Interdisciplinary Education: A Continuing Experiment

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Educational institutions are continually called upon to educate students who will participate in seeking solutions to major problems recognized by society. These calls raise a host of familiar dilemmas such as the proper mix of disciplinary and interdisciplinary effort, the relative emphasis on depth and breadth, the appropriate level for interdisciplinary efforts, and the appropriate roles of different kinds of institutions. This article describes 9 years of continuing experience in a broad-based interdisciplinary program at the graduate level, dealing with the environment, which included a faculty of about 15 and an average resident graduate enrollment of 50 students. Many academic colleagues, including faculty and administrators, have asked common questions about many facets of the program. While this experience does not provide definitive answers to many perplexing problems, a brief report from our experience, outlining some conclusions on a number of generic questions about interdisciplinary problem-oriented programs, may be useful to others concerned with similar efforts. Because of the ambivalent attitudes of educators and others toward such educational efforts, the title includes the word experiment. Such ambivalence led Kubie to title an evaluation of an aspect of medical education *The Half-Failure of the Full-Time System as an Instrument of Medical Education* (*1*).

The rationale for interdisciplinary studies is based on the common observation that problems in the real world are not separable into disciplines. While disciplines and departments in universities are an administrative convenience and provide a basis for needed specialized research and education, it is suggested that educational institutions should also grapple with problems, such as those of environmental management, which do not fall nicely into separable groups along disciplinary lines. It is argued that the educational institutions should grapple with these problems in order to achieve the cross-fertilization of ideas demanded by the solution of such problems, and to attract students interested in working on them. At the graduate level a corollary of these assumptions is that instruction requires concomitant research if students are to become both competent to pursue research that is related to fundamental problems on their own and aware of the way in which new knowledge can contribute to the solutions of important social problems.

Despite the reasonableness of these arguments, an educational effort along interdisciplinary lines confronts major difficulties in virtually every area related to the process of education. These problems involve philosophy, faculty, students, curriculum, research, money, and evaluation. Each of these is touched on below, with a brief discussion at the outset, and is then followed by a statement of conclusions that may have broader applicability.

Philosophic Problems

Although major efforts in fields such as agriculture and engineering have often been problem-oriented, most graduate studies in most universities have been structured along disciplinary lines. It is true that significant new fields, such as biophysics or biochemistry, have been created at the interface between old disciplines, and it can sometimes be shown that the greatest advances in new fields have been made at this interface between older disciplines. Nevertheless, every interdisciplinary or multidisciplinary effort must face the question: What is the core of study? Clearly, the problem, rather than a discipline, is the core. Because environmental and urban problems do not fit neatly in disciplinary departments, the problems themselves appear to provide a focus, or an orientation. Problems, unfortunately, do not provide an inherent structure or key philosophic concept around which to build an education.

In the Department of Geography and Environmental Engineering of Johns Hopkins University, three specialized areas were considered important to the solution of environmental problems: (i) natural processes at the surface of the earth, (ii) social processes and mechanisms of decision-making in society, and (iii) the application of engineering design to mitigating the impact of human activities on environmental systems. To bridge the gap between problem and discipline, the program drew on a number of doctrines and approaches, including those from systems and spatial analysis, ecology, the earth sciences, and economics. None, of course, provides the single "best" approach to environmental questions. In general, many of these disciplines or techniques provide ways of thinking about many questions of environmental management, and provide some tools applicable to their solution; the tools are not a substitute for a theory regarding the structure of the problems. Indeed, there may be a tendency to oversimplify the problems by attempting to describe them with very simple generalized models.

The absence of a simple definition of environment, or environmental problems, has led our environmental program to become, on occasion, more multidisciplinary than interdisciplinary. Students are encouraged to focus on specialized areas while developing skills and knowledge, such as the use of systems analysis or of ecological concepts, that are directly related to environmental problems. Specialization in one area, coupled with exposure to, and participation in, the analyses involved in making environmental policy-decisions, resulted from the fact that no single paradigm provided the core for an analysis of the broad range of environmental problems. However, a number of recurring environmental themes, such as the inseparability of natural and social processes, the existence of spillover effects or externalities, the problem of the commons, the existence of incommensurate and nonmonetary values, and the importance of large-scale natural processes undergoing dynamic and evolutionary change, appear to warrant continuing emphasis. While these themes can be recognized in a wide variety of problems, no one of them provides a core for an educational philosophy, nor do they collectively encompass the field.

For the above reasons, the Johns Hopkins University program in geography

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and environmental engineering has involved a continuous compromise in the tension between the breadth required by environmental problems, and the depth of knowledge or specialization demanded in the solution of such problems. This tension may always be part of any interdisciplinary program. There seems to be no simple educational formula for the resolution of the problem of depth and breadth.

Faculty Size, Recruitment, and Retention

In general, the recruitment of specialized faculty members is more difficult for an interdisciplinary program, both because of the demands of the job itself and because of the possible jeopardy that some feel that they enter on leaving disciplinary departments aligned with professional and scholarly societies in the field. The fact that a department must be small enough to provide interaction among the faculty permits only a limited number of specialists in a given area. In some cases a faculty member may essentially be alone, a difficult position for all but the most energetic and confident junior faculty. The necessity of ensuring a cadre of specialists in a given area makes recruitment vital and perhaps more difficult than recruitment in comparable fields, where departments number from 10 to 15 specialists in a given area. Presumably, a prerequisite for each faculty appointment, in the natural or social sciences, or in engineering, is a high degree of competence in some field of knowledge. As Mar *et al.* (*2*) note, specialists of the kind who might be most welcome in a first-rate department in that specialty need not be those who are most appropriate to an interdisciplinary research team. However, criteria for a cooperative research appointment may differ from those for a tenured faculty appointment. Thus, those specialists who are recruited for an interdisciplinary faculty must be those who choose to join a multidisciplinary program, rather than a more specialized one.

A faculty of about 18 was initially proposed, to cover the three broad areas of interest in our environmental program, although some cautioned that the number might be too few to provide the requisite depth. Since a single departmental faculty cannot, and should not, expect to cover in depth all subjects which students require, the counter argument was that too large a faculty would tend to divide into groups, effectively thwarting the objectives of interaction. While no figure for an optimum size has been established, experience has shown that 15 to 18 faculty members are sufficient to attract several faculty members in different areas of specialization and, at the same time (given faculty commitment to the program) offer a high probability of constructive interaction. Sixteen faculty, the largest size reached by our department, were sufficient to attract good young faculty and good graduate students, but not large enough to lead to excessive fragmentation. The number is of course not magical. Indeed, three or four committed faculty may be able to marshal the resources of a college or university and create a viable interdisciplinary effort, but commitment and continuity are difficult to maintain in such a small group, that is dependent on many other faculty to provide the needed breadth of knowledge.

The promotion and tenure of faculty proved to be a major concern of new young faculty members. Senior faculty who have chosen to work in an interdisciplinary program have, for the most part, satisfied the customary criteria for promotion in a graduate and research-oriented faculty, before committing themselves to the program. Young faculty are aware that the criteria for promotion may give heavy emphasis to scholarly research and publication. Of equal importance, they are aware that the fraternity of their peers is primarily concentrated in the recognized disciplines, and even subdisciplines, on which most university departmental structures are built. In a world of expanding knowledge, first-rate contributions to research and problem-solving are likely to be made within specialized areas and the results of research published in a restricted range of journals. Moreover, for the most part the academic readership confines itself to a limited number of journals (*3*), and hence visibility in the literature is much more easily attained by publishing papers in a few journals than it is by publishing the same number in a broader spectrum of journals. It may be argued that such blinders are irrelevant to scholarship, provided that the quality of the work is high. However, aside from the reasonable suspicion that young scholars are not likely to make contributions over a broad spectrum, other scholars in the field are simply not likely to be aware of the publications or, in fact, to feel themselves qualified to review them. For this reason, both the criteria for promotion and the selection of appropriate referees are of critical concern to young faculty looking forward to promotion and achievement of tenure.

Even where the appointment and promotion experience has been good, that is, where good faculty in a variety of disciplines have been promoted and given tenure at a rate comparable to that in the specialized disciplines, virtually all young faculty have, from the outset, expressed concern about the route to promotion, the nature of the peer review, and the criteria that would be applied in their evaluation. Because an interdisciplinary department runs against the grain of the traditional university structure, faculty are aware of the attitudes, and sometimes suspicions, of fellow disciplinarians. To some extent, the problem parallels one encountered in the evaluation of contributions in applied as compared to pure research, within universities. The depth of these concerns depends in part, of course, on the character of the institution as a whole. Specialized scholarship may be given more emphasis in one university than in another.

Cooperative efforts in a smaller institution may sometimes be easier than in a larger, more structured one, even though the potential opportunities available in a larger institution are greater. Interdisciplinary educational programs are, of necessity, heavily dependent on close relationships with faculty in a variety of other departments. It is important to note, however, that in general such associations are voluntary and develop out of mutual interests, sometimes stimulated by money. At the same time, such relationships are subject to the uncertainties generated by departmental autonomy. Where faculty have considerable autonomy, as they often do, no administrative mechanism guarantees continuance of important interdisciplinary interests.

The dilemma posed by departmental autonomy is clearly confronted when an interdisciplinary program turns its attention to interests which allied departments may not at that time share. A burgeoning development in one area may disappear, and with it several faculty members, when a potential cooperating department decides to direct its attention to unshared spheres. If continuity is to be achieved, it cannot be entirely dependent on the vicissitudes of wholly independent decision-makers with no stake in the interdisciplinary program.

It is often assumed that joint appointments in several departments can bridge the gap between specialty and problem areas. On occasion, they may indeed serve to cement relations between de-

partments or to encourage more frequent contact between faculties. As a rule, however, such cement and interaction either exists before a joint appointment is made, or develops without one, where the personalities and conditions are propitious. Where such conditions do not exist, a joint appointment cannot overcome their absence. In a sense our experience suggests that joint appointments work best where they are least needed. More often than not a major concern for a joint appointment develops into an unequal partnership in which the faculty member is more likely than not to move in the direction of specialization and away from the interdisciplinary program if he or she insists on an appointment in the specialized discipline.

It is an axiom of academic departments that the personality of a scholar is irrelevant to the evaluation of his competence. (Indeed, one is expected to lean over backward to ensure that personality does not influence a judgment of scholarly attainment.) Aside from the observation that human beings in general are probably incapable of behaving according to this strict dictum even if it is a good one, the necessity for faculty interaction in a program dedicated to interdisciplinary activity exacerbates the problem of personality. In a relatively small department, with acknowledged diversity of interests, the isolation of a few members severely constricts the academic program.

Visiting faculty can stimulate interaction and intellectual growth in a broad interdisciplinary program. As in all academic efforts, however, a visitor is likely to prove most stimulating where he or she finds a group of similarly interested intellectual peers. Here the matters of size and a concentration of talent become most important. While the notion of a new point of view or wholly different approach is attractive, perhaps few visitors are likely to make contact or provide inspiration. With some exceptions, in our experience, even a 1-year stay was insufficient to permit the full involvement of the visitor in research and education in the department, although first-rate teaching and participation in seminars and in some research were rewarding. In contrast, 3-year part-time appointees not only helped to establish the excellent continuing foci of interest, but also developed a deep involvement with students and faculty. A wide variety of reasons, including circumstances such as accidents of timing, influenced the varied results derived from the appointment of visiting faculty.

Graduate Students

Graduate students, with interests and high competence in a variety of fields relevant to the study of environmental problems, are essential in achieving the intellectual cross-fertilization expected of an interdisciplinary program. Graduate students learn a great deal from each other. Such learning includes not only formal information but also, in an interdisciplinary context, the important limitations of fields with which they are not familiar, as well as the complementary relationships of a number of specialties important to the solution of environmental problems. Thus, the intellectual cross-fertilization which occurs inside and outside of the classroom is the most successful method of transmitting the message of the interrelation among the inseparable parts of environmental problems. This too is a subjective judgment, but the degree of interaction and its impact on the thinking of the students has been evident in seminars, in the response of students at university oral examinations, in the choice of thesis topics, and in the way in which both seminar projects and dissertation studies have been carried out. For these reasons, the frequency distribution of students within areas of specialization in an interdisciplinary program is of major importance. While interest in different areas waxes and wanes, loss of faculty and students in one or another area can jeopardize the attainment of the objectives of an interdisciplinary program. The leaven required cannot be achieved without maintaining some kind of equilibrium between the important aspects of the field.

For the above reasons a program must be able to attract students well-trained in specialized areas among those requisite to the fields appropriate to the interdisciplinary interest. Many of the best of such students may logically choose the road of specialization. A lesser number, by prior exposure or bent, will choose the less certain route of an interdisciplinary program. Still others, mavericks of broad but shallower backgrounds, will be attracted to the less clearly defined interdisciplinary effort. Among the latter will be the best and worst of the zealots. The academic problem is not zealotry, but rather the necessity for letting students know ahead of time that interest or even commitment is not a substitute for knowledge in an academic endeavor. Interest and commitment are perhaps necessary but not sufficient criteria for fulfillment in interdisciplinary or problem-oriented programs, just as they are in any more specialized academic area.

The problem of identity among students in an interdisciplinary program is ever present. The dilemma of specialization as compared to breadth can be acute as students come to recognize, in the same way that junior faculty do, that for the most part the reward structure in academia heavily favors specialization. The title of a natural science or of an economics department automatically confers membership in a club on the recipient of a Ph.D. degree. This is not true in an interdisciplinary program. The degree to which such professional associations seem important to a student is a function of both his recognition of the potential importance of such an association and his level of insecurity. As was noted earlier, students in the department are required to specialize, and most join specific professional societies, participate in meetings, and organize seminars and courses in their areas of interest and specialization in an attempt to develop competence and an identity in those areas, along with their interest in broader environmental problems. The necessity to maintain contact with several specialties requires effort and, except among the most secure students, produces a continual nagging concern that they may not be readily accepted in their area of specialization, and in the same way may remain in professional limbo. The results, in terms of placement and recognition, suggest that this fear may be exaggerated since graduates do find placement in specialized disciplines in academia, as well as in government and private industry, where their broad interdisciplinary exposures are a significant asset. Graduates who have combined specialization with a broad background and exposure to environmental problems appear to be particularly sought after, and those with facility in the application of mathematics to problem-solving in environmental fields are in particularly heavy demand. Nevertheless, there is evidence that some graduates have been penalized in seeking employment in specific disciplines by their association with a broad and applied area rather than with a narrower discipline.

Curriculum

As noted above, the basic problem of specialization and generalization, or depth and breadth, cannot be resolved by a simple manipulation of the curricu-

lum. The environmental program emphasized specialization and an attempt to achieve breadth through projects, seminars, and studies designed to bring students with different specialized interests together to work on common problems. These devices have been successful in many cases. Some fraction of the students remain untouched by the effort and would probably do better in more specialized programs. The structure required by systems analysis, including the use of the computer, has sometimes proved to be useful in framing approaches to decision-making problems in environmental management. A large number of the students subjectively assessed to have benefited from the interdisciplinary program were those with competence in the use of mathematical tools of analysis. Some, however, were not. While the use of computer structure and rigor in problem-solving, including the necessity for explicit statement of assumptions and options, can serve as an integrative tool, some of the students who have the most to contribute to broadening the view of an environmental problem are precisely those without the requisite mathematical skill or bent. At the other extreme there are mathematical wizards with little feel for a real problem.

Despite the avowed intent of students and faculty in an interdisciplinary effort, the demands of learning burgeoning material in specialized fields maintains an ever present centripetal force. This is particularly true as participants discover that communication across different fields requires mastering new "languages." Not infrequently, it is assumed that these "other" languages are either simple or not central to the broad problem. The necessity for constantly disabusing both specialized faculty and students of the perception that the answer to the problem lies within anyone's single discipline is unsettling, particularly in a specialized academic scene.

Students who have chosen the interdisciplinary route do, of course, take on the personal task of mastering one or more areas in depth, and of grappling with the relation between their specialties and the larger problems of society with which they have chosen to struggle. The educational program of each student, while concentrated in an area of the social, natural, or engineering sciences, provides broad latitude for selection of courses beyond the specialization. A flexible program is then an enormous asset for those who are able to take advantage of it. A minority of the students, however, prove unable to do so. For them a more structured program both lessens the problems of identity and provides more security with less effort. To limit the number of applicants who may mistakenly opt for the broader and flexible program, the "stand on your own two feet" demand of a flexible program must be made as clear as possible at the outset.

Summary and Some Conclusions

The experience of the interdisciplinary or multidisciplinary program of the Department of Geography and Environmental Engineering suggests some tentative conclusions perhaps relevant to future efforts at forging viable and productive interdisciplinary programs. Because these points have been elaborated in the text, they are stated here with a minimum of qualification.

A vigorous program with an outstanding faculty can compete with specialized disciplines to attract good faculty and good students.

The scale of the effort represents a compromise between the need for specialists and that for a size small enough to encourage interaction among faculty and students with diverse backgrounds. At Johns Hopkins, it would appear that more than 20 faculty members would have created a faculty with strong tendencies toward regrouping along disciplinary lines. A faculty of less than 10, as a separate department, suffers severe problems of stability as well as coverage.

Interdisciplinary programs are viewed with considerable suspicion by many faculty. This is particularly true of their attitudes toward the educational function as opposed to the research function, of such efforts. In principle, such skepticism is unlikely to vanish, in view of the necessary tension between breadth and depth in an educational experience constrained by time.

University administrations differ widely in their interest and concern for problem-oriented programs. Those institutions in which the faculty controls policy and decision-making probably have less interest in such programs.

Because interdisciplinary efforts require cooperation beyond the confines of a single program or department, the mutual interests of faculty members in diverse areas must converge in order to provide a viable program. Again, the degree to which an institutional administration can ensure the continuity of a program depends on the size of the institution and the way in which departmental autonomy governs appointments. Large institutions with broad coverage of fields are more likely to ensure the presence of faculty members in appropriate areas of interest to environmental or other problems than are small institutions. Thus, programs at small institutions are probably more stable if they are formal departments, or other formal units, rather than ad hoc committees.

Because of the proper disciplinary structure of most academic institutions, both students and junior faculty must be concerned with the reward structure, which includes recognition, jobs, and tenure. Competent students and junior faculty have been penalized less than they perceive themselves to have been, but the perceptions are nonetheless real, particularly for the less able.

As some authors have pointed out (*4*), interdisciplinary environmental or urban programs can best be brought into being by the mutual interests of existing faculty. Such arrangements can be strengthened by the provision of independent funds for faculty, regardless of discipline or department, and by provision of fellowships and stipends to be used at the discretion of the interdisciplinary program or committee. In hard times it is surprising how much cooperation may be bought for a limited number of dollars. Faculty appointments cannot be purchased in the same way without some assurance of continuity.

The appropriateness of interdisciplinary programs depends on the institution and on the times. The success of the effort cannot be ensured by an administration, but its demise can be caused by either an administration or by a faculty. In the latter case, an administration can provide some protection.

An important contribution to highly specialized instruction and research in an academic institution can be made by an interdisciplinary program and department. The desirable amount of such leaven is clearly a function of the character of the institution and its resources.

In all likelihood the interests of society, which are often reflected in the job market, will have a greater influence on the attraction of good students to problem areas of inquiry than will the theoretical basis or justification for that inquiry. The recent attraction of graduate students in physics and biophysics to environmental studies is evidence of this influence.

Problem-oriented programs in universities are not a new phenomenon. Recurrent surges of interest in social problems,

such as environment, energy, or cities, renew demands for new or different programs. It is clear that the minimum requisites for the productivity of such programs are funding for graduate students, and at least an expected 5 years of continuity of funding for key faculty participants. This need not mean funding for all key faculty, but rather funding to ensure needed minimal coverage. The appropriate administrative home will depend on the institution. While one can generalize about the prospective problems of a multidisciplinary effort, comparable generalizations cannot be made about the optimal design for such a program beyond the statement of some minimum requisites.

While the view that the best generalist is a broken-down specialist has been put forward, society's needs appear to warrant continued multidisciplinary efforts despite the educational problems. The appropriate level for such programs may be the masters, the doctorate, or successive two-degree programs. Each has costs and merits, superficiality or time countered by depth and breadth. The job market, the subject, the institution, and the program itself, in some combination rather than alone, probably determine the level of education at which an interdisciplinary program is likely to be successful.

References and Notes

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5. Initiation of the program described in this article was made possible by a grant from the Ford Foundation.

NEWS AND COMMENT

Research Management Scandals Provoke Queries in Washington

The world of federal grants and contracts to universities, hospitals, and other research institutions, long thought to be self-regulating, is coming under intense scrutiny in Washington these days. An increasing number of government agencies, from Congress' General Accounting Office (GAO) to various elements of the Department of Health, Education, and Welfare, including the National Institutes of Health (NIH), are looking at how government research funds are actually spent at recipient institutions. The activities under examination range from out-and-out fraud to routine fudging of accounts, a practice that violates federal rules but that seems, nonetheless, to be common.

So, more and more congressional staffers and Executive Branch officials are learning the not-too-thrilling details of "time and effort reporting" and "monthly certification" and other features of the current system of managing federal funds for science. Rules and practice, however, diverge often enough that one official likens such study to "playing with Jello." But he and other officials, such as Representative L. H. Fountain (D-N.C.), are deeply concerned that this morass may conceal violations of peer review, not to mention strict accounting procedures.

Fountain's alarm is an important bellwether, because, as chairman of a Government Operations Committee subcommittee, he launched in the 1960's one of the most thorough and probing investigations Congress has ever made of how research moneys, particularly those of the NIH, are spent. His committee found considerable waste and mismanagement at that time and developed revised procedures aimed at cleaning things up. But recently Fountain told *Science*, "I am concerned that the reforms we accomplished in the 1960's may not have endured." The subcommittee's belief that granting institutions, together with government audits, have been adequately policing the system "may be illusory." Fountain says his staff is undertaking a major follow-up of its earlier work.

The issue has surfaced in the last year in Washington largely because of two incidents. One occurred at Harvard (*Science*, 23 September) and involved Phin Cohen, an assistant professor of nutrition who alleged that he had been made to sign blank forms vouching for how his NIH grant moneys had been spent, while the Department of Nutrition at the School of Public Health filled them in with unrelated items and forwarded them to the government. Not only did NIH investigators find the Cohen allegations true, but they found serious accounting problems in two other Harvard grants that they examined. NIH asked Harvard to pay back $132,349 to compensate for misspending on all the grants. HEW auditors are now beginning an audit of all federal funds—which total some $400 million—Harvard receives.

The second incident, which may have aroused the Secretary of HEW, involved the Eppley Institute in Omaha, Nebraska, which has received more than $18 million in funds from the National Cancer Institute to test chemicals for carcinogenicity. According to GAO investigators, whose report is about to be published, between 1973 and 1976 Eppley's contracts with NCI have been extended without using normal procedures. For example, some 11 projects, some of which had already begun, were approved with only a verbal say-so from NCI. Moreover, some 50,000 laboratory animals, bred at a cost of $1.75 apiece, turned out not to be employed in Eppley's research and apparently were destroyed. Finally, some of the equipment, materials, and animals the government paid for were used for Eppley's industrial research contracts according to GAO. The Eppley situation has suggested to several observers that some bending of the rules has been overlooked by NCI officials, because Eppley's director is Philippe Shubick, a member of the President's National Cancer Advisory Board, which has oversight responsibilities for the NCI.

[Eppley's Associate Director, Phillip Issenberg, told *Science* that Eppley had always "done what we were told to do by NCI" in renewing its contract. As for the 11 projects, "We did not have the good sense to put their response in writing." The misuse of equipment was minimal, he said, and the animals destroyed for good reasons. But he admitted that Eppley could have been more careful in having bred 78,000 animals of which only 27,000 were used in experiments. Eppley's NCI contract is currently up for renewal.]

It should be noted that no one is alleging—even in the most serious cases discovered so far—that scientists are using