The Need for Interdisciplinary Research and Education for Sustainable Human Development to Deal with Global Challenges

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Abstract

Major issues in society - developing alternate sources of energy and a sustainable environment, improving health, and minimizing the effects of climate change require a collective effort by different disciplines working in interdisciplinary groups. Indeed, the boundaries between the different disciplines are becoming increasingly blurred. Society's responses to major social challenges must be informed by an improved understanding of human perceptions, responses, and of the economic and social impacts of the physical, and biological processes to promote social wellbeing. A comprehensive understanding of the main social challenges requires the collaboration of physical scientists, social scientists, humanities scholars and engineers, and will be highly interdisciplinary. For example climate systems are highly variable, changing in hours, days or years. The need to create a new generation of students who combine a rigorous disciplinary depth with the ability to reach out to other disciplines and work in interdisciplinary teams is more urgent. Because these skills cut across traditional disciplinary boundaries, there is increasing support from government and business for the interdisciplinary programs that focus on identifiable long-term problems in the economy, society, and government, as opposed to department-based programs that focus on academically defined disciplinary paradigms. Interdisciplinary research preparation and education are central to future competitiveness, because knowledge creation and innovation frequently occur at the interface of disciplines. Interdisciplinary programs help to ensure better educational programs, which give students better ability to work in a problem-oriented way and at the same time the ability to think across fields and interact. It responds to the need to prepare students for an increasingly interdisciplinary, collaborative, and global job market. Interdisciplinary programs provide opportunities to strengthen the interaction between the business sector and research, especially in relation to the humanities and social science research and education, where interaction has been especially underdeveloped. There is a consensus that the current academic administrative structure is the most important barrier to interdisciplinary collaboration; other barriers like poor communication, etc., emanate from it. How can interdisciplinary education and research flourish while maintaining strong backgrounds in the disciplines? How can universities lower or remove barriers to faculty participation in interdisciplinary education and research and create porous, flexible, less redundant environment that facilitates the flow of ideas, people and resources across disciplinary boundaries? Is possible to have disciplines without disciplinary departments? In this short paper, the barriers and the challenges for developing interdisciplinary education and research will be summarized, lessons from some successful attempts and failures will be presented, and some approaches will be recommended for newly established institutions of higher education if the developing world such as Africa further discussion.

Introduction

The National Academy of Sciences defines interdisciplinary research (IDR) as "one of the most productive and inspiring of human pursuits—one that provides a format for conversations and connections that lead to new knowledge" (National Academies, 2005). It links and integrates theoretical frameworks from two or more disciplines and employs methods and skills from them (Aboelela, 2007). Interdisciplinary thinking and the creation of interdisciplinary programs, research groups, centers and institutes are rapidly becoming integral features of academia as the issues and challenges facing society become more global and complex. Such global and complex problems require the collaboration of multiple disciplines. The educational backgrounds needed by those who will meet these challenges cannot be provided by a single discipline. Our future researchers will require skills, information, and/or methodologies

traditionally compartmentalized in disciplinary programs. It is not possible to study the Earth's climate, for example, without considering the oceans, rivers, sea ice, atmospheric constituents, solar radiation, transport processes, land use, land-cover, remote sensing, etc. Furthermore, severe climate anomalies and disasters are processes in which the physical, biological and socio-cultural systems interact at their limits. The destructive impacts of natural hazards lead to material losses, deaths and physical and psychological stresses for the affected communities. Such events offer an insight into people's perceptions of and relationship to environmental forces (Pfister, 2007). It is therefore evident that the study of climate change requires the collaboration of scientists, engineers, social scientists, humanities scholars, health sciences practitioners, agricultural scientists and policy makers to have a comprehensive understanding its implications, impacts and mitigation.

Other major issues which face society—sustainable energy, a sustainable environment, improved health, food security, sustainable development, and an understanding of complex socio-environmental problems (Morse *et al.,* 2007) require a collective effort by different disciplines working in interdisciplinary groups. Policy makers and the public are increasingly demanding that scientists inform them of the socio-economic impacts of their research. Making decisions for changes in policy requires the integration of scientific information and data on the social impacts (Heberlein, 1988). A comprehensive understanding of these issues cannot be achieved solely through a disciplinary approach.

The need to prepare students for an increasingly interdisciplinary, collaborative, and global job market also calls for providing opportunities for interdisciplinary training of students. There is growing evidence that retention of students in STEM areas can be facilitated by enhanced interdisciplinary education and research (National Academy of Sciences, 2005). Students show increasing enthusiasm about problems of global importance that have practical consequences - all of which can best be addressed through IDR (Golding, 2009). Students, especially undergraduates are strongly attracted to interdisciplinary research and courses, especially those of societal relevance (National Academy of Sciences, 2005). Students need to learn to communicate effectively across disciplines, cultures and industries to be effective contributors to the economic development of a nation (Eagan, 2002).

There is also growing interest in interdisciplinary research among faculty in academe because the lines between "traditional" fields are increasingly blurred. The intellectual boundaries of today's research may not map onto disciplinary frameworks developed and organized over centuries. Therefore federal funding agencies such as the National Institutes of Health (NIH) and the National Science Foundation (NSF) have furthered this blurring by offering support for research that is explicitly "cross-cutting" or "bridging" between and among disciplines. For example, the National Science Foundation recently stated "NSF has long recognized the value of interdisciplinary research in pushing fields forward and accelerating scientific discovery. Important research ideas often transcend the scope of a single discipline or program. NSF also understands that the integration of research and education through interdisciplinary training prepares a workforce that undertakes scientific challenges in innovative ways. Thus, NSF gives high priority to promoting interdisciplinary research and supports it through a number of specific solicitations." Unfortunately, even the funding agencies are structured along disciplinary lines and reviews are conducted by disciplinary experts, who may not necessarily have the experience or the appreciation of interdisciplinary efforts. NIH has identified interdisciplinarity as an essential strategy to discover needed knowledge and made it an explicit priority in its recent roadmap.

There is a consensus among educators, university leaders, business leaders, and policy makers, federal agencies, and scientific associations on the need to advance interdisciplinary educational programs and research opportunities for students. Such an education prepares them to be competitive in the global market and provides them with a wider array of employment opportunities. However, the fact that *interdisciplinary research can happen only when it is done*

*by **disciplinary experts**, who remain leaders in their field* is often overlooked. *Any advantages which interdisciplinarity holds depend on the presence of experts with strong backgrounds in their disciplines.* On the other hand, while a strong background in a discipline depth is essential for investigating these complex issues, they also require a 'synthesizing mind' (Gardner, 2006, p.3). They require investigators who can engage in interdisciplinary translation and synthesis, as part of multidisciplinary teams or individually, in order to develop more complete pictures than would be possible from any one disciplinary perspective (Golding, 2009). One needs to learn how to access, understand, employ, and synthesize the expertise from various disciplines.

The implication is that we must educate for both disciplinary and interdisciplinary expertise. Building interdisciplinary programs is not doing away with disciplines. Interdisciplinary education must supplement disciplinary teaching and learning so students can learn how to respond to challenges that transcend their specific disciplines, work at the interface of confluence of multiple disciplines, and develop research trajectories that do not conform to standard disciplinary paths (Golding, 2009) and learn how to purposefully and reflectively integrate and synthesize the different perspectives from pertinent disciplines in order to advance understanding and solve problems.

Good interdisciplinary research structures not only open up new areas of research, but also provide flexibility and expansion possibilities for traditional disciplines. Research educational systems, which are weak in addressing such interdisciplinary needs, may miss research opportunities, fall behind in research areas, and lose many of their most innovative researchers. Interdisciplinary programs embody the essence of best practices that enhance student learning and prepare students for the complexity of real world issues. However they are highly vulnerable to disciplinary-dominated academic structures (Henry, 2005). In the competition for scarce resources, interdisciplinary programs are often marginalized by some mainstream disciplines, and are often assimilated by them.

How can interdisciplinary education and research flourish while maintaining strong disciplinary depth? Is it even necessary to have a disciplinary depth to conduct interdisciplinary research? How can universities lower or remove barriers to faculty participation in interdisciplinary education and research and create a porous, flexible, less redundant environment that facilitates the flow of ideas, people and resources across disciplinary boundaries? In this short paper, the barriers and the challenges for developing interdisciplinary education and research will be summarized and lessons from some successful attempts and failures will be presented along with some approaches recommended for further discussion.

Barriers to Interdisciplinary Research and Education

A number of authors have identified a variety of factors which can contribute to failure of IDR (Sidolk and Hibbert, 2009; Golde and Gallagher, 1999; National Academies, 2005; Rhoten, 2003; 2004; Feller, 2002, Institute of Medicine, 2002). We do not yet fully understand all the factors that facilitate IDR or all barriers to interdisciplinary scientific research collaboration. Some of the main barriers will be summarized here.

University Structure. Clark (1995) identified over 8,530 disciplines and fields of knowledge, and many more are being created as more and more specialization develops. Most funds flow into and are allocated to the disciplinary units. Faculty are hired into this the unit, and buildings or floors of buildings often physically delineate the departmental division of knowledge.

The current academic structure has led to a lack of historical interdepartmental or cross-disciplinary cooperation, and to turfism and over-sized egos (Golde and Gallagher, 1999). Disciplines have been dividing knowledge into components which served as the basis for organizing academic institutions and put professionals into autonomous fiefdoms (Gass, 1979). This has led to turf wars among colleges and departments over allocations of resources and course credits, and over development of new courses. Often loyalty to the department or college leads to irrational and anti-interdisciplinary decisions.

The academic reward structure is based upon the judgment of disciplinary peers. Professional recognition is derived by maintaining allegiances to departments. Faculty pursuing interdisciplinary research may find it hard to publish and have publications recognized by disciplinary peers (Feller, 2006; Mansilla, *et al*., 2006). Policies for awarding credit and resources often do not reward individuals or units for establishing crosscutting collaborations. Evaluation, promotion and tenure processes often do not properly evaluate collaborative and interdisciplinary work. The cultures and climate of departments and campuses are often indifferent or even hostile to such activities (Sa, 2008).

The current structure and lack of collaboration between the various academic silos has the following consequences:

1. Students are unable to transfer what they are learning from course to course, or discipline to discipline. (For example students studying a calculus course in a math department cannot effectively use the same concepts in their physics classes, etc.).
2. Faculty lack experience in developing and assessing course offerings that cut across disciplinary boundaries within the traditional STEM communities or those offerings which explore the ethical or socio-economical dimensions of STEM fields.
3. A lack of shared *mental models*, *common language* and *assumptions and even the desire to collaborate* may prove problematic, particularly when participants in a collaborative team have a particularly strong affiliation to their own groups (Jacobs, 2010).

Interdisciplinary research lacks the support structure that makes disciplinary research possible, particularly when such research integrates social sciences, humanities and the STEM areas (Heberlein, 1988). University administrators and STEM professionals often make formal pronouncements about and pay lip service to the need for social science involvement in STEM research. Funding agencies are also emphasizing the need. However these pronouncements are not backed by tangible efforts. (1) Funding decisions and allocations to researchers in the social sciences and humanities are still not adequate. (2) Social sciences and STEM programs are rarely housed in the same building. The physical and institutional organization of universities serves to keep the social sciences and STEM apart. (3) There is lack of knowledge of what the other group is doing. There is little if any exposure to how other disciplines operate. We don't attend each other's seminars or conferences or we don't organize common conferences or seminars.

Disciplinary Jargon- A Communication Barrier. There is a significant body of literature devoted to discussing communication as a barrier to IDR (e.g., Wear, 1999). Articles in different disciplinary journals or textbooks use different notations, or create their own particular vocabularies (jargon) to describe terms which are often not transferable. One often needs to relearn the notations and the jargons in other disciplines to be able to communicate and work effectively on an interdisciplinary research. It is hard to comprehend disciplinary jargon used, for example, in seminars and published articles (Jeffrey, 2003; Massey et al., 2006). Many researchers understand the rigidity of disciplinary structures, but they persist in staying well within them, and are reluctant to move to an interdisciplinary mode of working. Combining the study methods of different disciplines remains a challenge when if there is a willingness to work on interdisciplinary research. Each discipline has its own patterns, meanings, symbols and behaviors, and the thoughts and behaviors of discipline members are influenced by the "knowledge traditions" in which they reside that include categories of thought, common vocabularies and a code of conduct (Frost and Jean, 2003).

Another complaint by discipline-specific researchers is that, in learning another field of knowledge, the time devoted to their own discipline will be compromised. Often there is a feeling that disciplines are watered down to train interdisciplinary scientists and graduates are often considered somehow less competent than focused specialists (Naiman, 1999). Interdisciplinarity has been criticized as 'difficult to do well' and 'by nature superficial' (e.g., by Kincheloe, 2001).

For IDR to succeed, both dialogue and common ground must be established and maintained between those who have historically sought to distance themselves from disciplines

beyond their own. However, there can often be a failure to recognize or value contributions from "outside" (Bruce et al., 2004).

Pride in One's Discipline. Nearly all university faculty members are trained in disciplinary programs with specific majors and departmental affiliations; their values and methods are instilled during graduate school. As a consequence, other disciplines might be viewed as less rigorous or important. Disciplinary areas have their own pecking order, and social sciences are seen as easier and less quantitative. Each one considers his/her discipline as the most rigorous and most important. There is even a pecking order within a given discipline. As a result, STEM professionals see themselves as well qualified to do social science research, and social scientists seldom jump the disciplinary boundaries into the STEM areas. Often scientists and engineers denigrate the social sciences and there is a real barrier to equal partnership in the research enterprise between social scientists and STEM professionals (Sperber, 2003).

Personal Barriers. Personality traits which appear to matter in interdisciplinary work include willingness to accept alternative methodologies, the ability to learn rapidly, good leadership skills and an interest in real world issues that have long term impacts (Jacobs, 2010).

Amabilie *et al.* (2001) defined three characteristics which may impact the success of IDR. These are (1) collaborative skills, (2) project relevant skills, and (3) attitude and motivation. Additional important elements for collaboration include trust (absence of hidden agenda); mutual respect of other members; appreciation, understanding, and respect for other disciplines; and the ability and the willingness to develop a common language.

Teamwork also requires trust in another's skills and expertise and appreciation of the other discipline. Methods and criteria for evaluation are different for different disciplines. It may be difficult for interdisciplinary team members to evaluate each other's performance (Anbar, 1986). Reward systems and practices regarding authorship on refereed publications differ among disciplines and even in different branches within a given discipline (King *et al.,* 1997; Moore, 1989).

In building an interdisciplinary team, there must be clarity regarding roles, expectations, and authority. Clearly articulated protocols in data and resource sharing and leadership in projects is important for success (Bruhn, 1995; Grant *et al.,* 1998). Policies should be mutually developed and agreed on and be acceptable to a majority of the members to enhance the team members' personal and professional goals (McGuire, 1999). Success in interdisciplinary efforts requires expertise in one's discipline, good interpersonal skills, a strong leader, commitment, flexibility and willingness to work.

Lessons from Organizational Strategies to Foster Interdisciplinary Research

Interdisciplinary research and education is promoted by a number of universities through the establishment of interdepartmental or interdisciplinary degree programs (IDPs) or organized research units (centers and institutes). Several different processes to create and fund organized research units (ORUs) have appeared. Some are created as strategic administrative decisions and are provided seed funding (e.g., Ohio State, NCSU, Rutgers, UC Berkeley, UCONN, UVA, Vanderbilt, Virginia Tech., etc., to mention a few). Others are faculty initiated efforts which gain administrative support and some are created as a result of large external funding to groups organized as interdisciplinary groups (NSF-STC's IRCs, NSF-CREST Centers, NSF-IGERT, NOAA CSCs, NOAA CIs and other programs funded through NIH, DOE, DoD, NASA, USDA, EPA, Homeland Security, etc.). In almost all cases these ORUs or IDPs co-exist with disciplinary departments that retain exclusive control over academic life through hiring and tenure decisions, course approval and development, degree requirements, merit evaluation, etc., in general, keeping the barriers that have been identified as hindering interdisciplinary efforts. The National Academies' report contends that few universities have implemented systematic reforms to lower institutional barriers (National Academies, 2005). A study that examined the interdisciplinary centers of major universities reported that "Universities are failing to walk the walk"- or even to comprehend fully what doing so would entail." Most interdisciplinary efforts are merely

reconfigurations of old studies or traditional modes of work patched together under a new label (Rhoten, 2004). Despite the rhetoric and apparent enthusiasm for crossing disciplines, interdisciplinary programs (IDPs and ORUs) remain relatively difficult to initiate, fund and sustain. The lessons and examples cited are by no means an exhaustive list. It is intended to provide some representative examples.

NCA&T developed three interdisciplinary graduate degree programs based on interdepartmental collaborations; these graduate programs were placed under the graduate dean. The programs only have program directors and administrative support and courses and student supervision is done by faculty from all over the university. The programs were provided new faculty positions, to be hired as joint appointments, by disciplinary units where tenure decisions are made with little or no input from the interdisciplinary program. The interdisciplinary program that initiated the hiring has no say in the decision. There has always been a conflict on course load assignments as departments didn't value the participation of their faculty and others in the interdisciplinary effort. Another problem with joint appointments is that the department expects the interdisciplinary hires to carry a full load of department activities. Within a few years the interdisciplinary degree programs were engulfed by colleges and were turned into academic departments with an interdisciplinary label and no faculty to teach their core courses despite their increased enrollment and demand.

The NOAA Interdisciplinary Scientific Environmental Technology Cooperative Science Center (ISETCSC) at North Carolina A&T was a multi-institution center that brought together thirty one scientists and engineers in eleven academic departments to conduct research on development of technologies that support the prediction and understanding of climate and environmental change.

The center has led establishment of new degree programs that include a Bachelor of Science program in atmospheric sciences and meteorology and a PhD concentration in atmospheric sciences within the Department of Energy and Environmental Systems (EES) which was developed as an interdisciplinary graduate program. The center developed relevant interdisciplinary MS thesis projects and undergraduate senior projects for students supported by the grant in several STEM departments (physics, mathematics, chemistry, computer science, electrical engineering and chemical engineering). It also provided opportunities to develop interdisciplinary interactions and collaborations among faculty and students in all participating departments, including joint advising of graduate students and common seminars.

However centers like ISETCSC were created because of external funding and not because it was part of the institution's strategic plan; hence, sustaining the educational and research programs when external funding ceases is a major challenge. The participating departments are no longer motivated to work collaboratively. Faculty hired to support the degree programs created as a result of the funded center have joint appointments in the two programs that house the atmospheric sciences programs. The tension that resulted from narrow departmental interests and a lack of decisive action by university administrators has hindered the success and growth of these programs.

Conclusions

Interdisciplinary research must become a vested interest of all universities. At times, senior administrators may use the term, interdisciplinarity, without the benefit of a deep understanding of what interdisciplinary studies are all about. Meaningful interdisciplinary outputs will not emerge spontaneously from physical or intellectual proximity (Jeffrey, 2003). Organizational arrangements can also either support or obstruct IDR; therefore, changes may need to be made at the *institutional* level to intentionally remove the barriers, and the inertia in order facilitate IDR.

The 2008 IGERT program directors' workshop made several recommendations to develop transformative interdisciplinary research and graduate education including (1) the establishment of new organizational models around open-ended scientific discovery and

addressing social challenges, (2) the development of measures of success and milestones, (3) the development of more dynamic and flexible structures with some fluidity of movement and the elimination of hierarchical structures, (4) the basing of interdisciplinary graduate education in disciplinary programs, and (5) the extension interdisciplinary research and education into undergraduate education.

The most prevalent budgeting model of universities is a decentralized model in which the lion's share of resources flows to schools, departments, and other units. ***Deans, department chairs and other administrators are rewarded for strengthening their own departments, but not for building links to others.*** This reward structure only increases the turf war to the point that often college deans and department chairs brag about how they have successfully negotiated to increase their budget and holdings, and forget they are working for the university and expect people within their units to have loyalty first to their units.

Academic departments create an environment within which training and research occur. Discipline-oriented departments constitute a functional authority structure in charge of teaching, faculty recruitment, advancement, and promotion—as well as degree programs and courses. Funding processes reinforce the departmental structure. Departmental organization changes relatively slowly and there a tremendous inertia to change. Incentives may help bring some change, but not enough to meet the urgent need of interdisciplinary research and training needed to address pressing social, political, economic challenges society faces. The priority given to contributions in fields that correspond to departmental structures can inhibit interdisciplinary approaches. Institutional policies regarding allocation of laboratory space, hiring, and promotion policies vary considerably, but the department chair generally has a major influence. Often, the same barriers that hold back IDR hold back the natural evolution of the disciplines themselves.

Even though a number of authors have recognized universities' administrative structure as a major barrier for interdisciplinary research and education, the solutions offered and recommended do not go far enough to address the issue. The recommended changes fall short of enhancing full-fledged interdisciplinarity. The recommendations made so far only try to modify and tweak the current academic structure but not in a fundamental way. They try to improve communication and the structures for providing rewards, funding, incentives and course offerings. However, this leaves the very problem (structure) intact. Creation of interdisciplinary centers, institutes and degree programs which co-exist with the existing disciplinary structure does not change who still controls the funding, and the processes for tenure and promotion.

This is not advocating for anarchy in higher education. There is still a need to develop a new form of structure which is significantly different from what we have now. This new structure will simultaneously allow disciplines to flourish and grow with unprecedented innovation brought about by open communication and collaboration with other disciplines. This new structure will remove redundancy and duplication and allow and help students move and transfer skills and knowledge learned in one discipline to other disciplines, and also allow them greater flexibility and promote interaction for innovative new interdisciplinary products.

It may not be easy and may seem impractical to do away with academic departments and colleges created and in existence for centuries. But there is an opportunity for new and emerging universities, especially those in developing countries to be innovative and radical in the way they establish their institutions. For example in the last 10 years over 20 new universities have been established in Ethiopia. All of them have just copied the traditional structures and created academic departments and colleges. They also aspire to develop interdisciplinary programs while strengthening departments. But such young and emerging institutions have a real opportunity to be innovative and create a transformative structure that would change higher education in a fundamental way. This opportunity is being missed by all of them since they are duplicating a failed system.

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