The Formation of Interdisciplinary Scientists:
You'll know it when you see it

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Interdisciplinary Education

In recent years, interdisciplinarity has become synonymous with all things modern and creative, progressive and imperative about higher education (see, for example, DeTombe, 1999; Gibbons et al, 1994; Kahn & Prager, 1994; Nissani, 1997; Rhoten, 2004).

Voices from different corners advocate the importance of interdisciplinarity, arguing that many of today's pressing questions in areas such as the environment, health, technology, global security, and urban culture require the cross-fertilization of disciplinary skills, theories, methods, and ideas (see, for example, AACU, 1999; Colwell, 2003; NRC, 2000; Rustum, 2000). Recent reports from government and industry corroborate the call, emphasizing the need for Ph.D.'s, M.A.'s, and B.A.'s who can integrate and elaborate knowledge from varied fields, communicate and collaborate with diverse stakeholders, and operate in and navigate between cross-functional and cross-sectoral teams (see, for example, NRC, 1995; Business-Higher Education Forum, 1999; The New York Times Job Market, 2002).

In response, colleges and universities have implemented myriad new initiatives designed to train and educate students for interdisciplinary worlds of scholarly research, professional work, and civic responsibility. At the graduate level, there has been a diffusion of efforts such as the well-known Integrative Graduate Education and Research Training (IGERT) program. And, at the undergraduate level, as documented in *Greater Expectations: A New Vision for Learning as a Nation Goes to College* (2002), practices like first-year seminars, learning communities, capstone experiences, student portfolios, and, of course, interdisciplinary studies have become common campus features.

Despite the enthusiastic calls and sizeable investments to promote interdisciplinary education and training, there has been very little generalizable analysis about and/or empirical assessment of such initiatives. While many individual programs are reviewing their work as they go, they tend to rely on conventional methods and accepted (albeit slightly modified) measures used by their departmental siblings to evaluate program performance and individual progress. This default strategy suffers from proxy criteria that not only "sidestep the question of what constitutes interdisciplinary knowledge" (Boix-Mansilla and Gardner, 2003) but also

misrepresent interdisciplinarity as a subject matter or body of content rather than a process, set of skills, and worldview (Klein, 1990; Rhoten, 2004).

If it is true that new interdisciplinary education programs are imperative, then, transitively, it is equally essential that new means and metrics of interdisciplinary assessment be developed not only to design these programs but also to discern their success in the spirit of their founding goals and objectives.

Assessing Student Learning Outcomes of Interdisciplinary Education

Thinking about the assessment of interdisciplinary education requires grappling with the following:

> *What to assess?* Identifying, defining, and specifying what one is looking for when discussing "interdisciplinarity" and what makes interdisciplinary education distinct from disciplinary, general, or liberal arts education.
>
> *How to assess?* Selecting, modifying, or altogether creating valid and reliable indicators and instruments to capture and measure both processes and outcomes associated with interdisciplinary education.

What to assess?

There is no single, widely accepted definition of interdisciplinarity, no accepted theory of interdisciplinarity, and no single model of an interdisciplinarity. So, what qualifies an educational program as "interdisciplinary" or its graduates as "interdisciplinarians"? What constitutes interdisciplinary teaching, and what demonstrates interdisciplinary learning?

In addition to advancing critical thinking, problem solving, and analytic skills common to most higher education programs, interdisciplinary programs also report seeking to develop, for example, students' (meta-)cognitive aptitudes, epistemological beliefs, group communication skills, and civic commitments. More significantly, however, as Klein reminds us: "Interdisciplinarity is neither a subject matter nor a body of content. It is a process for achieving an interpretive synthesis, a process that usually begins with a problem, question, topic, or issue" (1990: 188). Thus, in her view and mine, the unique aspect of true interdisciplinarity and the signature trait of any verifiable interdisciplinarian is the ability to integrate and/or synthesize disciplinary knowledge and modes of thinking.

Synthesis and integration are terms used to represent a family of activities that range from assembling diverse data relevant to a research question (for example, Lepers et al., 2005) to a near-Hegelian creation fashioned of apparently inconsistent constituent parts (for examples, see James Clerk Maxwell's theory of electromagnetism and physicists' pursuit of the elusive Grand Unified Theory; in ecology, see Bradshaw and Bekoff, 2000), with a panoply of intermediates and variants in between. Underlying this diversity of definitions, however, is a shared kernel of meaning: in any of its various forms, synthesis and integration means that two or more disparate elements are combined to produce a meaning, explanation, or product that is more extensive and powerful than its constituent parts.

Assessing the ability of students to synthesize and integrate knowledge offers unique challenges to interdisciplinary programs, especially given the rather broad nature of the construct around which there is this consensus of meaning.

How to assess?

If we accept synthesis and integration as the distinctive hallmarks of interdisciplinarity, how do we then proceed to capture and measure these as student learning outcomes? How does one recognize, evaluate, and encourage these outcomes? Are there leading indicators of synthesis that would allow early identification and promotion of such learning, thinking, and understanding?

Possible approaches to assessing integration and synthesis might be developed by adopting and/or adapting an array of existing assessment strategies, ranging from those focused on indirect student measures (surveys, focus groups, interviews) to others concerned with direct student measures (standardized instruments, locally developed tests). However, many of these conventional assessment approaches tend to focus on single measures or reductionist strategies and to evaluate specific skills and abilities. As a consequence, they may not be well-suited to measure the complexity, ambiguity, and multiplicity of skills and aptitudes involved in the creation of new meanings, explanations, or products via interdisciplinary synthesis and integration.

Performance-based assessment approaches may offer some new avenues for the assessment of interdisciplinary programs. Examples of this type of assessment include the use of open-ended problems, essays, demonstration problems or projects, computer simulations of real world problems, juried presentations, and portfolios of student work. Collectively such measures are frequently referred to as "authentic" assessments (see, for example, Archibald & Newman, 1988; Wiggins, 1989) because they involve the performance of tasks that are valued in their own right. In contrast, paper-and-pencil, multiple-choice tests derive their value primarily as indicators or correlates of other valued performances.

Assessing Student Learning Outcomes of Interdisciplinary Education – An Example Strategy

As our study of the Integrative Graduate Education and Research Training (IGERT) program has developed, it has become clearer that the linear logic of conventional assessment techniques works well, up to a point, in assessing interdisciplinary learning outcomes. Following a conventional model of assessment can yield interesting and important information that satisfies the demands of internal and external audiences regarding rates of program participation and satisfaction, promotion and graduation, publication and employment. They can also offer insight into student acquisition and command of different realms of content knowledge, theories, methods, and techniques—most of which is disciplinary-based. While these data allow for the legitimation of interdisciplinary programs by making them comparable to disciplinary departments, these assessments only work to a point in that they do not capture and communicate what is different and unique about interdisciplinarity versus disciplinarity.

In an effort to close that gap, our study will experiment with a new interdisciplinary assessment exercise adapted from the 19th century concept of the "charrette." Although it is still very early in the design of this exercise, its preliminary the elements have been sketched below in order to invite discussion about the validity and reliability, desirability and feasibility of this and/or other experimental forms of interdisciplinary education assessment.

The word "charrette" translates literally from French to English as cart. However, in the 19th century, members of the school of architecture at the École des Beaux-Arts in Paris coined the term to mean "an intense final effort made by architectural students to complete their solutions to a given architectural problem in an allotted time …" (Grove, 1981). The genesis of this rests in

the tradition of faculty assigning design problems so difficult that only a few students could solve them in the allotted time before the “charrette” rolled past the drafting tables to collect the students' work, completed or not.

If we interpret the meaning of “charrette” loosely we can take the term to mean a short intensive study culminating in a presentation of results. If we then apply it to interdisciplinary education and contemplate techniques perhaps best described as "group brainstorming," charrettes can promote discussions that move beyond conventional thinking by building on ideas from many different participants, with the most successful inherently depending upon the ability of its participants to synthesize and integrate these ideas into a final product.

For our purposes, we will conduct a charrette with an experimental design that seeks to evaluate whether students trained in Integrative Graduate Education and Research Training programs (IGERTs) interact with their colleagues and respective knowledge-bases in a manner that transcends disciplinary boundaries and produces integrative and synthetic products that distinguish them from their colleagues trained in more traditional disciplinary departments. In this case, the product on which the charrette exercise will focus is the design and development of student research proposals, formulated in response to a specific interdisciplinary problem in the environmental science domain posed by a group of selected panel members with expertise in the relevant fields as well as interdisciplinary science.

The experimental design aspect of the charrette will entail a comparison of the collaborative processes and outcomes of 6-8 groups composed of junior versus senior students enrolled in integrative graduate programs (IGERTs) *and* junior versus senior students enrolled in traditional graduate programs in cognate departments (all within the environmental science domain). Students will be brought to the same space on the same dates where they will be given their group assignments and common problem statement simultaneously. Each group will have 48 hours to design and develop a Powerpoint version of a research proposal that they think would best address the problem posed.

Over the course of the 48 hours, each group will be assessed in terms of their group processes (e.g., team building, information sharing, knowledge making, etc). Then, at the end of 48 hours, each group will present their research proposal to the panel of experts (the same individuals who originally selected the focal problem). At this point, each group will be evaluated in terms of the group product (e.g., depth and breadth of different knowledge bases, inclusion versus interaction versus integration of different knowledge bases, the creation and composition of the proposal – indicators under development).

This is an example of extreme interdisciplinary assessment and one perhaps not widely replicable in its full form. However, assessment is as useful for formulating and enhancing our understanding of learning outcomes as it is for determining outcomes. Thus, if not replicable in the present as an option, this exercise will at a minimum be demonstrable of future opportunities.

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