Academic Futures: Interdisciplinary Graduate Education

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October 10, 2017

Innovation and invention increasingly take place at the boundaries of disciplines. Nobel laureate Richard Thaler described his groundbreaking research as filling the void between conventional economics and psychology during a recent interview with the PBS Newshour. In the same week, CU's College of Engineering and Applied Sciences announced the winners of "the college's first set of Interdisciplinary Research Themes", whose aim is to help the college and the university "Accelerate Our Research Impact". Earlier this year, the National Science Foundation identified "growing convergence research" as one of its top priorities for the coming decade. In the Foundation's words, "convergence can be characterized as the deep integration of knowledge, techniques, and expertise from multiple fields to form new and expanded frameworks for addressing scientific and societal challenges and opportunities."

A critical question facing our university and our nation is *how to prepare the next generation of scientists to excel in convergence research*? Our university is well-situated to develop exciting and effective new educational models, building on the experiences and lessons learned across our research Institutes and affiliated departments who have pioneered interdisciplinary degrees, certificates, and graduate experiences over the past decade. In this white paper, we outline six of the key attributes that an effective educational model should include. Conceptually, these attributes embody shifting from a department-centered model of graduate education to a student-centered model, where the locus of decision-making resides with a student's dissertation committee.

1.　　Flexible admissions into an area

By definition, cutting edge interdisciplinary research is not neatly encompassed by a single discipline. The current practice of requiring outstanding graduate students to be admitted by a single, disciplinary department constrains the selection of potential candidates from the outset. Ideally, candidates could be admitted into an area, broadly defined as a community of cooperating units. To provide a concrete example, consider the case of Patricia, an incoming graduate student who is interested in developing computational models of language learning in early childhood. Her research interests lie at the intersections of linguistics, psychology and computer science. Potential dissertation committee members and relevant coursework are distributed across these three departments. Patricia's choice of research area is potentially profoundly consequential: we know that there are vast individual differences in language learning in early childhood, particularly across children from different socioeconomics status, which deeply influences their readiness for learning and success in school. Yet under the

current structure, her options for both admission and the evolution of her research interests are constrained.

2.   Multidisciplinary dissertation contributions and committees

The gold standard for PhD research is to make a significant and original contributions to knowledge. Interdisciplinary research requires students to deeply integrate "knowledge, techniques, and expertise from multiple fields." In order to do so, students will need high quality mentoring from committee members across multiple departments and units. This multi-membership will need to go far beyond the current practice of having a single "outside" member. In Patricia's case, her ideal dissertation committee might include a psychologist specializing in infant development, a psychologist specializing in the cognitive neuroscience of language learning, a linguist expert in computational models of language acquisition, a computer scientist expert in cognitive modeling using machine learning, and a computer scientist expert in network modeling. Furthermore, since much of our exciting and innovative interdisciplinary research is taking place within our Institutes, we need to expand these mentoring and dissertation committee networks to include our extremely talented research faculty, many of whom want to supervise graduate students but are often prevented from doing so by departmental policies.

3.   Personalized coursework, including breadth requirements

Ideally, Patricia's committee could work with her to identify relevant and rigorous coursework spanning psychology, linguistics, and computer science that will provide Patricia with both broad and deep preparation in theory, research methods, and related ideas. While Institutes such as ICS have developed certificates, Joint PhDs, and even Triple PhDs, that promote and enable this type of deeply interdisciplinary coursework, they are all based on the model that interdisciplinary coursework is *in addition to* the required disciplinary coursework. This necessarily results in an over-crediting model, where students are required to take far more coursework than a conventional PhD. Within undergraduate education, there is general acceptance of the need to reduce over-crediting approaches as they greatly increase the cost and length of schooling, and the potential for student attrition. An effective model would recognize that the definition of breadth and depth of coursework will need to be individualized to the particular student's research goals, and that the dissertation committee is well-placed to guide these decisions. This challenges our current notions of "breadth" which are based on the assumption of developing a broad base of skills within a single discipline.

4.   Strong research methods training

To ensure that our interdisciplinary graduate students are producing outstanding research contributions, we will need to provide them with strong training in research methods tailored to their specific research goals. In Patricia's case, she will need to develop deep skills in two very different research methods: cutting edge computational modeling techniques that build on the latest advances in machine learning and network science, and the design and conduct of experiments involving human subjects (children in her case). Currently, these methods courses span different departments and Patricia may not be able to enroll in necessary courses as some are limited to majors only in an effort to keep course sizes manageable. A pedagogic challenge will be facilitating knowledge transfer. Even if Patricia is able to enroll in the network science

course, for example, she may need additional assistance understanding how to apply these algorithms and approaches to her novel research area.

5.   Explicit training in leadership, communication, management & innovation

Future graduates need explicit training to participate in, and lead, multidisciplinary teams where members differ both in disciplinary expertise and personal diversity (e.g., gender, race, ethnicity, etc.). Continued progress in both academic and industrial innovation requires new approaches to problem-solving, including incorporating diverse perspectives as part of team-based approaches that bring together experts from a variety of disciplines to solve problems that cross disciplinary boundaries. As problems become more complex, there are often a range of possible solutions, each with advantages and disadvantages. In this case, skills from several disciplines are needed, and a diverse group is more likely to generate a wider range of possible approaches and more likely to find a robust solution. The concept of T-shaped professionals describes individuals who are trained for interdisciplinary work. They balance the deep skills needed in a single, or aspects of multiple disciplines (the vertical part of the T) with the broad skills needed to succeed in working in teams and across discipline boundaries (the horizontal bar of the T). Importantly, these skills, taught to majority and minority students, focus on project goals and processes, and also provide the basis to support diversity in our student populations. This educational strategy provides skills to participants that will enable them to work effectively in diverse groups, as well as providing a basis for long-term, persistent, structural changes that will lead to a less biased work team environment over time. Such training, along with training in effective communication skills, principles of innovation and entrepreneurship, and management more broadly, will help students succeed in an evolving academic landscape and enhance their employment options beyond academia following completion of their degrees. Attention to this changing job landscape for graduate students is an essential requirement of top graduate programs.

6. Incentives and revenue to support participation, improvement, and scaling

As with any new initiative, considerable and creative thought is needed to generate appropriate revenue streams to support student recruitment, program implementation, continuous improvements, and scaling. We have already seen that in many areas, the best interdisciplinary programs often "out recruit us" because they are able to provide better support for the best students. We will also need to attend to equity: students across a broad range of intellectual areas should be able to participate, irrespective of their funding source (e.g., GRA or TA positions). Furthermore, faculty should be encouraged and rewarded for serving on interdisciplinary committees, and this service should be valued equally with serving on disciplinary committees from their home departments. Finally, revenue models for tuition return will need to be adjusted. Faculty and departments that enable students pursuing interdisciplinary degrees to enroll in their courses will need to be rewarded and appropriately compensated. Likewise, units offering interdisciplinary degrees, certificates, and courses will also need to be rewarded and compensated for providing these services, irrespective of the home department or unit of participating students.