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Improving Interdisciplinary Research: Integrating the Social and Natural Sciences

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Abstract *The relationship between social sciences and natural sciences in the natural resource area is explored. Five barriers to joint involvement of the social and natural sciences include the weakness of the social sciences, a perceived illegitimacy of the social sciences, the punishments associated with interdisciplinary research, the lack of disciplinary support structures, and conflicts over power and control.*

Progress toward bringing research together in these two clusters of disciplines might be enhanced by institutional and administrative support to develop specific research structures for interdisciplinary natural resource related research; the physical, social, and organizational integration necessary to improve the image of interdisciplinary research and to increase rewards for individual scientists; and efforts to improve the science by specific funding for interdisciplinary natural resource research.

Keywords: interdisciplinary research, social science, natural science, natural resource policy, sociology of science.

Resource policy issues rarely involve single disciplines. Even the best information about the biological or physical aspects of an environmental issue is rarely sufficient to establish a policy. Policymakers and the public increasingly demand information about social and economic impacts. Who is affected? What will it cost? How can people be influenced? If scientific study does not provide this information, policymakers are forced to guess. Consequently, a policy judgment requires the integration of scientific information about the biological, physical, and social aspects of the problem. At the same time, information generated in an academic setting is heavily disciplinary; biologists look at certain issues, physical scientists and engineers look at other issues, and social scientists seldom are involved in matters defined as technical problems.

Social scientists in the natural resources area find themselves frustrated by their lack of involvement. Natural scientists, on the other hand, complain that the social scientists are not interested. Some visible and invisible barriers seem to keep us apart, and the public is ill-served as we present pieces of the puzzle, but seldom the whole picture. This article is based on ideas generated at a weekend-long seminar sponsored by the University of Wisconsin-Madison Center for Resource Policy Studies and Programs, during which a variety of scientists in a variety of disciplines met to explore these issues, to identify these barriers, and to suggest ways that the disciplines might better work together.

The participants included several social scientists: a resource economist, an environmental psychologist, and an environmental sociologist. Also attending were a geologist who has attended to policy issues, a geographer with strong credentials in both the physical and the social sciences, a soil physicist who chairs a department, and a Wisconsin Department of Natural Resources research administrator who has an advanced degree in wildlife ecology and administers both biological and social science research.[1]

Barriers to Interdisciplinary Research

The group identified five major barriers to successful involvement of social sciences with the natural sciences in interdisciplinary projects.[2] These include:

1. Weaknesses of the social science disciplines,
2. Perceived illegitimacy of the social sciences,
3. Punishments for interdisciplinary involvement,
4. Lack of a disciplinary support structure, and
5. Issues of power and control.

These five categories are somewhat artificial and have some obvious overlap, yet they represent a convenient way to characterize the wide variety of ideas articulated by the seminar participants about the problems of interdisciplinary involvement.

Weaknesses of the Social Sciences

The group generally agreed that the social sciences have some real and serious weaknesses. The social sciences are less developed than the natural sciences in terms of theory, data, method, and tradition. This lack of development presents a fundamental difficulty for being a full and equal partner with the biological and physical sciences in interdisciplinary projects. The disciplines of sociology, economics, and psychology emerged in the late nineteenth century while biology, chemistry, and physics have much earlier origins. As a result, the social sciences bring fewer scientific resources to the interdisciplinary enterprise.

Paradigm Conflict. Social scientists within their own disciplines are still debating the basic paradigms for understanding the social world. Sociology, for example, includes Marxist, structural, social psychological, and other perspectives. In social psychology at least five major theoretical perspectives attempt to explain attitude change. The concept of "attitude" itself has no widely shared theoretical or empirical definition. This creates great conflicts among social scientists. Their internal debate is exacerbated across the social sciences as psychologists, economists, and sociologists struggle to explain similar phenomena using different terms and world views; the debate creates a considerable amount of internal conflict. It is no surprise that our natural science colleagues must think that we are sometimes speaking in tongues. This internal conflict also tends to make social scientists hypercritical of each other. Because there is so little agreement, peers often disagree, and negative peer-reviews result. Seminar participants reported that National Science Foundation peer reviews in the social sciences, for example, are considerably more negative than the natural science reviews. Social scientists seem to take great delight in saying negative things about each other, while the natural scientists tend to support their peers' proposals.

Lack of Data and Resources. Much more data seem to be available on the physical and biological aspects of a particular problem in the area of natural resources. Water and forest resources are good examples. Research by university and governmental agencies provides substantial knowledge of water and forest resources. The social science database is much weaker, and it seems that social scientists usually have to start from scratch. Who uses the forests for recreation? How many jobs are created from a logging enterprise? What are farmers' attitudes toward ground water? The disciplines and departments in the University of Wisconsin-Madison College of Agricultural and Life Sciences have developed substantial databases on natural science issues; in contrast, the resource social scientists are few in number and widely scattered, and social science disciplinary questions divert interest from resource-oriented questions, while in the natural sciences the discipline tends to push toward resource-oriented questions.

Poorly Crafted Social Science Proposals. Those who have reviewed social and natural science proposals noted that often the social science proposals are much weaker in scientific form than are natural science proposals. It is no surprise that the proposals are weaker given the above discussion. The theoretical diversity of the social sciences coupled with the absence of data make it exceedingly difficult to write a tight, well-documented, theoretically strong, empirically grounded research proposal on social science aspects of a natural resources problem. The "if-thens" and the knowledge gaps are much better established in the biological and physical aspects of most natural resources issues.

Lack of Tangible Products for Social Science Research. Much research in the natural science aspects of natural resource problems has a product-oriented, tangible outcome. If asked why the research is being done, an explanation like "more fish," "cleaner water," or "bigger trees" follows. Social science research seems to lack these tangible objectives. We describe our research products in terms of "better government," "protecting the public interest," "preserving scenic beauty," or "better decision-making." While these may be noble goals, they are not tightly or clearly linked to the research enterprise.

Perceived Illegitimacy of the Social Sciences

The previous discussion was directed to structural problems of the social sciences; the following discussion will turn to perceptions of the social sciences. These perceptions are often held by the social scientists as well as the natural scientists and act as significant barriers to interdisciplinary involvement.

Low Status of the Social Sciences. Science has its own pecking order. Disciplines that require more mathematics are viewed as more rigorous than those that require less. Physics may be at the top of the heap in the natural sciences, followed by chemistry and then biology. The social sciences are seen as easier and less quantitative than all of the natural sciences. Natural scientists and engineers often see themselves as well qualified to do social science research, while social scientists seldom jump the disciplinary boundaries into the natural sciences. Undergraduates who can't do the natural sciences fall back into the easier social science disciplines. Thus, people denigrate the social sciences by referring to "science" when they mean science that deals with physical and biological issues, and using the terms "social science" or "social studies" when referring to

science that deals with human behavior. This differentiation subtly denotes the low status of the social sciences.

The situation is debilitating for joint work; both social scientists and the natural science colleagues with whom they collaborate see the social scientists as less adequate. This negative evaluation is not necessarily justified. There certainly is variance and perhaps much inadequate research in the social science disciplines, but at the leading edges of econometrics, experimental psychology, and quantitative sociology the social sciences are every bit as scientific as the natural sciences. Indeed, problems of conceptualization, measurement, and dealing with unclear theory make the social sciences "harder" (to play on the "hard" science vs. "soft" science put down) than the natural sciences. There is a real barrier to equal partnership in a research enterprise when both the social scientist and colleagues in the natural sciences see the social science disciplines and the individual social scientist as less adequate than the natural sciences and scientists.

Exaggerated Faith in the Natural Sciences. While social scientists are overly critical of their own disciplines, they seem to have overarching faith in the effectiveness of the natural sciences. They believe these sciences to be accurate and to almost always reach clear and demonstrable results, with few measurement or theoretical problems. They simply view them as being "right."

The general public and research administrators also seem to share this view. Experience in interdisciplinary research, on the other hand, shows that the natural sciences and the social sciences share the same kinds of problems and complexities. Problems are difficult to conceptualize, variables tough to measure, and clear relationships elusive. Natural scientists understand this but seem to feel that with enough money and time any question can ultimately be answered—at least in that nonsocial environment. On the other hand, they appear to be much less optimistic about the potential effectiveness of the scientific method for understanding human social behavior. This is true of social scientists as well. If asked to solve a natural resource-related problem, social scientists who were allocating budgets likely would decide to spend most of the money on natural science research because of their faith that it could deliver answers.

Social Science as "Trivial" or "Wrong." Because the level of theorizing or discourse in the social sciences, the research findings (particularly when communicated to those in other disciplines or to policymakers) appear either trivial or wrong. Thus, if farmers are found to be economically rational in some specific decision, the social science research is seen as producing rather trivial findings. If the research shows farmers to be acting inconsistently with price signals, then the work is viewed as wrong because of our implicit belief in human rationality. There is often a factual basis to this criticism. Mindless statistical descriptions of human populations, in fact, are often trivial, and social science research based on inadequate theory and data is often so flawed as to be wrong.

Social Science Perceived as Not Needed. On many projects there is a tendency to view the social science component as unnecessary. The logic is that if we can just figure out the natural system, the social system will take care of itself. Getting cows to give more milk is an interesting biological question, but the research on how to get farmers to adopt the technology or on measuring the social impacts of increased production is less important and can be studied later. Given limited research budgets (and they are always limited), the natural sciences take precedence. The perception seems to be that social science is nice, but natural science is important.

Punishments for Interdisciplinary Research

In addition to actual and perceived weaknesses of the social sciences, there are general problems of interdisciplinary research. Specifically, there are substantial professional risks and punishments for participation in interdisciplinary projects.

Inadequate Reward Structure Interdisciplinary research produces fewer professional rewards in most cases. The probability of publishing in one's own disciplinary journals is reduced. When one does publish, the articles and reports have multiple authors, and the attribution of credit to a particular individual is less likely. Interdisciplinary projects have higher risks. The probability that the work will not be completed satisfactorily is higher and fewer publications result per unit of effort. There are fewer publication outlets for interdisciplinary research. Presentations at meetings outside one's own discipline are more limited. When one does attend these meetings, the variety of irrelevant sessions and the lack of history and contacts with other participants make them less rewarding personally and professionally.

Increased Effort Required As one seminar participant put it, "Interdisciplinary research is plain hard work." It takes a lot of effort to keep up with one's own discipline, let alone the work involved in learning enough about another discipline to do the necessary interdisciplinary work. One is more comfortable working in familiar areas. It takes serious intellectual effort to master enough knowledge of another discipline to be effective. Finally, the interdisciplinary researcher must deal with another world view, which requires tolerance and the ability to take the other person's perspective even if one finds it trivial or disagreeable or intellectually uninteresting.

Increased Time Required. Because interdisciplinary research involves coordinating work with others, it almost always involves more time than does disciplinary research. One must have meetings and coordinate schedules. People working on the project are in different buildings and have different department-driven schedules, so it takes more time and effort to coordinate than it does with people in one's own department. The other requirements discussed above also add to the time commitment.

Loss of Self-Esteem. Interdisciplinary research is hard on the ego. This is not a trivial issue because much research is motivated by the self-gratification of the scientist. Interdisciplinary research can make a person feel bad about himself or herself and, as a result, can be personally punishing. Interdisciplinary research increases the probability of criticism between colleagues, and criticism of even the most constructive sort has its punishing characteristics. The impact of criticism is increased in interdisciplinary research because it is done in the presence of colleagues. Moreover, each investigator must tolerate criticism about his or her own disciplines, often from people who don't know very much about the discipline. These criticisms can be naive or can hit real sore spots. A group of sociologists working together do not spend time criticizing sociology, but in an interdisciplinary setting people are critical of others' disciplines and the assumptions of those disciplines. It seems to social scientists that more of the criticism comes from the natural sciences to the social sciences, than vice versa.

Lack of a Disciplinary Support Structure

The basic disciplines provide tremendous support for the research process. Interdisciplinary research, besides struggling against many barriers, lacks the support structure that

makes disciplinary research possible. This is obviously a general issue for all types of interdisciplinary research, but the issues raised by our group focus particularly on the problems of integrating the social and the natural sciences.

Disciplinary Funding Base. Research funding generally is specified by disciplines. The concept of peer review implies that the peers are in the same discipline. What makes sense to them is, of course, what makes sense to the discipline. Interdisciplinary proposals sent to disciplinary programs in National Science Foundation (NSF), for example, fare poorly. Occasionally, small amounts of money are set aside for interdisciplinary programs. Think about what it would be like the other way around. Suppose all research money were set aside for interdisciplinary research, and only a small amount set aside for basic biology. The hue and cry would be great, which simply demonstrates the current strong support for disciplinary fundings. Interdisciplinary research and programs always must fight the disciplines for funding.

The Lip Service Phenomenon. One hears again and again—from administrators, the general public, and natural sciences themselves—of the need for social science involvement in natural resource projects. But when the dust settles and the budgets are drawn up and the work planned, social scientists often seem to be left out. It is usually the social concerns that generate the demand and the funding for interdisciplinary projects, and then when the work is allocated the social scientists get the smallest share of the projects. It appeared to many seminar participants that there were little genuine institutional support for and commitment to serious integration of the social with the natural sciences.

Ecological Problems. Getting together is a key requirement for interdisciplinary research. Housing in most universities is by discipline. Thus one meets and talks to people in his or her department. To do interdisciplinary research and to be aware of interdisciplinary issues, one needs to cut across departments. The people to whom one must talk are in different locations. The departments, in most cases, act as a barrier to the integration of the social and the natural sciences. A department like Soils at UW-Madison has physics, chemistry, and biology represented, so it acts in an interdisciplinary fashion, but it has no social scientists on its faculty. It is well known that some plants can grow only in certain complexes (e.g., shade, sunlight, etc.); the same is true of human enterprises. The physical and institutional organization of the university serves to keep the social and natural sciences apart.

Narrow and Misinformed Knowledge of the Other Disciplines. In order to work together efficiently, scientists must know something about other disciplines. If disciplinary training began early in one's college career, there is little if any exposure to how other disciplines operate. Many social scientists believe that those in the natural sciences have only a vague idea of what the social sciences do. Economics is equated with business or accounting, and psychology and sociology are vaguely referred to as "public relations." Social scientists also may be misinformed about the natural sciences, although *Science* magazine, for example, devotes much more space to the natural sciences than the social sciences. In order to work together, interdisciplinary researchers must have some idea of what each other's discipline entails. With current trend toward increased disciplinary focus, we see this declining rather than growing.

Lack of Information and Models. There is a serious lack of books, journals, and models

to help integrate social and natural sciences in interdisciplinary research.[3] Where does one find out how to do this, except by trial and error? Although almost all participants at the seminar had experience on the topic, few had any references for methodology. In short, the scientific knowledge base to guide such a process is difficult to locate. It is also more limited than the substantial methods-literature in most disciplines.

Uncertainty About How or Whether to Train Students in the Area. Because of the knowledge gap noted previously, it is very difficult to figure out how to train students in interdisciplinary research, and particularly how to integrate the social and natural sciences. There is some concern about whether we should be training students in this area at all, because it is important to gain solid disciplinary training before moving into interdisciplinary areas. In any case, the disciplines guide the training, which serves as a barrier to integration. But certainly this is a key issue. One cannot do good research if one is not trained for it.

Issues of Power and Control

Science does not go willy-nilly on its own way. It is driven by a number of forces, some of which have already been identified. Our group identified a number of issues related to power and control of the scientific enterprise, especially as it is organized around the university. These issues act as significant barriers.

Control of Research by Non-Social–Scientists. Research administrators in the College of Agriculture, where much natural resources work is done, are not social scientists. The National Science Foundation and the National Academy of Sciences are also heavily weighted toward the natural sciences. The articles in *Science* and membership of the American Association for the Advancement of Science make it very clear who controls science—and it is not social scientists. One's disciplinary perspectives influence how one sees problems and solutions. Research budgets for biological and physical science on the UW-Madison campus, for example, are large not because these problems are more important than social problems but because budgetary decisions are made by the scientific community that represents these interests. This bias is not malevolent; it is simply a matter of fact that one's disciplinary orientation influences how one sees problems and the options for solutions. Thus, with a natural resource problem that is of equal parts—social and biological—the preponderance of the research money and support is likely to tilt toward the biological under normal circumstances. Those in charge will simply see it as the right way to go from their perspective.

Research Agendas Set by Non-Social–Scientists. While the above issue deals with funding and other resources, this barrier deals with intellectual issues. Scientists are driven largely by curiosity, and freedom is a hallmark of the research process. Yet large, potentially interdisciplinary projects are typically organized and administered by natural scientists. They see large social components and then try to find the social scientists to do the job. This may work in a contract research situation, but it doesn't work well in the university. Social scientists are driven by their intellectual curiosity and wish to set their own agendas. The agenda set by a natural scientist is rarely satisfactory to the social scientist and vice versa.

Social Control of Social Science Outside the Department. As a result of the recalcitrance of social scientists in showing an interest in their problems, a number of production and natural resource departments in the UW-Madison College of Agricultural and Life Sciences are considering hiring their own social scientists. This greatly concerns the social science departments because they have no way of reviewing quality and setting standards for people in their own disciplines outside their departments. On the other hand, if new members are added to social science departments to study issues related to production or natural resources, those departments may rightfully worry about the person being drawn into disciplinary areas. Thus, the departmental structure and control issues set up barriers that make it difficult to unite social and natural sciences.

Problems Linking Natural Science with Social Science Models. We all like our own models, and both the social and natural sciences are data-driven. That is, we look under the street light for the key, even if it was lost down the street in the dark. A number of us have had the experience of finding that the natural scientists on a project were running a model that provided output in a set of units or for areas that could not possibly fit with the social science data or models. For example, point estimate data would have to fit with census tract data that apply to a broad area. In our experience the natural scientists would not change their models even though the unchanged models could provide information of no social utility. This is especially frustrating in policy research when social utility is the major reason for the project's existence.

Clearly, there are other problems linking the social sciences and the natural sciences in interdisciplinary projects. Also, different orders of abstraction clearly are possible. Many of those abstractions listed are interrelated, and some are subsets of others. Given the enormity of these barriers, it is strange that any interdisciplinary research gets done at all, and especially research that integrates the social and the natural sciences. That such research does get done shows just how powerful the necessity of linking the two must be; it is a tribute to those unique individuals who risk career and a comfortable existence to overcome them.

Overcoming the Barriers

After a long and lively discussion of the problems, the group considered solutions. This was a much quieter and shorter discussion. These problems are fundamental and serious, and mechanisms for bringing the disciplines together are neither clear nor easy.

Administrative and Institutional Support

Because of the serious barriers to interdisciplinary research, especially between the natural and the social sciences, there is a need for special kinds of administrative and institutional support that are either less necessary or already in place for disciplinary research. It is necessary for top administrators and faculty to buy into the concept of interdisciplinary research. To foster this, a series of administrative seminars and training on interdisciplinary research would be useful. It is important also to elect members with interdisciplinary experience to committees dealing with faculty governance issues and research agenda-setting. Since departments almost by definition support disciplinary efforts, this suggestion was made to bypass departments and seek the support of the chancellor and the deans for modifying the reward structure. These levels of administrative structure are

more likely to have an appreciation for broader issues that require interdisciplinary research.

The group also discussed a number of other administrative changes. These included splitting faculty appointments or portions of appointments to interdisciplinary groups and creating or merging current centers for interdisciplinary research. A more radical point of view is that a change the tenure system may be necessary to support interdisciplinary research.

At the operational level, the participants felt that a structured dialogue between the social scientists at the university and the resource-based state agencies would be useful and that interdisciplinary projects need a full-time coordinator to keep the parts together in order to be successful.

The Tenure Dilemma. The tenure issue in general comes up repeatedly. There is an interesting paradox here. The tenure process inhibits interdisciplinary research activities by assistant professors. It slows publication and leads to publications to less prestigious disciplinary journals or in journals outside the discipline that are seldom read or appreciated by one's colleagues. Interdisciplinary research also produces co-authored papers that make it difficult to judge the performance of the individual. In plain words, if one does interdisciplinary research, one is less likely to get promoted to tenured rank in the university. On the other hand, tenure is very important for those who are doing interdisciplinary research. One needs the security of tenure to branch off into uncharted areas which may not be supported by disciplines. Without tenure, the disciplinary drives throughout one's career might be even more persistent and insidious. Tenure is possibly even more important for another reason. The push for interdisciplinary research comes from the policy area, as the state and nation ask the researcher to provide guidance on policy alternatives. Researchers need the insulation of tenure to pursue politically unpopular but promising alternatives. The paradox here is that while the tenure process may inhibit interdisciplinary research and career development, at the same time it may be most necessary for the activity.

The Disciplinary Dilemma. A second administrative dilemma involves the maintenance of quality standards for interdisciplinary researchers. Strong disciplines are necessary to establish and maintain standards as well as advance knowledge in the field. To have good interdisciplinary research, one needs strong disciplinary structures. On the other hand, the existence of strong disciplinary structures inhibits the development of effective interdisciplinary programs.

Reward Structures for Interdisciplinary Research

Because of the many rewards for disciplinary research, special steps should be taken to reward interdisciplinary research and practice. In particular, a special award for outstanding interdisciplinary research or activities on campus might be useful. Besides recognition, special funds should be set aside for travel and project assistants, and other research support should be earmarked for interdisciplinary projects. Senior colleagues should help by acting as advocates for junior colleagues who are trying to do interdisciplinary research. As interdisciplinary projects are being planned, it is important to build in funding and time and to make plans for disciplinary papers that can emerge from the

research. Disciplinary and interdisciplinary research can be merged. If this is done, it will produce more rewards for the researchers

Physical, Social, and Organizational Integration

In reviewing both the origins of interdisciplinary research and the factors that made this research a success, it was clear that serendipitous factors that bring people together played a key role. Coffee in a central location, travel with research counterparts, or field work that brought people together for extended periods made the research work. Simple attention to these matters may result in a low-cost and easily implemented program facilitating the integration of social sciences and the natural sciences. Coffee rooms, shared trips, and retreats are good ways to bring people together. A mechanism to identify people with overlapping interests so that faculty would know with whom they have something in common and so that interdisciplinary teams might be formed faster would be useful.

There should be more opportunities for social scientists and non-social-scientists to visit each other's departments. Departmental open houses in universities would allow faculty members a chance to learn what other departments are doing. In particular, joint housing is necessary for interdisciplinary projects to be most effective. Joint housing of natural resources and social sciences would greatly facilitate the genesis and fruition of joint projects. Finally, leadership staff is necessary to play interdisciplinary roles.

Improving the Image and Increasing Promotion

Everyone knows how disciplinary research works, but few know about interdisciplinary work. Much could be done to point out the opportunities and to highlight the success stories of interdisciplinary research. A videotape of a successful project and other ways of highlighting the success of these projects should be explored. Meetings with agency heads to discuss interdisciplinary projects and administrative training seminars also could be useful for promoting the image of interdisciplinary research.

A bibliography on interdisciplinary research methods and reviews of successful cases and a consciousness-raising document with suggestions on improving interpersonal relations with colleagues in interdisciplinary projects would also help interdisciplinary research.

Improving the Science

Interdisciplinary research would attract more people and produce better products if the quality of the science were improved. Factors that could improve the science would enhance the probability of good interdisciplinary work. Social scientists need to be involved in projects early and to do more agenda-setting. This will increase the probability that social science research would be viewed as intellectually interesting and so would make a contribution to the discipline. When natural scientists set the agenda for the social science research or when social scientists set the agenda for the natural science research, second-rate research is a frequent outcome. Outside help, either in terms of funding or talent for interdisciplinary proposals, would improve the quality of the science.

Better training in interdisciplinary research methods for graduate students and faculty

is important for developing interdisciplinary research. It would also be useful to encourage social science methods that parallel natural science methods, such as experiments, models, and longitudinal studies rather than simple opinion surveys. It would be useful for social scientists, rather than natural scientists, to take the initiative of pursuing and developing a large interdisciplinary study. Finally, sponsoring social science research on both the problems of interdisciplinary research as well as the issues involved in better integrating the social sciences and the natural sciences would help improve the quality of such interdisciplinary projects.

Funding to Promote Social Science Involvement

Funding is, of course, what makes things work. Scientists cherish academic freedom, but they are heavily influenced by funding. Currently the funding imperatives are for disciplinary research. This focus must be changed if we are going to see a genuine increase in interdisciplinary research and the involvement of the social sciences in this work. Funding should be provided to help with interdisciplinary proposals. The universities with research funds available should help set research agendas and set aside funds for interdisciplinary proposals. Those interested in interdisciplinary work should seek an outside "godfather" to provide the funding to develop the appropriate infrastructure. It also would help the funding picture if we were to build on specific initiatives rather than to try to develop funding independent of specific projects.

Conclusions

In summary, we identified five general barriers to successful involvement of the social and the natural sciences. These include the weaknesses of the social science disciplines, the perceived illegitimacy of the social sciences, the punishments associated with interdisciplinary research, the lack of disciplinary support structures, and conflicts over power and control. These formidable barriers are not easily knocked down or overcome. To make progress in bringing the disciplines together, it is necessary to have institutional and administrative support, to develop specific research structures for interdisciplinary research, to provide physical, social, and organizational integration, to improve self-images and increase promotion possibilities, and finally to improve the science and provide specific funding.[4]

Acknowledgement

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Notes

1. Participants in the seminar included Richard E. Chenoweth, Associate Professor of Landscape Architecture; Richard C. Bishop, Professor of Agricultural Economics; Stephen M. Born, Professor of Urban and Regional Planning; Thomas A. Heberlein, Director of the Center for Resource Policy Studies; Kent E. Klepinger, Director of Bureau of Research, Department of Natural Resources; Diana M. Liverman, Assistant Professor of Geography; C.B. Tanner, Professor and Chairman of Soils. All faculty were from the University of Wisconsin-Madison.
2. In most cases joint work between social and natural sciences is multidisciplinary rather than

interdisciplinary. Throughout this paper the term interdisciplinary is used generically to cover both categories.

3. There is not so much a lack of information than a difficulty in finding it. After the speech was given, the Policy Center funded a small project to locate this material and a 10-page bibliography was prepared. A number of these are referenced in Note 4.

4. While the participants in our seminar were not familiar with a literature on interdisciplinary research, a postseminar search located over 100 references. Some of the most useful are listed below to provide further guidance and information for those interested in bringing together the natural and the social sciences.

Anbar, M. July, 1973. The 'bridge' scientist and his role. *Res./Devel.*

Mar, B.W., W.T. Newell, and B.O. Saxberg. 1976. Interdisciplinary research in the university setting. *Environ. Sci. Technol.* 10:650–653.

Chubin, D.E., A.L. Porter, F.A. Rossini, and T. Connolly, eds. 1986. *Interdisciplinary analysis and research.* Mt. Airy: Maryland: Lomond Publications.

Fischoff, B., 1981. No man is a discipline. In *Cognition social behavior and the environment,* ed. J.H. Harvey, 579–583. New York: Lawrence Erlbaum Associates.

Mathiasson, J.S., 1968. My discipline is better than your discipline: Some barriers to interdisciplinary research. *Can. Rev. Sociol. Anthropol.* 5:263–275.

Saxberg, B.O., W.T. Newell, and B.W. Mar, 1981. Interdisciplinary research—A dilemma for university central administration. *J. Soc. Res. Administrators* 13:25–43.

Sproull, R.D., and H.H. Hall, 1987. *Multidisciplinary research and education programs in universities: Making them work.* The Government-University-Industry Research Roundtable.

Stone, A.R., 1969. The interdisciplinary research team. *J. Appl. Behav. Sci.* 5:351–365.

Wohl, R.R., 1955. Some observations on the social organization of interdisciplinary social science research. *Social Forces* 33:374–383.