PREPARING UNDERGRADUATE STUDENTS FOR A CAREER AS A PROFESSIONAL PHYSICIST

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SUMMARY

This article describes ways to prepare undergraduate students for transition into a career as a professional physicist.

One of the seven principles for upper level physics courses [1] is using course activities that model professional practice. In this article we develop that idea into a set of practical methods that can be incorporated into the undergraduate curriculum.

PHYSICS IS MORE THAN PHYSICS

Too often we stop at the physics principles, rather than go on to consider social, ethical, economic or public policy aspects surrounding that physics. As a professional physicist, you are not divorced from aspects that go beyond physics. For example research proposals often consider impact on a wider community, and industrial physics work almost always must include economic as well as physical or engineering considerations. Class activities and assigned work should similarly ask students to work within a broader context. In teaching an energy course a few years ago I found that class activities that integrated physics principles with economic factors motivated high student engagement. It is highly relevant that one of the five bullets under the experience component in the P.Phys. certification requirements is "understanding the social implications of physics," [2] and that should start in our undergraduate courses.

MAKING IT REALISTIC AND WORTHWHILE

Too often, students perceive the 'work' they are given as "class work", with no relevance to the working world. This starts with first year problems that are closed with a single precise answer and with all relevant input parameters isolated. We all know that the real world of a professional physicist is much more like a series of Fermi problems [3], with the need to make reasonable approximations and to evaluate what information is relevant.

Students value more highly work that they regard as meaningful. While service learning and co-operative programs naturally contribute to this, there are ways that you can build these components into any class. For example, consider making class presentations open to a wider audience. When possible, have students work on problems that are genuine. These can either be locally relevant questions emerging from one of your department's research labs, or a broader Fermi question such as what are the risk and environmental consequences of an asteroid impact. These real world problems challenge students to evaluate and apply a broad array of physics principles, along with requiring that they determine what is relevant and seek a myriad of sources of reliable input information. Why not consider making some of your lab experiences tackle a real local issue? Many physics classes now use video analysis of motion as part of lab experiences. Why not collaborate with an athletic group to use physics skills to provide guidance for improved performance?

WORKING EFFECTIVELY WITH OTHERS

In most future career paths, physics graduates need to be able to work effectively with supervisors, peers and potentially others. There is strong evidence that collaborative learning in physics classrooms is an effective way to learn physics [4] but the good collaboration skills that result are an important additional benefit. Effective student teams don't just happen and you should give thought to how you can assist teams be productive and positive [5]. Your department may want to consider an integrated approach to building collaboration skills, starting perhaps with peer learning or studio-style collaborative groups in first year and progressing to challenging open-ended team projects in the upper years. An interesting question is whether teamwork in physics should be restricted to physics students or if it is feasible to have teams across courses beyond the physics department – for example have students in physics and economics work together on an industrial physics proposal, or have students in physics and public policy tackle a question such as the medical isotope shortage or the future of nuclear power in Canada.

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FINDING CHALLENGE AND OPPORTUNITY

Professional physicists thrive on challenge and to be successful must seek opportunities. We should not be afraid to truly challenge our students and to give them ownership in the task of finding innovative ways to apply their physics skills. While genuine undergraduate research experiences are the most obvious way to meet these aims, research experiences are not the only way. Have you considered having your class work collectively to create an electronic textbook tailored specifically to your course, with each student having a clear role (both in writing and reviewing)? Alternatively, could your class together create a quality media production on some physics topic intended for a broader audience? It is unfortunate that case studies are not more widely used in physics learning. There are a number of physics-themed case studies in the National Center for Case Study Teaching in Science [6]. Why not consider having your students develop case studies that can be shared with other physics educators? Case studies are ideal for professional physicist preparation, since they naturally combine physics principles with social, ethical and economic aspects.

COMMUNICATING TO DIFFERENT AUDIENCES

Many undergraduate physics courses, particularly at the upper levels, incorporate elements of scientific communication. These may be in written form, such as lab reports, simulated grant applications, essays, poster papers or scientific papers, or as oral presentations within class or to a wider audience. I would like to stress two main points: the first is to give consideration to the audience, and the second is to encourage students to 'speak' to different types of audiences. Communication will be more highly valued if there is a genuine audience, one that is beyond the instructor and other class members. Engage your students in the early planning of a course communication component, and be flexible and open to their suggestions in this regard. Students can write for publications, create and post YouTube videos, produce a series of Twitter posts, maintain a public blog, speak to local media, etc. As physicists, it is perhaps natural that we seek, and more highly value, opportunities to speak to other physicists. I feel that we miss many opportunities when we limit ourselves in this way. The life of a professional physicist requires regular and effective communication with those lacking physics expertise, and we should start such communication during the undergraduate years. Think broadly - e.g. could students write a children's book on the advanced physics in your course, or conduct a related workshop at your local science centre or children's museum? Does your course content relate to a current public policy issue, and if so could you have students prepare position papers and then present them to politicians and community leaders?

ETHICS AND RESPONSIBILITY

Ethics and responsibility play major roles in the P.Phys. [7], yet infrequently are these topics explicitly addressed in undergraduate physics courses. A few years ago we ran a science research program for highly motivated high school students [8], and as one component of that we initiated evening discussions on social and ethical aspects of science. The topics were widely varied, everything from scientific fraud, to reviewer responsibilities, to the perception of scientists in the media. These high school students enthusiastically and eloquently debated issues, and expressed the regret that they had not been similarly engaged during their formal science education. Our physics classrooms should not artificially divide the implications of physics from the physics concepts. While our primary goal, of course, is to teach physics concepts, spending a small amount of time to place these scientific ideas within a context helps to prepare students for life as a professional physicist as well as a more fully rounded scientist.

BECOMING PART OF A PHYSICS COMMUNITY

As a professional physicist, you are part of various professional communities: professional groups such as the Canadian Association of Physicists (CAP), national and international research collaborations, and your own research and development group. You should provide opportunities for students to begin to feel part of a physics community beyond your class and university. Regional or national undergraduate conferences, such as the Canadian Undergraduate Physics Conference, are an obvious first step, followed by attending and presenting at the annual CAP Congress or at other professional workshops and conferences. Having students meaningfully interact with visiting scientists is another way for them to begin to build their physics community. While being considerate of demands on their time, consider fostering electronic communication between national and international research collaborators and students in your research group or upper level classes.

Social media provide a valuable way for physicists to stay connected with a broader community. Sites like ResearchGate provides an avenue for professional discussion, as well as a resource of published literature. LinkedIn is a valuable tool for young physicists seeking future employment possibilities. A number of departments use a LinkedIn group for graduates and current students to connect with each other. Twitter can be a powerful means of interacting with a 'community' that is not limited geographically or in terms of expertise. While Twitter has become heavily used in some disciplines (e.g. astronomy and planetary science) it seems much less universally used thus far in most areas of physics. If you are not on Twitter, I urge you to set up an account and give it a try for a month or so. Meaghan Duffy has written a good account on why she uses Twitter [9]. Although she is not a physicist, all of her ideas transfer to physicists: keep up with literature, conferences, technical help, live-tweeting of talks or events, finding examples for teaching, learning to be concise, and connecting to science writers. I would add to that list that Twitter helps you connect with those who work in science policy. If you find

Twitter valuable personally, consider urging your students to use Twitter within the context of your class. Many of the themes explored in this article, such as seeking opportunity, speaking to diverse audiences, forming a wide community and meaningful engagement, can be well supported by Twitter.

CONCLUDING REMARKS

You should not see helping students prepare for the transition to a professional physicist as something you must do in addition to your teaching. Many of the ideas expressed here, making content relevant, applied, interdisciplinary and meaningful, and requiring collaboration and communication as part of the learning process, are core to effective learning. Indeed, the CAP Division of Physics Education revitalization document [10] draws on many of the same themes. We urge all instructors to explicitly consider career-related transition as one facet of instructional planning. Great advice for students and instructors can be found in this Canadian publication [11]. In their report "Why many undergraduate physics programs are good but few are great" [12] many of the features of great physics programs described in the article contribute to a climate encouraging transition to the life of a professional physicist.

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