Overcoming institutional barriers to a true interdisciplinary curriculum at CU Boulder

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We present this white paper from the perspective of educators at the front line of interdisciplinary Science, Technology, Engineering and Mathematics (STEM) education. The institutional barriers we identify draw from six years of experience implementing the BioFrontiers Institute's Interdisciplinary Quantitative Biology Graduate Program (http://iqbiology.colorado.edu), which involves educators from eleven STEM departments and two colleges at the University of Colorado Boulder. The program has been funded through the National Science Foundation's initiative to train the next generation of interdisciplinary scientists, the Integrative Graduate Education and Research Traineeship (IGERT).

Interdisciplinary study is recognized by major educational, research, and funding organizations as a means to accelerate new solutions to 21st century complex problems. For example, in October 2017, two leading international councils for science and social science, the ICSU and ISSC, respectively, voted to permanently merge their organizations to address global challenges confronting societies, citing the need to break down traditional disciplinary structures. The benefits of interdisciplinary research align perfectly with CU Boulder's mission "to shape tomorrow's leaders, be the top University for innovation, and to positively impact humanity."

Faculty and student perspectives are shifting toward interdisciplinarity (Van Noorden 2015). In the U.S., students are increasingly interested in interdisciplinary courses that require cross-field collaborations and address global-level issues, especially those that impact humanity. There is also increased participation in joint program concentrations, even when the programs require additional education, as is often the case with graduate studies (National Academies 2005).

As an R1 institution, CU Boulder has vast faculty expertise it can harness to train students in interdisciplinary research, thinking and techniques. However, most U.S. universities, including CU Boulder, face strong cultural, political, and administrative barriers to interdisciplinarity (Ledford 2015), as the current educational scheme is developed around siloed academic departments and specialties of individual faculty. In 2005, the National Academies summarized these barriers, reporting that promoting and teaching innovation that cuts across disciplines requires key elements - fostering collaborations and providing incentive structures, such as funding allocation and changes to tenure and promotion policies.

In this white paper, we focus on two interdisciplinary education curriculum reform goals. Although we understand the applicability and importance of our goals across all disciplines, we focus on STEM education reform. This includes better *(1) support for faculty who occasionally team teach by giving them full teaching credit* and *(2) support for graduate students by incorporating flexible 'breadth' course requirements into STEM graduate curriculum.*

1. *Team teaching is not half-time.* Faculty need full credit to effectively team teach interdisciplinary courses.

As a research community, we preach the benefits of faculty research collaborations. However, collaboration is much rarer in the classroom. Ironically, faculty teach foundational, interdisciplinary topics through the lens of single-discipline expertise.

One interdisciplinary learning course model is team teaching. In team teaching, faculty use skill- and problem-based student learning. Faculty address cutting-edge research techniques and questions in their own fields, as well as how their disciplinary knowledge integrates across other scientific fields (Lattuca 2001, DeZure 2010). Here, we advocate for a two-instructor collaborative model in which both faculty contribute equally and are present in the classroom the majority of the time. Faculty must jointly develop course structure, syllabi, topics, assignments, and grading expectations. This level of course integration requires extensive planning and coordination from both instructors and their physical presence during all or most classes to avoid student feelings of disjointedness in faculty teaching, expectations, and management (e.g., Davis 1995, Friend & Cook 2010, Plank 2011, Metzger 2015).

In developing team-taught courses, faculty demonstrate a model of interdisciplinary collaboration for their students. Faculty employ teamwork and successful communication across disciplines to attain levels of problem solving that would not otherwise be possible (Shibley 2006). Research shows that team teaching expands the faculty knowledge base, and it can provide support similar to what faculty experience during research collaborations, including better communication to a wider audience, novel breakthroughs, learning new and integrative topics, new perspectives and methodological tools, and a willingness to take risks and innovate. For students, team teaching has been found to improve students' abilities to grasp the language and culture of new disciplines, improve interdisciplinary teamwork and management skills, improve reconciling and synthesizing complex problems, allow for better relationship building with instructors, and achieve higher modes of critical thinking. Team teaching provides access to course topics for non-major students while remaining rigorous. Additionally, it can retain students in STEM fields through foundations courses because students grasp difficult course topics through multiple perspectives and understand the broader relevancy of those topics outside the classroom (Klein 1990, Haynes 2002, Lyall & Meagher 2012, Metzger 2015, Buick 2016, Soto & Everhart 2016).

A successful example of a CU Boulder, team-taught course is *Statistics and Computation for Genomes and Metagenomes*. The course was cross-listed across four Arts & Sciences departments and team taught by two faculty affiliated with the BioFrontiers Institute, Applied Mathematics, Molecular, Cellular and Developmental Biology, and Computer Science. Faculty co-developed the course around a current, interdisciplinary problem to “equip students with a repertoire of concepts and methods that are rarely well known by experts mastering a single [discipline].” Students could take the course with prerequisites from four different STEM backgrounds, ensuring a diverse student group. Students learned how to do interdisciplinary research and finished the course with a collaborative student term project. The course received high FCQ scores (5.4/6 overall) and was recognized by NSF’s IGERT program as an interdisciplinary educational achievement. However, it was only offered for two semesters because faculty did not receive full credit to team teach the course despite the course being a full-time workload.

STEM faculty are often discouraged from team teaching courses as they only receive half credit for a full-time, or more than full-time, commitment. Despite occasional, cumbersome workarounds, faculty risk the perception that they are not meeting departmental teaching loads if they choose to team teach. Faculty and staff spend excessive energy vying for administrative buy-in, as team teaching is most often an ‘exception’ that must be explained when teaching credits are reviewed and during tenure and promotion. Though faculty often dedicate time to projects that do not fall concretely within departmental requirements, faculty have limited capacity and are discouraged from devoting the significant amount of energy required to develop a new course when it falls outside a departmental reward structure.

CU Boulder should incentivize faculty who occasionally team teach by a) encouraging faculty teaching collaborations across departments and colleges, b) acknowledging that collaborative team teaching, as described above, is a full teaching load, and c) giving full teaching credit for two-person faculty teams, thereby integrating team teaching more universally into CU Boulder culture and policy.

2. *Breadth courses are rigorous too.* Students need full graduate credit to take flexible ‘breadth’ courses.

STEM departments vary widely in the types, numbers, and strictness of their course requirements for graduate students. Some departments have no set graduate curriculum, while others have strict course requirements rostered only in the home department. Students will always need to develop a strong knowledge depth in one discipline. However, there is often an interdisciplinary ‘tax’ on students taking unrequired breadth courses that are most relevant to their training in pursuit of becoming leaders in innovative research. As Frodeman *et al.* 2010 recommend, “To continue to have significance [academia] must both increase its ability to respond to the need for the resolution of systemic problems in economies, the environment, and medical practice while meeting the demands of mass education.” Relaxing departmental barriers to interdisciplinary graduate curriculum is a clear step in the right direction.

Interdisciplinary curriculum reform requires a re-evaluation of course levels appropriate for graduate student education. Breadth coursework should be determined based on student research needs and include courses across departments, colleges and 'disciplinary difficulty' levels. If students need to acquire the literacy of a STEM field or technique outside their home department, a course offered by a different college or an advanced undergraduate course may have the appropriate interdisciplinary difficulty level for a graduate student. For instance, students in the BioFrontiers Institute's Interdisciplinary Quantitative Biology Graduate Program enter the program with exceptional academic credentials in either a computational or biological field. Biologically focused students may require advanced undergraduate-level quantitative courses, such as a computer science course that exposes them to data structures, necessary for their interdisciplinary dissertation research and collaborations. In this case, an advanced computer science undergraduate course is appropriate for graduate-level study. Similarly, an advanced undergraduate-level biology course is appropriate graduate-level study for a computationally focused graduate student. These breadth courses fill a student knowledge gap required to succeed in interdisciplinary research.

STEM graduate students are often penalized for taking courses that advance their interdisciplinary research skills because of strict disciplinary requirements. Undergraduate courses cannot count toward students' dissertation or graduate credits. Additionally, interdisciplinary coursework is often in addition to disciplinary coursework, putting additional time, mental, and tuition burdens on students with interdisciplinary research goals. CU Boulder has the opportunity to incentivize departments to accept and train students from other departments, providing departments with the resources to allow for scenarios like higher student enrollment in popular courses.

CU Boulder should support students' interdisciplinary research needs by a) authorizing a subset or "track" of flexible, rigorous courses that are required graduate curriculum to avoid interdisciplinary students having additional course loads, and b) allowing courses outside a student's home department or college, as well as advanced undergraduate courses, to count toward graduate credits when such courses are appropriate for interdisciplinary core knowledge and dissertation research.

Interdisciplinary education faces enormous institutional barriers, and many CU Boulder departments, institutes, and centers have developed programs, certificates, and joint graduate studies that are investing two or more times the effort per student to achieve student access to a meaningful interdisciplinary education. If CU Boulder can tackle high-impact barriers, like team teaching and graduate coursework policies, it will be on a path toward an education system that is more applicable to student learning, research goals, and the complex problems students tackle in the next stages of their career.

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