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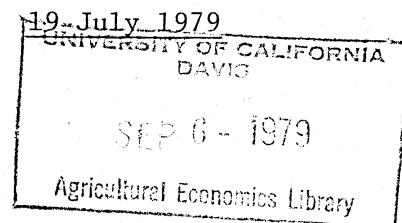
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Working with Other Disciplines

Earl R. Swanson



I

In this paper the term "discipline" simply refers to a specialized field of knowledge. Each discipline thus defined usually has a professional association and at least one journal. Equating a discipline to a profession is not completely satisfactory for all purposes but it is consistent with common usage and convenient for the task at hand. Within a university context, a discipline corresponds approximately to an academic department, and disciplines develop when both faculty and administration come to recognize reasonably distinct areas of inquiry.

It is important to recognize that each discipline is usually composed of a set of narrower specializations and that the comprehensiveness of the discipline has at least three properties. First, there is a common conceptual model, shared to some extent by individual members of the discipline. Second, there is also a set of phenomena common to the various specializations within the discipline. Finally, it is a collection of individuals with varying specializations, and the breadth of the discipline is rarely embodied within any one scholar (Campbell, p. 328-331). Cohesiveness of the discipline is achieved through the overlapping of the multiple narrow specialities which facilitates communication to a greater degree than is possible between disciplines.

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Footnote for page 1

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Figure 1, A Systems View of Problem-Solving (Mitroff et al. 1974,  
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II

Agricultural economists have a long tradition of relationships with other disciplines. These relationships have taken a variety of forms. For many of us, our undergraduate education included a substantial component of the natural sciences, together with an occasional sampling of the social sciences. In graduate study the contact with other disciplines frequently focuses on the so-called tools that can be used by the agricultural economist. These contacts are absorbed into our cluster of specialties and become a part of our collective professional competence. In our diverse professional activities we characteristically use data assembled by, and to some degree concepts borrowed from, other disciplines. But our profession also has a history of contributing to other disciplines as well as benefiting from them. Although it is not always apparent to our colleagues in other agricultural disciplines, our influence as an integrating discipline for the applied natural sciences in agriculture has been pervasive. The assessment of this potential by John D. Black in 1925 was essentially accurate. Just after the passage of the Purnell Act, in a talk to the Association of Land Grant Colleges and State Universities, Black emphasized the relevance of production economics to Experiment Stations:

"If I had time to do it, I could show that most of the problems of an economic nature which confront our (experiment) stations, require a combination of economics and natural science analysis. All problems of the relation of input to output are of this nature, all fertilizer input studies, many feeding experiments and cultivation experiments."

Our record of joint research with the natural sciences and with engineering is well documented in the AAEA surveys of agricultural economics literature. For example, Ben French has reviewed the marketing work that has been done with engineers and other specialists. Harald Jensen and Roger Woodworth have reviewed the parallel work of production economists with the biological scientists, in particular with those in agronomy and animal science. Stanley Johnson and Gordon Rausser have inventoried and evaluated simulation models, a number of which have dealt with data from natural science disciplines.

Relating of agricultural economics in a systematic way to the social sciences other than economics does not have a parallel record. For at least two decades, a recurring theme of presidential addresses, invited papers, and Fellow's lectures at our annual meetings has been the admonition to borrow from or work with other disciplines, usually other social sciences, in a problem-solving mode. These speakers gave advice in different forms, but the general direction, if not the implications, of the messages is clear.

### III

Well over half of the presidential addresses in the last 20 years have at least mentioned the need to relate to other disciplines. Only a sample follows. Bushrod Allin in 1961 told us that in order to keep farm economics relevant to its dominant purpose of improvement of the relative economic position of farm people, our intellectual interest must not be bound by blind devotion to any single social science discipline (p. 1018).

In his 1967 presidential address, Ed Bishop discussed the urbanization of rural America and noted that, "While we must lean even more heavily upon economics as our parent discipline . . . , we must also become more knowledgeable about the tools of the sociologist and political scientist" (p. 1007). Harold Breimyer also pointed out the need to borrow from sociology and political science to better understand the emerging economic structure (p. 1102).

After identifying research needs and problems, Dale Hathaway in 1969 indicated that, "If the needed research is to be done well, most of it must be interdisciplinary, involving technical as well as economic relations and other social sciences" (p. 1021). In the 1971 invited lecture, Glenn Johnson developed in some detail the rationale for working with other disciplines. Among the incentives for such effort, he recommended that our association join other associations in sponsoring an annual award for "distinguished public administration of issue-oriented problem-solving research programs" (pp. 737-738). In his 1972 presidential address, "Economics and the Quality of Life," Emery Castle commented on that supporting multidisciplinary endeavors was popular, but that the best way to organize for such integration with simultaneous disciplinary penetration was unclear (p. 729). The need for contributions from other disciplines in rural development was pointed out by Kenneth Tefertiller in 1973 (p. 771), and James Nielson, reflecting his experience as an experiment station director, advised in 1974: "We ought to do more to serve other disciplines and more work on disciplinary teams . . . . Frequently the biggest contribution of our profession has been to help synthesize results from other disciplines" (p. 870). James Bonnen's 1975 presidential

address considered needed improvements in the design of agricultural information systems. He noted that if such a system is to solve problems, it will inevitably combine and use different fields of knowledge (p. 760). As an incentive for working with other disciplines in the public policy area, Kenneth Farrell suggested in his 1976 presidential address that an AAEE award be given for outstanding contributions within the profession to the advancement of public understanding of major policy issues, with preference to contributions that are multiunit or multidisciplinary (p. 792).

Let us conclude this sample of advice on relating to other disciplines with Carroll Bottum's counsel given in an agricultural metaphor. In his Fellow's address in 1975, Policy Formation and the Economist, he indicated in a summary statement that we should ". . . split some new rails and spend a little less time sandpapering the old and we will have a bigger pasture. And, let's put in a gate so some of the other pertinent disciplines can join us in this enlarged pasture" (pp. 764-765).

At this point we conjecture that these numerous prescriptions reflect not only the increasing complexity of problems addressed by agricultural economists but also the trend, accentuated in the post World War II period, toward recognizing economics as the parent discipline of agricultural economics. As Kenneth Boulding noted in 1950, the success of what was then called the Ames School in agricultural economics was attributed to the discovery that there was no such subject as agricultural economics--that there was only economics applied to agriculture (p. vii). This distinction implies that we do not have our own cluster of specialties but that we are a part of another cluster--economics. In commenting on this

trend, last year Don Paarlberg observed: "The change in our discipline has been difficult for the traditionalists . . . some of our painfully acquired skills become obsolete. But, all members of the agricultural establishment have, to a degree, in their actions if not in their words, accommodated themselves to the change" (p. 774).

Some evidence that agricultural economics has retained its distinction from economics may be found in the 1978 presidential address of Tjalling Koopmans before the American Economic Association. He pointed out the need for economists to work with other disciplines in collaborative efforts but, noted that, "To economists (collaboration) is a new challenge and a new frontier" (p. 12). For agricultural economists, and to some extent for specialists in labor economics, finance, business administration, and other areas related to economics, it is an old frontier, but nevertheless one that needs our most careful attention.

#### IV

A fundamental question has been raised: Who should integrate the results of research in the separate disciplines? Should it be the specialists working together in the research process, should it be the decision maker, or someone in between? Clearly, this question cannot be answered in the abstract, but the weight of professional advice has been to shift emphasis to additional integration in the research process itself.

Although difficult to document, there has been some response to the call for interdisciplinary research articulated by AAEA speakers. The fact that reports from cooperative studies with other disciplines do not often appear in the American Journal of Agricultural Economics indicates



in part that the research output from such projects does not lend itself easily to journal reporting, but also that such studies are not perceived to be in the mainstream of our profession. An informal survey of the AJAE over the last 20 years indicates that virtually the only kind of joint research reported is that with natural scientists within colleges of agriculture.

In the remainder of this paper the focus is on the process of research with other disciplines. An improved understanding of the process should assist us to allocate our research resources and, for that fraction devoted to working with other disciplines, to improve our effectiveness.

## V

Before proceeding to analyze the nature of cross-disciplinary research, we distinguish the classes of research activity along a continuum. These classes range from unidisciplinary to multidisciplinary to interdisciplinary to transdisciplinary, depending on the degree of integration, a concept introduced by Rossini et al. Note that this classification refers to a particular research activity or project and not to other relationships among the disciplines. Implicit in the concept of integration is an anticipated trade-off between comprehensiveness and depth of analysis. A narrow disciplinary mix may lead to analytical depth at the expense of comprehensiveness. This balance can only be judged with respect to the objective of the particular research effort. Research output in the form of a published report is the most easily available evidence for evaluating the degree of integration.

Editorial integration in research output is the lowest level of integration. It results in a report or a set of disciplinary reports on the same topic edited without accounting for differences in terminology and concepts among the disciplines. While the report or reports may share an introduction and a conclusion, these sections are not of an integrative nature and may simply describe the history of the research project. Improvement in editorial treatment may involve consistent use of terminology throughout the study and the avoidance of isolated vocabularies. The report(s) that result from editorial integration may be considered multidisciplinary, and in the nature of a patchwork quilt. On the other hand, interdisciplinary research ideally would yield a seamless garment.

Interdisciplinary research is characterized by systemic integration. This implies that there is a common view or representation which permeates and dominates the entire research effort. Such integration may be achieved by the use of a formal model, but this should not be viewed as a stringent requirement. However, evidence of strong integrative links among the various parts of the report is required.

Finally, the upper limit of our continuum, a theoretically complete integration, has been termed transdisciplinary (Rossini et al., p. 6). This classification implies that we transcend our individual skills and disciplines and that we work with other disciplines to create a new common cognitive map of the problem. This classification remains a theoretical ideal for any study of more than a very limited scope.

## VI

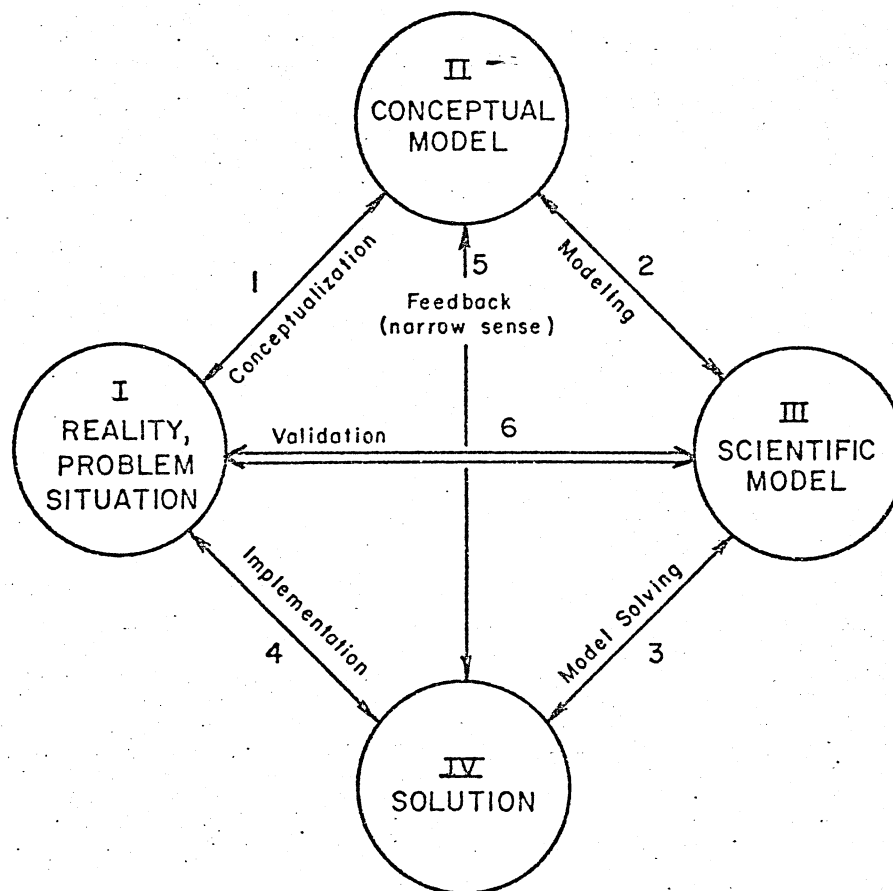
If we wish to achieve the interdisciplinary or systemic level of integration in a research effort, what obstacles are to be overcome? Two related considerations are involved. The first consists of the knowledge or epistemological

problems and the second of social elements (Petrie). The high level of interaction between these two elements implies that we find it difficult to separate them even for exposition. In this section we discuss the knowledge aspects of crossdisciplinary research.

The admonitions that we have received to work with other disciplines have been linked with problem-solving, implying that the research output should be useful to public and/or private decision makers. Given the problem-solving basis as the need for working with other disciplines, a more formal perspective will facilitate our analysis. We choose a systems view as the most appropriate (Figure 1). This view is sometimes referred to as Singerian-Churchmanian and we employ the version presented by Mitroff et al., and Mitroff and Pondy. Systems analysis in relation to agricultural and natural resource economics has been discussed by Johnson and Rausser in Volume 2 of the AAEA literature survey.

A particular research activity may begin at any of the four elements and may end at any of the four elements. One may begin with taking any of the following as a given: problem, conceptual model, scientific model, or solution. Each path between these four elements exists in both directions implying a wide diversity in the individual processes involved in problem-solving. In fact, even the simple system of Figure 1 has 3555 total sub-systems that can be formed by considering all possible ways of combining 2, 3, and 4 elements. This number also includes the directionality of the connections between the four elements.

Although not every crossdisciplinary inquiry starts with element I, reality or the problem situation, it is appropriate for our discussion to



A SYSTEMS VIEW OF PROBLEM-SOLVING

FIG. 1

start at that point. The first phase then requires formulation of the conceptual model. In some cases the conceptual model may be formal, a more likely occurrence in economics and the natural sciences than in the other social sciences. The conceptualization process defines and bounds the problem in broad terms, the variables that are to be considered, and the level of aggregation. Development of the scientific or formal model (III) is the next step. The modeling process includes the translation of the conceptual model into relationships which are then given greater empirical content. This is followed by the solution (IV) and, finally, implementation brings us back to an impact on the initial problem situation (I). For completeness, note that paths also exist for model validation, between I and III, and for feedback interactions between II and IV. Certainly, the ideal problem-solving loop I-II-III-IV-I is not often found in individual projects. More often a subset describes the activity.

It is tempting, and only somewhat diversionary, to classify the research efforts of agricultural economists operating in their single disciplinary mode through use of this diagram. The required skills vary among the elements and this variation represents another dimension of specialization among persons within our profession. Very few members of our profession have seriously worked in all four elements.

Among the many loops let us consider two illustrative ones, II-III-IV-II and I-II-IV-I. Those agricultural economist who follow loop II-III-IV-II are concerned primarily with the activities of modeling and model-solving. Improved solutions to more complex models with feedback in the narrow sense (Figure 1) and no immediate interest in implementation characterizes

this loop. Many of our colleagues in the natural sciences operate with this loop and acknowledge this loop as the only valid form of scientific activity.

Another loop used in agricultural economics is I-II-IV-I. This loop omits element III (Scientific Model). There is confusion in this loop between conceptualization and modeling and an attempt to substitute a conceptual model for a scientific model. No matter how rich in detail the conceptual model might be, it does not, in my judgment, substitute for a validated scientific model. Omission of the scientific model implies the loss of the opportunity to develop the logical structure of the conceptual model in a systematic way and to perform the important validation process. Thus the approach implied by the I-II-IV-I loop weakens any potential implementation.

We now return to the knowledge aspects of crossdisciplinary research. In terms of our system view (Figure 1) it is necessary for participants to communicate with other, ideally, in each of the four elements--problem, conceptual model, scientific model, and solution. Perhaps the most important communication takes place with respect to the conceptual model. Each specialist can be expected to bring his own paradigm (Kuhn, Maruyama, and Johnson and Rausser) into play as he conceptualizes the problem. The degree to which core members of the research team share these paradigms is crucial in determining the level of integration in the final report.

As an example, let us consider three so-called pure paradigms (Maruyama):

1. unidirectional-causal paradigm,
2. random-process paradigm, and
3. mutual-causal paradigm.

There are, of course, mixtures and overlaps between and among these three paradigms as well as between these and many other paradigms. For example, the combination of 1 and 2 may describe the classical approach to production function analysis, with multiple regression forming a part of the scientific model. Suppose that an agricultural economist is using this 1-2 combination paradigm and that he is working with a biological scientist who subscribes to paradigm 3, a mutual-causal paradigm, as a description of the system under study. Thus the biological research worker looks for feedback loops in the system and for self-cancellation or self-reinforcement based on concepts of homeostasis. Although the economist may be familiar with related concepts from general equilibrium theory, the concept of the production function from the static theory of the firm does not carry him very far toward achieving a common view with the biologist. Until they have at least moderate agreement on the paradigm, their prospects for successful interdisciplinary research are limited.

The concepts and terms from statistics may form a useful communication device. Discussion of the design of the experiment or the survey in the development of the scientific model will often lead to an improved understanding of the difference in paradigms originating in the disciplines of the participants.

Recent developments in the field of sociobiology have helped identification of certain concepts common to economics and biology (Ghiselin and Hirshleifer). Scarcity, competition, equilibrium, and specialization play similar roles in biological and economic systems. There are also certain terminological pairs--mutation/innovation, optimizing/adapting, and

evolution/progress, which are common to the fields. In a sense, economics can be viewed as a subfield of sociobiology (Ghiselin). In the other direction, Becker has modified economic theory to provide an explanation for altruism among persons which parallels a biological explanation applicable to other species.

A few examples from the social sciences other than economics will indicate that there are also some common starting points for conceptualization of a given problem with these disciplines. The simple unidirectional causal paradigm corresponds to a social organization that is hierarchical, while the mutual-causal paradigm implies a nonhierarchical social organization with considerable interaction among members. The equilibrium concept, a member of the mutual-causal paradigm, is also present in law (Timmons). The transaction is the unit of study in law, and the relative stability of the system's behavior is an area of inquiry. Although the more traditional political science concepts do not appear to be highly structured, they do appear to be contextual in the sense that they may utilize some variants of the mutual-causal paradigm with an embodied economics component (Nagel).

We should not underestimate the difficulty of achieving mutual understanding of paradigms between disciplines. Rossini et al. report that in a number of interdisciplinary studies, economics was the most difficult for participants from other disciplines to understand. The jargon, methodological preoccupations and world view frequently proved difficult for noneconomist research collaborators.

Without at least a minimum of the sharing of paradigms among the specialists involved in a joint research effort, the frustrations from



communication are going to be very high. In particular, if the communicating parties are unaware that they are using different paradigms and are aware only of differences in vocabulary or language, each party will view the communication difficulty as resulting from the other specialist's lack of intelligence, deceptiveness, or insincerity. This leads us to the second aspect of research with other disciplines, the social process.

## VII

Before treating organizational alternatives for the research team itself, consideration should be given to the institutional setting (Petrie). If the research is to be both problem-solving and interdisciplinary, an academic institution is not likely to provide an ideal environment. The linking of research with graduate education leads to emphasis on loop II-III-IV-II in Figure 1 which develops skills in conceptualization, modeling, and model solution, rather than the implementation phase associated with decisions made in the public and private sectors.

In order to encourage cooperative research among disciplines, a number of academic institutions have formed units outside the usual departmental pattern (Ellis, and Capener and Young). For example, special institutes have been established to study the energy problem, the environmental problem, and so forth. Less formal structures such as committees have also been employed, especially within agricultural experiment stations. The problems of a reward and incentive system that follows disciplinary lines and the attendant risks for younger staff members who participate in such interdisciplinary undertakings, have been spelled out elsewhere, in particular

in the paper by Glenn Johnson in 1971 and by Koopmans (p. 13) The most successful interdisciplinary research projects at academic institutions appear to be those that have been externally funded and that have a rather limited group, with no more than four or five disciplines represented. The institutional environment for the research team must be one that permits a substantial amount of start-up time and that has flexible hiring arrangements. It is important that institutions contemplating the support of interdisciplinary work understand its somewhat peculiar nature.

It is unlikely that a research team deliberately selects in advance the intellectual and social components that determine the organizational pattern. It is more likely that the organization evolves into a stable pattern by trial and error. Nevertheless, it is useful to identify four types of approaches to interdisciplinary research and briefly to discuss their strengths and weaknesses (Rossini et al.). These refer principally to teams containing from three to five core disciplines.

A. Common Group Learning

The research problem is defined and bounded by group decisions. Based on the interests and competencies of the team members, a division of effort is decided upon. Preliminary analyses are prepared and each member reads the analysis of every other member. After discussion, reports are re-written by members who are not specialists in the area (Figure 2A). The final report is the common intellectual property of the group. This approach clearly limits the disciplinary penetration. In terms of our systems view (Figure 1), the interactions take place primarily between the problem (I) and the solution (IV).

## A. COMMON GROUP LEARNING

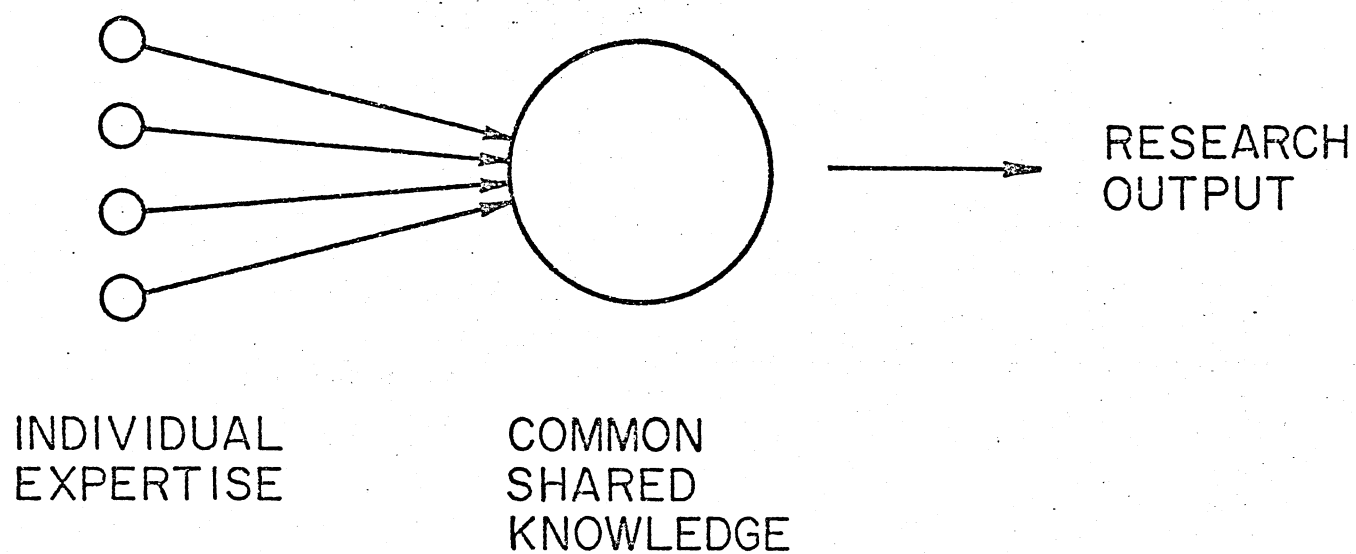


FIG. 2A

### B. Negotiation Among Experts

The beginning of this approach is similar to Common Group Learning, with assignments of parts to disciplinary specialists. Attempts are made to bring the full power of the appropriate discipline to bear on its assigned part, and integration takes place by negotiation (Figure 2B). Negotiation focuses only on the overlaps and linkages among the separate draft reports. The next iteration, done by the initial authors, takes into account the results of the negotiation. Nonexperts do not rewrite the separate sections of the final report. Many agricultural economists may be uncomfortable with this approach, especially when economics is competing with other disciplines as an integrator. Committees of the National Academy of Sciences and task forces of the Council for Agricultural Science and Technology often tend to follow this pattern in the preparation of assessment and state-of-the-art reports.

### C. Scientific Modeling

A formal model may serve a key integrative role. All members need not participate in model construction (Figure 2C), but ideally all should contribute data. Models often tend to narrow the research focus, but they also encourage systematic collection and analysis of data. This approach works best when closely related disciplines are involved in solving an easily-defined problem. For public policy-related studies, implementation usually requires a framework broader than the model alone. Finally, the model may have the advantage of depersonalizing the process of getting input from each participant.

### D. Integration by Leader

The problem is divided and allocated by the leader on the basis of expertise and interests of participants. The only interaction occurs

## B. NEGOTIATION AMONG EXPERTS

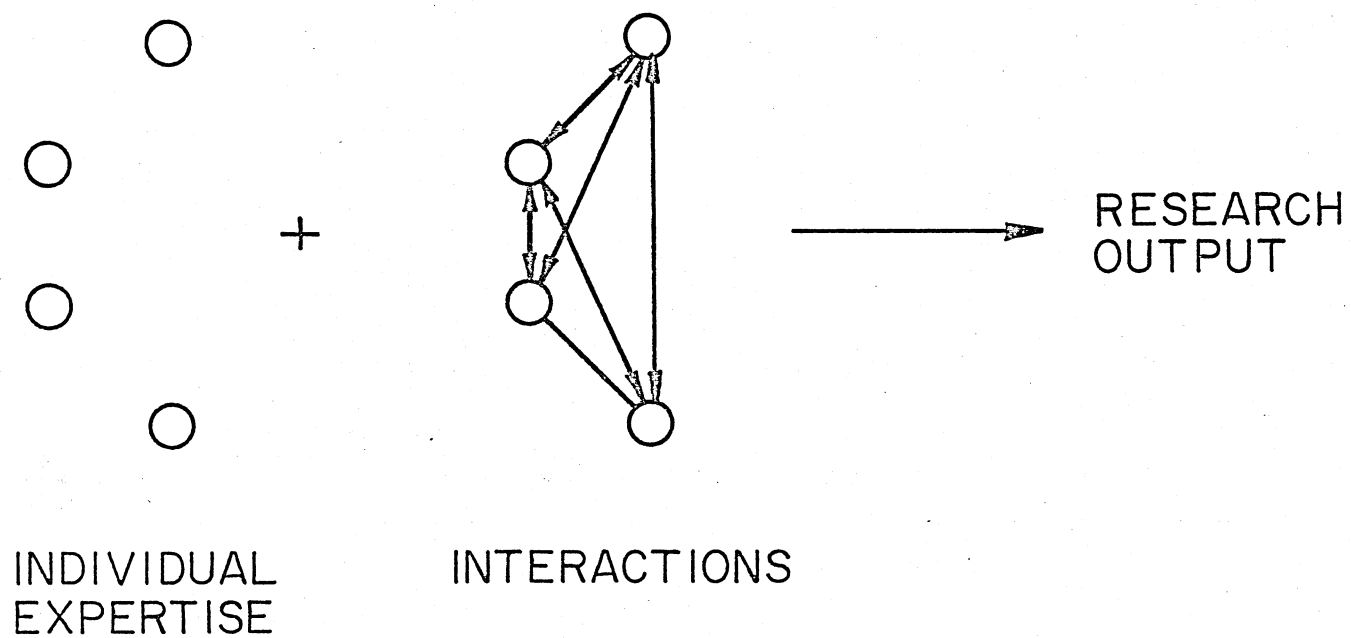


FIG. 2B

## C. MODELING

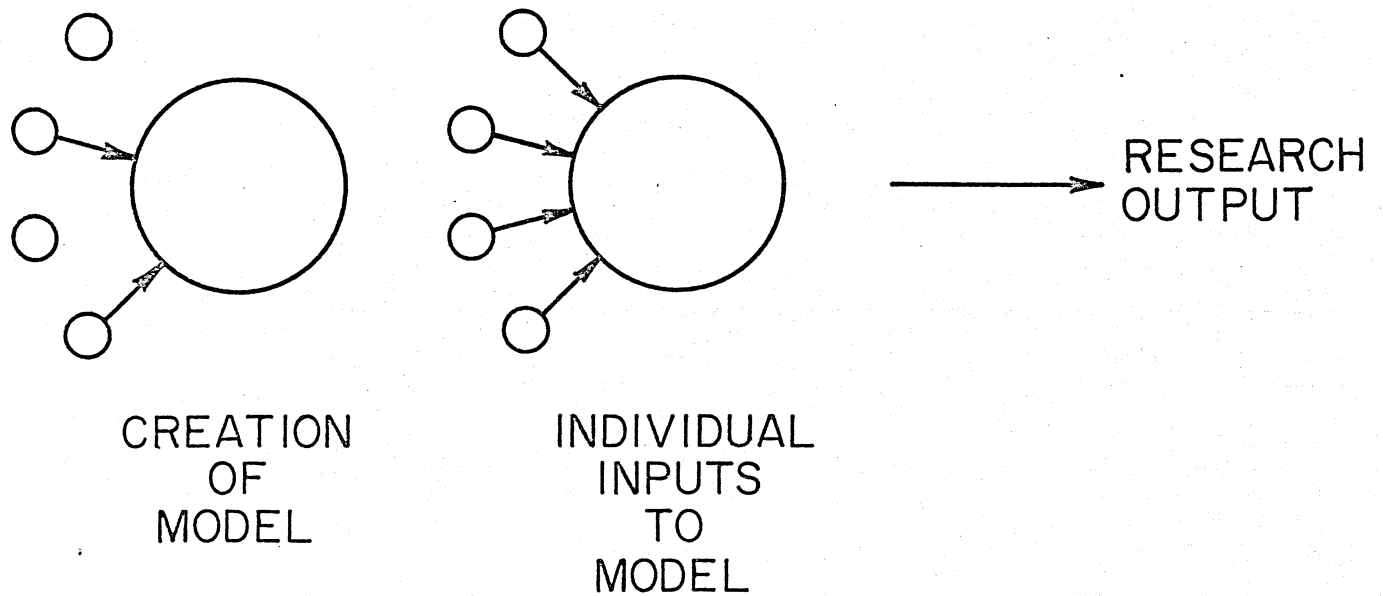


FIG. 2C

between the leader and the individual team members (Figure 2D). The communication pattern is that of hub and spokes, an efficient one for communicating simple tasks in small groups (Bavelas, and Guetzow and Simon). In the other three approaches, common group learning, negotiation among experts, and modeling, the communication network needs to provide direct channels between most of the individual participants.

Each of these four ideal models implies a somewhat different kind of leadership style. Consider the following five leadership styles (Robinson and Clifford):

1. activator,
2. controller,
3. martyr,
4. cavalier, and
5. abdicator.

The activator uses a democratic-facilitating type of leadership in which the style is group centered. He is active and flexible in structuring group behavior and recognizes that everyone in the group has some skill or knowledge which exceeds his own. The controller's pattern is described as autocratic or authoritarian with rigid behavior that strengthens his position in the group. The martyr is passive and hopes that the participants will feel pity for him and perform their assigned tasks. The cavalier is permissive and, although he may entertain the participants, he cannot structure group behavior. The abdicator assumes little responsibility and behaves passively.

## D. INTEGRATION BY LEADER

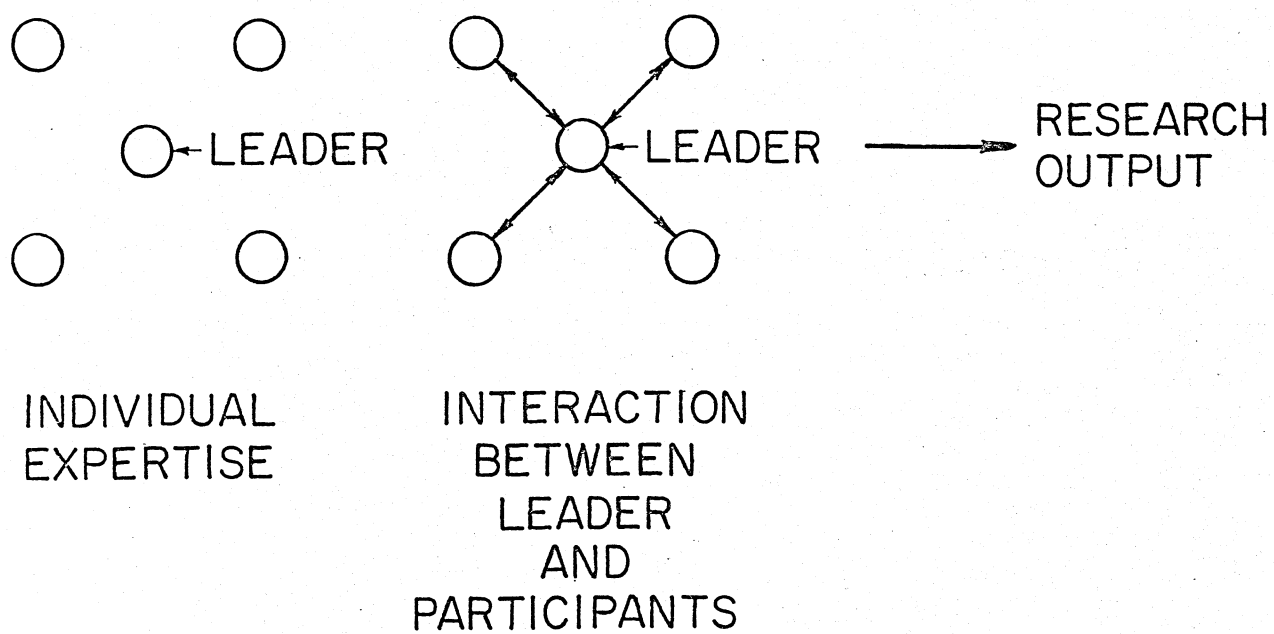


FIG. 2D



In the Rossini study, it was not surprising that the activator style of leadership appeared to be the most effective in terms of achieving integration in crossdisciplinary research. The second most effective was the autocratic or controller style, while the lowest level of integration was achieved with nondirective and permissive leadership styles (martyr, cavalier, and abdicator).

For the common group learning (A) and negotiation among experts (B) approaches, it is clear that the activator is likely to be most effective. The use of a model (approach C) should at least be initiated with activator leadership, but may require a shift to the controller pattern in the final stages.

The success of the integration-by-leader approach (D) depends very much on the leader. The routine demands of administering the project may be such that, even in the unlikely event that the leader is an expert in all the separate disciplines involved, the integration will be weak and the research output multidisciplinary rather than interdisciplinary.

#### VIII

The type of research team organization that is used for a given project usually cannot be determined by reading the report of the results; participants in the research process are the only source of information. Consequently, in order to illustrate the use of the classifications and concepts presented, I now draw on some research efforts in which I have recently participated.

In the early 1970s, the College of Agriculture, University of Illinois received a grant of approximately \$600,000 from Rockefeller Foundation for the project, "Nitrogen as an Environmental Quality Factor." The funds were allocated largely on a departmental or disciplinary basis, with five major groups participating: rural sociologists, agricultural economists, agricultural engineers, agronomists, and veterinary scientists. The common theme of nitrogen and the environment was the connecting link in the five separate efforts (Deeb and Sloan, Dickey and Lembke, Swanson, Taylor, and van Blokland, van Es and Sofranko, and Welch). A book in preparation is being written by a single author. This study corresponds to our multidisciplinary category because the separate disciplines approached a common problem, and the integration was at the editorial level, not at the conceptual level. Thus, the grant provided additional funds for departments to do research on the topic but did not necessarily provide the ingredients to integrate the results. The members of the team met to

discuss one another's progress only occasionally. Although useful and meaningful work came out of the project, it cannot qualify for the title "interdisciplinary."

A second project also had an environmental orientation. The project, "Soil Loss from Illinois Farms: Economic Analysis of Productivity Loss and Sediment Damage," was funded at a level of \$122,000 by the Illinois Institute of Environmental Quality, a state organization. Six watersheds were studied. The organizational mode featured economics as the integrating discipline, and a formal model provided the scheme for integration. This organization is an example of approach C (modeling) discussed above. Contributing specialists included an agronomist, a hydrologist, an agricultural economist, and a finance analyst. All persons were hired to work in the Department of Agricultural Economics, an arrangement that clarified administrative allegiance. Early establishment of a satisfactory economic model permitted the contributors to identify their own objectives and contribution to the project. The impact of the results on public policy can only be identified indirectly. A member of the Illinois Pollution Control Board mentioned that it would have been helpful if every important policy decision made by the Board could have had a comparable base of information. The usefulness of the report was, in part, a result of the interdisciplinary character of the project, even though economics was the only social science discipline.

A third project, sponsored by National Science Foundation-Research Applied to National Needs, was an assessment of hail suppression technology (Changnon et al. and Farhar et al.). The 18-month project, carried out under a grant of \$260,000, involved agricultural economists and other social scientists including sociologists, a political scientist, and a lawyer.

Natural scientists included those from atmospheric science, one of whom served as team leader, and an environmental scientist. The organizational approach was a combination of B (negotiation among experts) and C (modeling). Although the central economic analysis used the usual economic concepts implicit in a national spatial-equilibrium model and the theory of the firm at the individual farm level, these concepts were modified in the course of the project. The modifications represented important inputs from sociologists and the lawyer as well as others. In the preparation of the conclusions and policy recommendations, the political scientist and the lawyer had important contributions to make. Among other things, the study recommended that funds for research and development of hail suppression either be substantially increased or eliminated. As a result of the study, NSF has now discontinued the five-million dollar line in their budget for hail suppression research. In addition, many of the recommendations have found their way into statements of national policy (report to Secretary of Commerce from the Weather Modification Advisory Board 1978). The success in terms of policy impact was due, in a large measure, to the interdisciplinary nature of the study.

A final example is the National Defense University Long Range Climate Project. This project proceeded in three phases. First, climatologists assessed global temperature and precipitation changes to the year 2000 for different major crop producing areas of the world. Then, five climate scenarios were constructed. The second phase produced estimates of yield responses to weather variables made by agronomists. This permitted an assessment of the yield consequences of each climate scenario. The final

phase was the input of this information into the USDA's grain-oilseed-livestock (GOL) model to determine the impact of the five climate scenarios on location of crop production, international trade, and crop prices. Although the GOL model provided the integrating framework, the climatologists were unaware, or had only very hazy conceptions of how the GOL model operated when they made their assessments. Similarly, the agronomists were not aware of the various aspects of the GOL model when they made their crop response predictions. Nevertheless, the GOL model served as an integrating device for the total project. Organizationally, this project represents a mix of modeling (approach C) and integration by leader (approach D).

## IX

To sum up, let us first consider those research efforts in which agricultural economists work with natural sciences and engineering. In my judgment, the modeling (approach C) or integration by leader (approach D) are more likely to provide a satisfactory environment in which agricultural economists may contribute. However, one should not presume that what seems to be a natural integrative role for agricultural economists will be automatically perceived as such by natural scientists and engineers. These disciplines also have competing macro models (ecosystems, energy accounting systems, etc.) with integrative potential and some melding of concepts may be required.

If social scientists, in addition to agricultural economists, are included in the research team, agricultural economists may again find their contribution greater under the modeling (approach C) with participation, as far as possible, of all team members in the modeling effort. The

economic modeling may serve to integrate the important elements of the natural sciences and engineering. In many contexts, however, there is an integrating task that is beyond economics. If the research has an implementation objective such as the drafting of legislation, it is important for those responsible for that part of the project to at least be somewhat familiar with the modeling process.

An alternative appealing to some agricultural economists in joint research involving other social scientists is negotiation among experts (approach B). Given the preferences and skills of the individuals involved and a limited time frame, this approach may provide a better organizational structure for interdisciplinary research than one involving modeling.

In this paper an attempt has been made to describe research processes involving more than one discipline. Substantial effort, together with some compromise, is required to prevent research projects with interdisciplinary objectives from becoming multidisciplinary. Although the potential contribution from agricultural economists working with other disciplines remains high, allocation of large segments of our professional resources to such activity should be done with caution. The gains from specialization are too high to be casually sacrificed; the opportunity costs of doing interdisciplinary research may easily be underestimated. We should recall that the objective of the American Agricultural Economics Association is to further the development of systematic knowledge of agricultural economics. A part of the development of that systematic knowledge requires working with other disciplines, and it is important that we do that part well.

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