Incorporating Problem-Based Experiential Teaching in the Agriculture Curriculum

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ABSTRACT

There is an urgent need for students in agriculture and natural resource management to develop competencies to solve problems in multiple-goal situations. Useful materials for problem-based experiential teaching are being incorporated into curricula and courses at agricultural universities worldwide. A forestry and an agronomy course at Iowa State University have incorporated problem-based team projects on real-world situations as a means of providing students with integrative and meaningful experiential learning. Teams pick their own problems, identify the subject matter competencies required to confront the problems, decide on team membership based on these competencies, and spend a significant portion of a semester in out-of-class activities researching their problems and developing recommendations to confront the problems. Teams present their recommendations before an audience composed of class members and/or clients for whom they have developed their analyses and recommendations. Grades are assigned in a way that recognizes both the effectiveness of a team in meeting its assignment and the contribution of each individual to team activities. Student evaluations of these courses indicate that students recognize the integrative nature of the problem-based team activities and appreciate the practical value of this teaching approach.

Problem-solving and critical-thinking skills are among the most cited educational needs in curriculum revitalization efforts of colleges of agriculture and natural resource management the world over (Bentley et al., 1992; Coulter, 1992; Goodman, 1992; Gordon, 1992; Merritt and Hamm, 1994; Pauker, 1987; Porath, 1987; Richards, 1988). These needs can be puzzling since the very business of agriculturists is to solve problems such as finding the optimum fertilizer recommendation, formulating the ration that will give the best daily rate of gain, or finding an insecticide that will selectively control a pest. In spite of an impressive litany of apparent successes, modern agriculturists have created a number of new, unforeseen problems while attempting to solve the old ones. In part, this development is due to the intrinsic complexity of industrial production systems (Wilson and Morren, 1990) in contrast with (i) the linear and compartmentalized education received by most students of agriculture (Pearson and Ison, 1992), and (ii) the simplistic criterion by which the success of such systems has been traditionally evaluated: generation of the greatest economic value possible with the minimum investment (Hall, 1990). These approaches to agricultural education require additional dimensions to adequately address the features of broad-based agroecological systems. As stated in a recent newsletter for agronomists:

It is apparent, now, that American agriculture affects the integrity of ecological systems, and that the growing public concerns about the effects of some agricultural practices on the environment and food safety must be addressed. To maintain the viability of American agriculture, the research community must develop new practices and technologies to ensure that agricultural production is not only efficient and profitable, but also environmentally safe and socially acceptable (ASA, 1992).

Such newly defined goals extend beyond the traditional agricultural objectives of maximum productivity and economic efficiency. The study of agroecological systems and their modern problems must include multiple objectives and constraints. Yet, most agriculturists are trained in methods of inquiry that do not emphasize multiple-goal resolution of problems (Foster and Pikkert, 1991). A disinterested observer of the situation could not be blamed...
for asking: "Are the specialists who have given us modern agriculture, with its full slate of environmental and social ills, the very people whom we should depend upon to confront the problems that are largely of their own creation?" (cf. Ludwig et al., 1993).

MEETING THE CHALLENGE

The analysis of Bawden et al. (1986) is that problems resulting from application of modern agricultural approaches result not from the intent nor incompetence of agriculturists, but from the lack of appropriate methods of inquiry. The application of positivist/reductionist approaches prescribes that systems under investigation must be simplified to their smallest functional units, then studied while holding variable influences fixed (Kuhn, 1970). Scientific method, therefore, promotes the isolated study of system components in linear fashion (one problem at a time), and leads to the assumption that there is closure and advancement as these individual and neatly packaged experiments are completed (Platt, 1964).

It can thus be understood why the scientific agriculturist favors research on aspects of the production system that are amenable to simplification and reductionist approaches. Scientific research, so structured, does not pretend to comprehend agroecological systems in their totality, but rather confronts problems as they "emerge" and according to their economic importance (Busch and Lacy, 1983). This narrow view leads to disparity between the apparent gains of science and technology and the hidden and unaccounted social and environmental costs of that technology. As Viederman (1992) puts it:

The "scientific assessment" and the "public assessment" of environmental problems are both based upon an implicit or explicit cost-benefit analysis, an understanding of possible trade-offs, and of opportunity costs. But in reality there can be no trade-off, for example, between jobs and the environment because people and nature are both of value. The alleged trade-offs are forced in public debate today, in large measure because we have allowed economics to become the language of politics, ignoring ethics and values...Politics must be informed by a new ecological economics that, unlike the present neoclassical paradigm, will pay serious attention to the natural world, both as a resource and as a sink for the wastes of our lives, and will deal seriously with the need for equity and distribution for both present and future generations. It will avoid the "physics envy" of the neoclassicist's model that regales us with elegant statistical and mathematical manipulations, giving seeming precision to matters that are basically moral and ethical...Policymaking is an exercise in values and morality that requires public participation, which scientists seem to distrust.

Perhaps it would be more accurate to state that scientists are uncomfortable with, rather than distrust, situations that require understanding and manipulation of a number of intangibles according to ill-defined rules and processes and that produce results judged by subjective norms (Vitore and Cradle, 1992). Yet such situations describe the very processes by which individuals, organizations, and government agencies arrive at decisions crucial for the management of resources. Goodman (1992), an industrialist, states: "As I think about the needs of industry in a changing world, I think of needs such as flexibility, diversity, perspective, and values." Scientific reductionism is clearly not a method of inquiry uniformly suitable to satisfy all these needs. If institutions are producing graduates of agriculture and resource management disciplines for whom scientific reductionism is the only way to confront the most serious environmental crises that humankind is likely to encounter, such students are done a serious disservice.

Students prepared with an assortment of problemsolving approaches will undoubtedly be better able to confront complex situations than those who must adapt all problematic situations to suit their only tool. There is a proper place for the application of reductionism, but the teaching of agriculture as the infallible application of reductionist science to the natural world has discouraged normal and healthy questioning of principles and practices in their ecological and social context. With diversity comes versatility, and as Campbell and Martin (1992) point out, different inquiry methodologies are suitable for different purposes. One of the main objectives of successful agricultural education should be for students to perceive agricultural science above all as a human activity, responding to human needs and subject to human fallibilities. This perspective allows students to recognize the limitations of scientific reductionism as an exclusive method of inquiry and to appreciate that the best educated scientist knows when and where to apply the techniques of reductionism, and when and where to apply more comprehensive approaches (Wilson and Morren, 1990).

Despite the existence of literature and experience (Bawden et al., 1986; Checkland, 1981; McRae et al., 1989; Pearson and Ison, 1992; Richards, 1988; Straquadine and Egelund, 1992), many agricultural educators may not be aware of the research that has been devoted to teaching strategies and techniques that produce agriculturists competent to deal with agricultural issues in broad, systemic fashion (Foster and Pikkert, 1991). As early as 1982 the USDA, academic deans of land-grant universities, and several industry sponsors supported the creation of a National Agricultural and Natural Resources Curriculum Project whose purpose was to develop new curricula and instructional approaches for six priority areas (Wilson and Morren, 1990):

1. Systems analysis in food, agriculture, and natural resources
2. Problem solving
3. Ethics and public policy
4. Cultural and social aspects of domestic and international agriculture
5. Energy use in food and agriculture
6. Integrated reproduction management

The outcome of this project was a body of resource materials (Merritt, 1986), a textbook (Wilson and Morren, 1990), and a number of instructors trained at a series...
of regional workshops on systemic, problem-based, experiential teaching methods. A number of courses have been created, and many agriculture college curricula of U.S. universities have been revised based on the outcome of this project.

A CURRICULUM REVISION EMPHASIZING EXPERIENTIAL PROBLEM-SOLVING SKILLS

At Iowa State University (ISU) a recent revision of the undergraduate agriculture curriculum has resulted in a new emphasis on coursework and experience in a formal curriculum component called "Personal Development, Human Relations, and Global Awareness." Included in this revision are courses and experiences in ethics, critical thinking, environmental awareness, and experiential problem-solving (Green and Mullen, 1993).

EXAMPLES OF PROBLEM-BASED EXPERIENTIAL TEACHING

Iowa State University's emphasis on course work and experience recognizes the need to teach multiple-goal problem-solving by means of realistic scenarios with immediate and practical feedback. Students respond to and assimilate personal experiences more favorably than they respond to controlled exercises with contrived goals and solutions, i.e., those where they feel that they cannot really affect situations or alter outcomes (Kolb, 1986). Following are examples of two courses that illustrate the effective incorporation of experiential learning techniques.

Forestry Capstone Course. In 1975 a major change was made in the teaching of the capstone senior course in forestry (Forestry 454). This course requires students to synthesize biological, economic, social, and political principles studied in preceding courses. Teaching experience indicated that methods in addition to role-playing and analysis of case studies were needed to retain the interests of students. It was decided to organize student teams to work on actual problems submitted by practicing foresters and other clients throughout the state (Countryman and Thomson, 1979).

Students organize the teams and select a problem from among those submitted. Students must consider the skills needed to address the problem of their choosing and must then find class members with those skills. To do this, students must be familiar with one another's interests and learning styles. During the course introduction, the instructor provides the opportunity for students to describe themselves and their preferences. Each team begins its activities by defining the problem they face. Working from materials submitted, discussions with their client, and site visits, the team develops a class presentation on the four elements of a problem described in Stoltenberg et al. (1970): (i) the decision-maker (in this case, the 'client'), (ii) the decision-maker's objectives, (iii) the alternatives, and (iv) the context.

The client is the individual (or group) responsible for the outcome of a decision. Often, clients have one or more objectives that must be defined, yet they may have difficulty articulating their own objectives and criteria. The student teams must begin by working with the decision-making client to formulate statements expressing clearly defined goals.

Teams are assigned the task of recommending at least two alternative solutions or improvements for the client's problematic situation. The problem-solving process should clearly identify and balance constraints and trade-offs associated with meeting the client's objectives. An important element of the problem definition phase is the context or environment of the situation. Every decision-maker is faced with external or uncontrolled factors that affect the final choice made. Such factors include physical, legal, and economic constraints.

Teams then collect necessary data, develop alternative solutions, analyze consequences expected from each alternative, and present a written and an oral report of their findings to the client at the client's place of business. Before making this final formal presentation, teams rehearse their presentations in class. Such presentations are critiqued by both faculty and classmates. To provide a friendly and nonthreatening environment for students testing various presentation styles and technologies, these initial presentations are not graded. Based on this informal evaluation, teams develop the final presentations given to clients. Oral reports are approximately 1 h in length, followed by a question and answer period. On the basis of the oral and written reports, clients can make informed decisions based on a number of alternatives.

Students are graded in a manner that reflects the many facets of the situations confronted (Table 1). First, half the grade is a team score assigned equally to all members. The second half is individualized for each member. In addition, one-third of the grade is a score derived from teammate opinions about individual contributions to the total team effort. After the final presentation, each team member is asked to allocate a number of points to their teammates, giving none to themselves. The criteria given are effort, intelligence, and reliability. Before students allocate the points, they are assured that their evaluations will be kept in strict confidence, but that each student will know the total number of points they receive from their teammates. Another third of the score comes from the client, based on the situation's difficulty, the effort displayed by the team, and the usefulness of the team's approach. This portion of the score reflects how well the team focuses on a client's problem and rewards teams for undertaking complex problems. The final third of the

Table 1. Grading of students in Forestry 454 reflects team and individual effort, as well as independent evaluation from faculty and clients.

<table>
<thead>
<tr>
<th>Source of evaluation</th>
<th>Points</th>
<th>%</th>
</tr>
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<tbody>
<tr>
<td>Individual evaluation by teammates</td>
<td>200</td>
<td>(33.3)</td>
</tr>
<tr>
<td>Individual evaluation by faculty members</td>
<td>100</td>
<td>(16.7)</td>
</tr>
<tr>
<td>Team evaluation by client</td>
<td>100</td>
<td>(16.7)</td>
</tr>
<tr>
<td>Team score based on difficulty of problem, team approach and effort</td>
<td>100</td>
<td>(16.7)</td>
</tr>
<tr>
<td>Team score based on oral report</td>
<td>50</td>
<td>(8.3)</td>
</tr>
<tr>
<td>Team score based on written report</td>
<td>50</td>
<td>(8.3)</td>
</tr>
<tr>
<td>Total</td>
<td>600</td>
<td>(100.0)</td>
</tr>
</tbody>
</table>
score is derived from faculty evaluation of the team and its written and oral reports.

Class size has varied from 15 to 60 students during the 18 yr the course has been taught with this format. Teams of five members have ranged from 3 to 12 per class. A total of 559 students have taken the course and have completed a qualitative evaluation (90% response rate). There has been much student enthusiasm for the class. Ninety-four percent of respondents have indicated that the course forced integration of subject matter they have previously learned, and regarded this as a worthwhile learning experience. Each team visits its project location an average of three times (averaging 13.2 h total travel time). In addition, individual students report spending an average of 113.7 h working on project activities outside the classroom. This averaged to 7.6 h per week, an amount of time comparable to that expended for a four-credit course over a 15-wk semester. Clients often reimburse student teams for some costs associated with travel and presentation of team reports (e.g., printing costs). Students report spending an average of $24.27 on unreimbursed expenses. These personal expenses are comparable to the cost of a textbook. No text is required, though the instructor bases much of the problem-solving technique recommended in the course on the Stoltenberg et al. (1970) text.

**Agronomy Experimental Course.** An experimental course (Agronomy 499x "Society and Agriculture: Confronting Modern Problems") was introduced in 1991 and was taught once in Fall 1991. In preparation for student experience in confronting problematic situations related to agriculture and natural resource management, the first portion of this course (8 wk) was spent exploring the methods of "Soft Systems Analysis" (Checkland, 1985), as described in the course text (Wilson and Morren, 1990), which provides detailed explanations of concepts and methodologies for problem assessment and confrontation, together with a number of documented case studies. During this phase of the course the learning techniques employed included examination of case studies, computer simulations, and role-playing. The second portion of the course (6 wk) consisted of independent work on problematic situations identified by students. Students organized four teams (Table 2), ranging in size from two to five, where membership was determined by (i) identifying competencies required by the team to analyze a specific problem, and (ii) matching those needs with individual expertise and learning styles (Checkland, 1981) as collectively determined by students. These criteria maximize objectivity in deciding team membership and minimize the potential for ostracism.

During the phase of independent team work, there were no formal class meetings—students organized their own meetings, objectives, activities, and methods. The main activities of students were fact gathering (interviews, review of videotape, and literature sources) and analysis (mind-mapping, group discussion of alternatives, and modeling of consequences). Students and instructor interacted by electronic conferencing and personal consultation. Students were evaluated in terms of their capability to analyze problematic situations, to understand a variety of viewpoints about an issue, to determine activities suited to improve the situation, and to perform cooperatively within a team. In place of an examination, students demonstrated their skills by organizing a 30-min team presentation of their analyses. Three of the teams chose to present a standard oral report, supported by slides, overhead transparencies and posters of their own design, and one team simulated a congressional hearing at which a number of subject matter experts provided to policy makers conflicting opinions on the potential impact of banning the use of certain herbicides. To make the team reports meaningful, a realistic audience was arranged that included the Dean of Agriculture Academic Programs, the chair of the college Curriculum Committee, the chair of the Sociology Department, professors from the departments of Agronomy and Horticulture, and representatives from the State Extension Service and the Monsanto Corporation.

Student response to the course was very favorable. Comments returned on evaluation forms (Table 3) indicate that students perceive practical value in this learning approach and focus. The instructor concluded that contrary to standard faculty preconceptions (Foster and Pikker, 1991), students display a natural ability to deal with complex situations in holistic fashion. This tendency may be suppressed by standard curricula that seek to shape specialized "scientific agriculturists." Some educators believe a pressure toward conformity and the dulling of complexity to agriculture and natural resource management, the first portion of this course (8 wk) was spent exploring the methods of "Soft Systems Analysis" (Checkland, 1985), as described in the course text (Wilson and Morren, 1990), which provides detailed explanations of concepts and methodologies for problem assessment and confrontation, together with a number of documented case studies. During this phase of the course the learning techniques employed included examination of case studies, computer simulations, and role-playing. The second portion of the course (6 wk) consisted of independent work on problematic situations identified by students. Students organized four teams (Table 2), ranging in size from two to five, where membership was determined by (i) identifying competencies required by the team to analyze a specific problem, and (ii) matching those needs with individual expertise and learning styles (Checkland, 1981) as collectively determined by students. These criteria maximize objectivity in deciding team membership and minimize the potential for ostracism.

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Table 3. Students in an experimental problem-based agronomy course appreciated the opportunity to analyze problematic situations holistically.†

Learning to be sensitive to people with seemingly ridiculous views was the greatest thing that I learned.

At first I was a little confused as to what the class was about. However, I have learned to look at a situation more objectively—rather than make a hasty decision.

The course gave me a new insight on how to solve problems. Instead of looking at it as a problem/answer/solution it was looked at as a complex situation with no right answer. What was most valuable was looking at a problem holistically and not narrow-mindedly.

The process we learned to solve situations is unique to the process most other classes have taught us [sic]. Why can't this idea be incorporated into other classes? We learned how to look at the “big picture” rather than immediately focusing on one particular solution.

The most valuable aspect of the course was to learn about learning and that all projects on the improvement of agroecological systems management have to be people-oriented.

The course was very worthwhile. The steps and techniques we learned are important and can be used by anyone in real-life situations we encounter. Working on the group project was interesting and [I] enjoyed finding and uncovering information. The most important things were the techniques learned and actually getting to apply them in a real situation.

The course broadened problem-solving knowledge from what my major has taught me.

The course provided a totally new aspect to problem-solving. The most valuable thing learned was the soft systems approach—specifically the diverging stage and keeping an unbiased approach. Also taking this information and forming mind maps and models.

† Total enrollment was 14; number of evaluations returned was 13. All comments are quoted from students choosing to respond (62%) to the item: “Was the course worthwhile? What items did you find most valuable?”

The goal of producing agriculturists with subject matter proficiency and practical problem-solving abilities need not be a difficult and intangible proposition. It is demonstrable that there exist both thought and experience with appropriate didactic methods and resource materials to accomplish this goal. Furthermore, a number of courses and curricula already incorporate many such approaches and principles (Bawden et al., 1986; Countryman and Thomson, 1979; Green and Mullen, 1993; Merritt and Hamm, 1994; McRae et al., 1989; Pearson and Ison, 1992; Richards, 1988; Simmons et al., 1992; Straquadine and Egelund, 1992). As indicated by student evaluation of ISU courses in problem-solving (Table 3), students appreciate the value of problem-based experiential teaching and feel that it enhances their ability to appraise problematic situations constructively and objectively. Little else can be asked of a broad-based higher education, one that seeks more than merely to train employees for the agricultural industry and strives to prepare students to be critical and constructive members of their society.

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