas Gavroglu and Yorgos Goudaroulis. I had founded the series with the aim of examining philosophical issues grounded in studies of actual scientific practices. It was open to historians, philosophers, and scientists. They fit the bill perfectly, and their book examining the conceptual development of low temperature physics was the first book I contracted in the series. By coincidence, I had just become a Fellow at the Pittsburgh Center for Philosophy of Science and discovered my office mate, Aristides Baltas was a colleague and friend of Kostas and Yorgos, and then I met Dionysios Anapolitanos, who was working on his PhD in Philosophy at Pitt. Through all of them I learned about their desire to create a department of History and Philosophy of Science in Athens, which was founded in 1993. As part of the plan, they were sending out the next generation of researchers to study at prestigious universities around the world, with the goal of their becoming the junior faculty who would grow and sustain the department. In 1988, I now had a position at Princeton and Theodore applied to work with me, which deepened my connection to the Greek academic community. I don't recall quite when, but it was near the time of the founding of the department I introduced Kostas and other HPS colleagues to Stella Vosniadou, whom I had come to know from my work in cognitive science, and they conceived of having a cognitive science division within the department. Finally, when I moved to Georgia Tech, I met a student in the history of technology, Telly Tympas, who convinced me to be a member of his dissertation committee, and he is also now a member of the department. Together with all the other faculty and administration, they have grown what was an idea in the 1980s into a widely recognized, world class department. I have often commented, ironically and with envy, that I had a hand in putting together my dream interdisciplinary department of which I was not a member. So I am delighted and proud today to officially become

a graduate!

I was asked to prepare some remarks, so since this award is for my contributions to philosophy, history, and psychology of science, I decided to reflect some on my life as an interdisciplinary researcher. In the process I've realized I could write a book, but I promise not to talk that long.

After many years of research into the creative research practices of interdisciplinary scientists and engineers, and having myself been an interdisciplinary researcher all of my career, I have lately turned to examining interdisciplinarity itself. I'm especially interested in similarities and differences in interdisciplinarity as it is enacted – what I call interdisciplinary-in-action – across the sciences, humanities, and arts. As part of my research I have started an interview book project with my colleague Lisa Osbeck called *Interdisciplinary Lives: Women Crossing Boundaries*. Of course there are likely as many interdisciplinary men as women, but I decided to focus on women because, as we found in our pilot interviews of both, for us it has often been – and in some fields continues to be – a course for professional survival as well as an opportunity for creativity. Also, we found women to be much better story tellers, for whatever reason; better able to build the intellectual, emotional, and social dimensions into the narrative of their intellectual lives, and thus to provide richer data for analysis. Finally, it is usually the young women in the audience when I speak about interdisciplinarity who come up and ask if there's anything written that can give them some guidance – which there isn't yet. We have not progressed far enough on the project for me to talk about it here. Instead, for my brief remarks here, I decided to reflect on two of our interview questions myself.

***How did you become interdisciplinary?**

The short answer to that is I have been following the problem, coupled with leveraging some serendipity in that quest. As the philosopher Karl Popper noted, “We are not students of the same subject matter but students of problems. And problems may cut right across the border of any subject matter or discipline.” Interdisciplinarity is a problem-driven enterprise. I would add that finding and formulating the problem and determining the resources needed to advance the problem are a major part of the process.

My problem, as I would formulate it now, 50 years on, is

Science is one of the most significant creative pursuits of humankind. How can we understand and account for the epistemic accomplishments of science given that scientists are limited beings and the natural world is vastly complex?

This problem is itself complex and my research has focused on two interrelated components:

conceptual innovation and methodological innovation. In unfolding the various dimensions of those I have found that advancing the problem requires at least the combined resources of philosophy, psychology, history, and anthropology. How I've gotten to that point is a long story and I will just highlight important transition points along the way.

I'll start when I was quite young in order to underscore how important teachers have been to my interdisciplinary life. I have always loved and been intrigued by science. I started out to be a theoretical physicist. I was passionate about physics for as long as I can remember. I have a vivid recollection of my elementary school teacher telling us about why Albert Einstein was important when he died in 1955. I don't recall what he said, but it must have been inspirational since I know from that point onwards I wanted to understand what Einstein had done. I wanted to be a physicist. Indeed, the very first book I ever bought myself was around that time, and it was *Electricity and Magnetism Made Simple*. I tell you this since those in the audience who know my work will find it amusing. I had no idea how much of my life would revolve around trying to understand what was in it, my final take being my 2008 book, *Creating Scientific Concepts*.

In college in the late 1960s I was quite a good physics student and in fact the only female degree student, but I couldn't get my professors to discuss the conceptual issues I was interested in, about Einstein's work on relativity theory in particular. I stumbled into philosophy of science through choosing to get a BA rather than BS. Since I had taken a number of courses in literature, languages, and music the BA seemed a better choice. The only problem was that it required taking the dreaded Introduction to Philosophy, a notoriously difficult course and a subject which others had led me to believe was navel-gazing nonsense. I simply chose a course that fit an open time slot. It turned out to be an introduction like none other. It was taught by Milič Čapek, a noted philosopher of space and time, and instead of the usual Plato, Aristotle, and Descartes, we read Poincaré, Bergson, and Reichenbach. I found nirvana. I realized there were also physicists in philosophy departments. Since my physics professors offered me no encouragement to pursue a career in physics, and my philosophy professors did, I set off to study the foundations of physics. I was told that the best person to work with was Howard Stein, and so I set off for graduate school at a place I had never heard of, Case Western Reserve, itself an interdisciplinary hybrid of a science and engineering institution and a humanities, social sciences, and arts university. Parenthetically the latter was also important for my other passion and the activity that helped me keep my sanity – singing – since I was able to study voice and opera at the Cleveland Institute of Music while being paid by my philosophy fellowship.

Under Howard's direction I was encouraged to continue taking graduate physics courses, and when I became frustrated with philosophy of science courses which seemed to have much to do with language but little to contribute to understanding real science, he gave me the advice that unfolded the rest of my saga: read the scientists who have worked on the frontiers and have made

fundamental transformations in our understanding of nature – in the process they articulate and address deep epistemological, conceptual, and methodological issues. As a physics student we had only read textbooks or recent publications, but reading the historical scientists, especially their more speculative archival materials: drafts, letters, diaries, and so forth, opened a whole new dimension of what we now call scientific practice to me.

The historical records led me to an important general insight: creativity is best understood not as an act – an “aha” moment – and not as an attribute of a special individual, but as a process – a problem solving process. In the case at hand, scientific discovery is a problem-solving process. To understand the epistemic achievements of science one needs to examine the *processes* of discovery. I decided to investigate the origins of the field concept, so important for the development of relativity.

In investigating the historical records from Faraday through Einstein it seemed central to me to understand what role the sketches that filled the margins of Faraday’s diary, the analogies employed in his and Maxwell’s thinking, their thought experiments and those of Einstein were playing in the *construction* of their theories. At the time these were dismissed as ancillary – mere aids – to scientific reasoning by both philosophers and historians of science. But these records led me to the view that they are essential to the problem-solving process – to the view that scientific reasoning is not only logic, but also includes the powerful heuristics I called “model-based reasoning.” These heuristics have their origin and place in everyday reasoning as well, and I realized to fully articulate the notion of model-based reasoning required understanding how human cognitive capacities afford and constrain scientific reasoning, and in what ways scientists have been extending these to more abstract thinking. What was needed was a cognitive science of science.

The evolution of my problem and myself as an interdisciplinary researcher has been entwined with the fact that I didn’t secure a position in a philosophy department. Here we get to more serendipity. First, after my time as a Fellow at the Pittsburgh Center for Philosophy of Science, I approached the outstanding cognitive scientists at Pitt and at Carnegie Mellon University about a research position. That opened the unanticipated opportunity to bring my research on scientists’ model-based reasoning practices to bear on science education – work that has continued throughout my career – while at the same time developing into a cognitive scientist. It turned out, surprisingly, that Herbert Simon had an abiding interest in the work of Maxwell, and that got my foot in the door.

I wasn’t trained as an historian but I had done extensive archival research on the Dutch physicist H. A. Lorentz and had translated his dissertation into English with Floris Cohen. That, coupled with my book on the field concept, *Faraday to Einstein: Constructing Meaning in Scientific*

Theories, got me the job in history of science at Princeton. There I had the opportunity to work with philosophers and cognitive psychologists to develop a program in cognitive science. While on the faculty I took advantage of learning from both world class historians of science and cognitive scientists to continue to develop as both and advance my research program. Doing both at the same time opened up my thinking to not only about the cognitive, but also the material, social, and cultural resources scientists bring to bear on their research.

I began to see the dichotomy in the science studies fields between socio-cultural accounts on the one hand and cognitive accounts on the other as a false dichotomy – an artifact of Cartesianism and of our analytical methods. Doing science requires the kind of sophisticated thinking that only rich social, material, and cultural environments can enable. Figuring out how these work together in creating the epistemic achievements of science – what I call the *problem of cognitive-cultural integration* – has been, and continues to be, the focus of the last 20 years of my research. I realized that attacking this dimension of my problem required moving beyond the limitations of historical records to using ethnography as a tool to investigate the dynamics of how scientists, while drawing on current resources, create novel resources to further problem-solving; that is, how they build *complex cognitive-cultural systems* of scientific practice. This would require analysis of science-in-action – of the exploratory, incremental, non-linear problem-solving practices of frontier science, their origins and evolution, and the epistemic principles guiding them. How to find research labs to study and in what field was the question. Again we come to serendipity.

With the move of the independent Princeton Program in History of Science into the Department of History, I was again in need of a home. An unusual position opened up at Georgia Tech. They were looking for someone to build a cognitive science program, but no department was willing to pay for a whole position for a truly interdisciplinary person, so I was offered the challenging position of a three-way split among schools and colleges of computer science, psychology, and literature, communication, and culture, with later appointments in public policy and architecture added.

In working to create the Program in Cognitive Science, I had the opportunity to bring together a range of faculty – and especially students – from engineering, sciences, liberal arts, and architecture. As director of the program I seized an unanticipated opportunity that ended up providing the means to do the ethnographic investigations of frontier research labs in bioengineering sciences that have been the focus of the last 20 years of my research. The biomedical engineers wanted help from cognitive science to build an educational program from the ground up, and I convinced them that the way to do that was to have me investigate their research labs to determine what are their cognitive practices and what it takes to learn them, and help them translate findings into a practice-based, problem-driven curriculum. I knew I didn't

have all of the expertise needed to carry out the project I had proposed, but I also knew I could use it to further my own problem. So, I applied for – and received – funding from our National Science Foundation sufficient to build a highly interdisciplinary research group – Cognition and Learning in Interdisciplinary Cultures – that, as it evolved over the years, comprised the expertise to help the biomedical engineers with their problem and me with mine, while creating new dimensions of the problem that were ours. That group contained wonderfully creative and interesting human beings with whom I consider a privilege to have worked, and in some cases continue to work with.

In concluding, I now turn to another question from our interdisciplinary lives project.

What advice would you give to someone starting on an interdisciplinary life?*

Here are a few of my own thoughts, coupled with and reinforced by what I've been finding out in our interviews thus far.

Everyone has said you have to have courage – courage to stick to what you see as the way forward, to trust your intuitions, but also the courage to change course – you need to be both resolute in advancing your project and flexible enough to change the plan as needed.

Develop the expertise necessary to advancing your problem so no one can call you an amateur or a dilettante; but also because you need to have sufficient knowledge of the content, methods, and epistemic values of the participating fields for productive interaction.

One of the most rewarding and difficult aspects of being interdisciplinary is your reliance on others. Interdisciplinarity requires interdependence. Cultivate being a good listener; be open to learning from others; look for what you can offer them.

Find yourself a niche – a base from which you can work, even if that means doing things you'd rather not or had never seen yourself doing. Be open to finding the possibilities that can further your project in the situation you are in – look for the opportunities that might not be immediately evident, create them where you can.

Try to frame or define your problem in a way that it is compelling to the range of perspectives you are engaging. Muster all your intellectual force and passion to do what you need to advance the problem you have said we should pay attention to.

Finally, have patience. Interdisciplinary problems take longer to work out – and I wish administrators understood this better when trying to determine how to support their

interdisciplinary researchers. What you need to know only becomes evident as you go along. *Becoming interdisciplinary is a process throughout your intellectual life.* I'm still in the process of working out the interdisciplinary life that I started on nearly 50 years ago.

Thank you for your attention, and, again, thank you for this honor.