Cross-Disciplinary Science: Fostering, Recruiting, and Reviewing Multidisciplinary Work

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Scientists in the 21st century cannot exist in ivory-tower isolation; they must be able to collaborate with researchers in a wide variety of fields. Current and projected market trends demand that investigators be conversant in more than one field, and funding agencies increasingly focus on research projects with broader appeal. As the physical sciences infiltrate the biologic sciences and vice versa, the trend toward cross-disciplinary science will increase, involving more investigators in diverse fields.

Agencies and institutions face an array of issues in supporting this nontraditional science. A productive multidisciplinary research endeavor requires integrative scientific and intellectual challenges, leadership and vision, creative investigators, an enabling environment, resources, an appropriate reward structure, and engaged students. Undergraduate students start out as the ultimate multidisciplinarians, only to narrow their focus as they progress in their education. Institutions like Stanford University and the Massachusetts Institute of Technology enable cross-disciplinary science via structures intended to promote interdisciplinary actions across departments. Agencies try to accomplish a similar goal by offering multidisciplinary thematic areas and structures.

Multidisciplinary research is changing how academic institutions define themselves. Virtual departments, interdisciplinary clusters, and so-called chocolate-inspired think tanks (informal gatherings of scientists who initially believed that a sweet tooth was all they had in common) are bringing researchers together and expanding the traditional boundaries of science. Even the Council of Science Editors, in changing its name from the Council of Biology Editors, is broadening its horizons. However, both money and scientific insight are needed for cross-disciplinary science to thrive.

Multidisciplinary researchers are looking for journals to publish their work. Editors can attract multidisciplinary manuscripts by expressing interest in related fields, commissioning review articles, inviting or writing other secondary materials, and hosting conferences. Cultivating personal relationships is also important for attracting the best papers, but journals must not lower their standards simply to publish cross-disciplinary work. Editors should understand and appreciate the many cultural differences between physical and biologic scientists, including the desire for simplification versus details, the role of theory, competitiveness and independence, software preferences, and perceptions of preprints, preprint servers, and letters to the editor.

How are the standards of different disciplines melded in a multidisciplinary research project? The earlier linear combination of several fields' standards is now giving way to a more integrated approach. Multidisciplinary research projects are reviewed by experts in the appropriate fields, but such peer review can be tricky. Panel review, which enables dynamic exchanges among reviewers, has been shown to be extremely helpful. Should we apply the standards of all the constituent fields or "lower the bar"? The National Science Foundation requires reviewers to evaluate both intellectual merit (knowledge and understanding in and across fields, qualifications of investigators, creativity and originality, conception and organization, and access to resources) and broader factors (integration of research and education, broadened participation, enhanced infrastructure, dissemination of results, and benefit to society). Reviewers may be able to critically analyze only portions of manuscripts; therefore, additional reviewers may be needed, and peer review might require more time. Editors must anticipate and address reviewers' potential concerns and, once the reviews are received, pool the disparate comments into a cohesive whole to determine whether the study contributes substantially to more than one field.

The success of an interdisciplinary project is determined by the quantity and breadth of students and new knowledge generated in the short term (output). In the longer term (outcome), success is best indicated by longitudinal examination of both the students produced and the impact of the new knowledge generated to assess the benefit over time. A primary challenge is to address the paradox of encouraging multidisciplinarity while maintaining strength in the constituent disciplines. Cross-disciplinary science offers new and exciting ways of collaborating, not only for scientists, but also for institutions, funding agencies, and journals.