Discovering the Whole: Multiple Paths to Systems Learning[1]

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Abstract

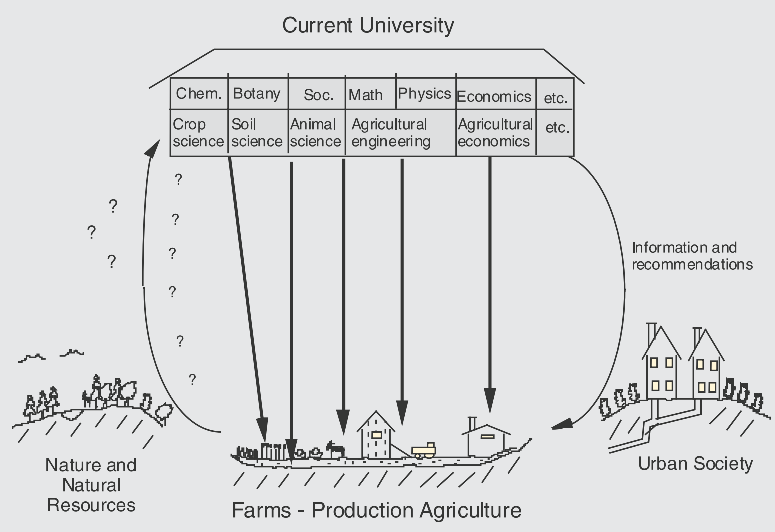
In today's university learning environment information and study are divided into discrete packages by discipline, while the problems our graduates confront are multi-faceted and complex. Universities are sometimes accused of producing narrowly focused technicians who are not prepared to deal with uncertainty, context specificity, changing demands, and farming systems. We have come from different directions to study agriculture and food systems, and find that an appreciation of systems can be generated from foundations in philosophy, engineering, international studies, environmental studies, and agricultural education. Divergent paths have led us to the conclusion that dealing with tomorrow's problems will require close collaboration and highly interactive communication across a range of disciplines. We need to recognize where and how integration can take place in the university, and strive to make this happen in as many levels as possible. Several models of action education are described, as well as ways that multiple majors and minors and individualized programs can help students meet goals of breadth and integration. Six specific case studies are described, along with a model for future university organization. We conclude that there are multiple paths to discovering the whole and ways in which university students can achieve interdisciplinary learning.

Introduction

It was the best of teaching. It was perhaps the worst of learning. This paraphrase from Dickens' (1965) A Tale of Two Cities could describe our rush to specialization in agricultural university and college education. Instructors who are often researchers focus on ever-narrowing fields, and as they extend the process to the classroom we find the same reductionism driving the teaching of components rather than systems. We fine-tune the packaging and transmission of factoids, yet it may be the worst of learning if the details and narrow processes become ends in themselves. If we lose sight of the whole, and how these components contribute to production and equity in the food system, we have forgotten John Dewey's (1963) insistence on contextual framework and experience as the basis for learning.

The current university structure is shown as a diagram in Figure 1, where the specialized disciplines are represented by their isolated boxes on the university campus. The primarily one-way communication out from the university is parallel to the one-way communication from teacher to student within the university walls, as lectures continue to be the dominant teaching method in most undergraduate courses (from Lieblein et al., 2000). This traditional university structure has changed little over centuries, with theater-style seating in most classrooms that is focused on an authority figure in front. Conventional teaching and classical subject matter may be useful for basic understanding of principles, but is unlikely

Figure 1. Schematic diagram of current university structure with conventional departments, one-way flow of information, and disconnect among natural resource, farming, and urban environments (from Lieblein, Francis, and King, 2000; reprinted with permission of Journal of Agricultural Education & Extension, Wageningen, Netherlands).



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to prepare students to deal well with the speed and complexity of change in modern agriculture.

A major change in how we view both research and education, especially within agriculture, may begin with the new publication, Frontiers in Agricultural Research: Food, Health, Environment, and Communities from the National Research Council (NRC, 2003). The following excerpt makes clear the need for reconsideration of the current university structure: "Today, the increasing complexity of the issues and challenges facing our food and fiber system, the environment, and families and communities requires disciplinary, multidisciplinary, and systems-level approaches. The future success of the agriculture enterprise in solving complex applied problems will require collaborative and interactive participation across greater numbers of disciplines (p. 97)."

The current university structure, in both research and education, addresses and equips students almost solely with disciplinary perspectives and methods. For example, as we focus only on corn and soybean production practices, many would claim that we lose sight of commodity prices that sever the family from the farm, agricultural subsidies that result in surplus production and grain dumping on global markets, the long-term impact from loss of half of our topsoil in the U.S., and our increasing dependence on fossil fuels. When practiced without context, a discipline-oriented approach produces graduates who are narrowly focused technicians, unequipped for real-world problem solving and critical thinking (Orr, 1994). Alternatively, the inclusion of multidisciplinary and systems-level approaches to research and education better prepare students and researchers alike for solving increasingly complex challenges in the food system. We explore several successful alternatives.

Multiple Paths to Systems Learning

Each person involved in this project has taken a different path to arrive at a similar concern about the importance of system thinking in education. Mindi Schneider spent three years as a philosophy major before interest in environmental ethics and food systems led her to study horticulture and organic farming. Her M.S. thesis research focus was on the relationships among environmental land ethics, land use, and local food systems. Ashley Colglazier's initial major was chemical engineering, then she changed paths to biological systems engineering, and then graduated in agronomy. Rhoda Beutler was seeking a broad insight on world issues to prepare her to address complex global questions, and she decided on a dual degree in agronomy and international studies. Caleb Pollard began his college education as an environmental studies major with an emphasis in biology, then designed an Individualized Program of Study to integrate social, political, developmental, and environmental issues and complexities into a major he named, 'International Sustainable Development'. Charles Francis studied agronomy and crop breeding, then lived in several countries and worked with farmers with diverse cropping systems. Teaching agroecology as "the ecology of food systems" has further convinced him that the greatest gains in science will be made through study of complex systems with multidisciplinary teams.

Concept Definition and Organization

There are numerous methods and models for multidisciplinary and systems learning within the undergraduate setting, although the majority of students do not take advantage of them (Schneider et al., 2005). The goal is to help students understand the complex issues and challenges in the food system through integration, sharing of information, knowledge, and methods among and between disciplines, and consideration of whole systems in research and education. Where could integration take place? We recognize four levels of increasing specialization in the Institution, College, Department, and Course. Figure 2 has examples from the University of Nebraska Lincoln (UNL) that are similar to other universities and useful for explanation and reference.

The Institution sets the Comprehensive Educational Plan for the entire university, including courses that "provide students a context for understanding the breadth of human endeavor", and that "engage students in actively developing their ability and desire to analyze, evaluate, and communicate complex material and positions" (UNL 2004-2005 Undergraduate Bulletin).

The College sets core requirements with the total number of credit hours required for graduation. Interdisciplinary courses can be created that bridge disciplines both within and outside the college, and individualized study programs can be created.

The Department is responsible for the definition of Major and Minor requirements. This framework is nested within both the college and institutional systems, and specificity is increased. Here the opportunities for creativity and applied integration are highlighted through capstone courses, seminars, team teaching, learning communities, interdisciplinary courses, and other methods for systems-level and multidisciplinary approaches to education.

The Course level decisions by each instructor determine method of instruction and required reading material. This level may be the most critical in successful integration efforts. Integrating concepts, methods, and ideas from other disciplines and courses can have the most direct influence on individual student learning of systems perspectives. Courses that do not recognize and require integration of material will be less successful in preparing students for the complexity of the food system. The framework created by the higher levels at the university may be lost if efforts are not made within courses to illuminate connections and bridges between disciplines and among system components. A number of systems-level and multidisciplinary methods at this level have been reported in NACTA Journal and include:

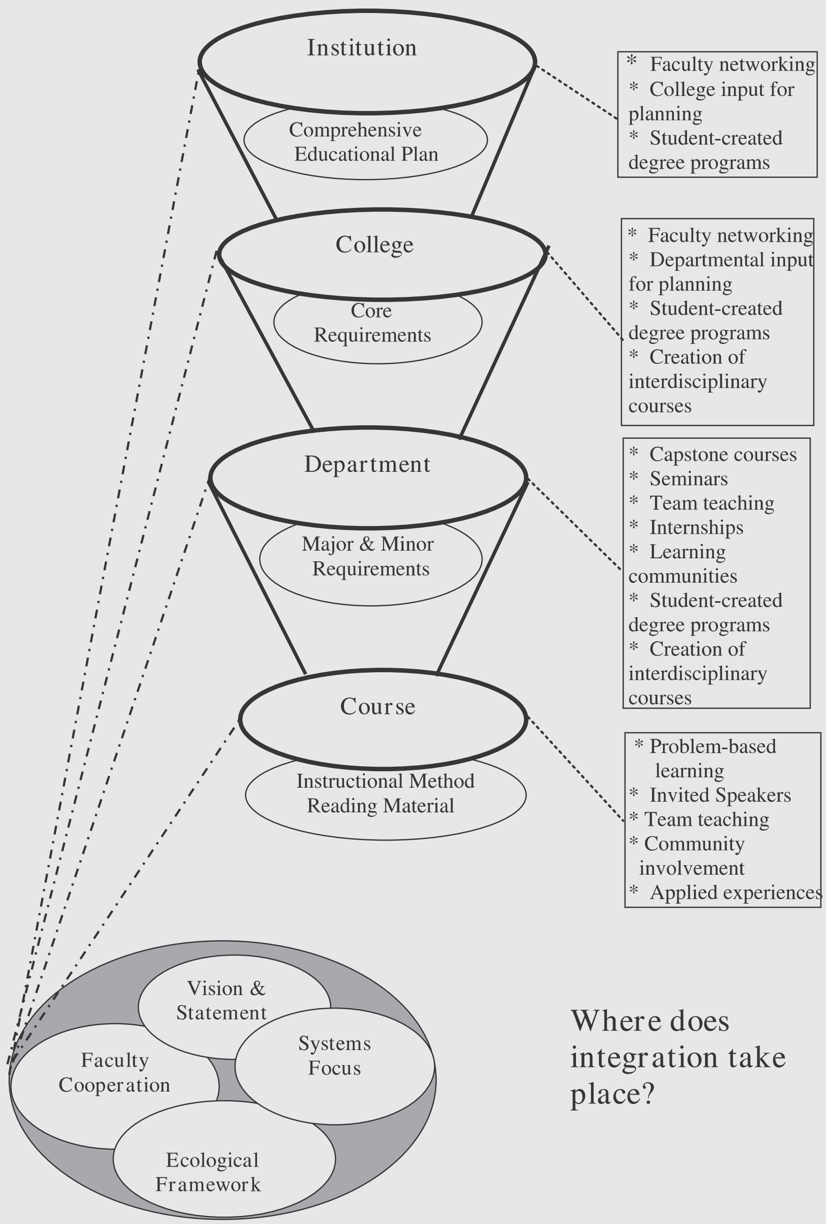
- Problem-based learning/Action education
- Team teaching
- Invited speakers from various disciplines, professions, areas of expertise
- Assigned reading material that encompasses a wide range of thought and application
- Community involvement in the class, and class in the community
- Applied experiences
- Inclusion of timely challenges faced by modern society

Requirements for students to complete specified credit hours in defined disciplines do not assure integration. The separation of colleges, departments, and majors is useful for budgeting and structure but ideas and methods must be re-united for students to gain a more complete and integrated perspective.

Models for Integration: Systems-level and Multidisciplinary Approaches

We perhaps overstated the gloomy situation in current university teaching in the introduction, in an attempt to draw attention to the challenges we face in designing education in large-scale issues and broad systems. Many good things are happening. The following models illustrate examples of practical systems-level and multidisciplinary methods, including team teaching, problem-based learning or action education, multiple majors and minors, and individualized programs of study. Each has been used in different universities with varying degrees of success. It is often difficult to assess the effectiveness of each model since this is confounded with the interests of faculty and subject matter.

Figure 2. Hierarchy of directional power and methods for systems education.



A. Team Teaching

According to Davis (1995), team teaching is “the teaching done in interdisciplinary courses by the several faculty members who have joined together to produce that course”. In its simplest form, team teaching may involve two professors from different departments collaborating on a single course. When carefully planned and supported, team-taught courses expose students to the disciplines of each faculty person involved in the course.

One ultimate goal of team teaching is the exposure of students to systems learning. Through the development of a broad, colorful knowledge base, students can begin to view problems and solutions from many different angles. Lattuca (1995) states that the value of exposing students to systems learning can be described as follows: “Many of today's interdisciplinary scholars are more revolutionary in their ideals and are eager to interrupt disciplinary discourse and to challenge traditional notions of knowledge and scholarship.” Interdisciplinarity provides the student with more tools to question what is being taught, and to recognize the intricacy and connections within the whole system.

B. Problem Based Learning/Action Education

Problem-based learning (PBL)

was formalized for medical school curricula where students worked in small groups on medical case studies under the supervision of a facilitator (instructor). The constructivist philosophy that underlies PBL is based on the assumption that learning is a product of both cognitive and social interactions in problem-centered environments (Evensen and Hmelo, 2000). Similar to Socratic methods, in this approach students are presented with problems that can only be addressed through questioning and self-directed learning. Students examine their own beliefs about knowledge, and 'make sense' for themselves (Savin-Baden 2000). The problem drives the learning.

The general process for PBL is as follows. Students in groups encounter a problem 'cold', without any preparatory study, and then determine their collective knowledge base as it relates to the problem. Ideally, groups will be made up of students from different disciplines. Hypotheses about the underlying mechanisms of the problem are formulated, and further learning needs are identified. Students undertake self-study between group meetings to satisfy perceived gaps in the knowledge base, and then reconvene to integrate this newly gained group knowledge. The process of seeking information continues until the group is adequately equipped to approach and solve the problem. At the end, students reflect on the process and on the learning (Schwartz et al., 2001).

C. Multiple Majors and Minors

Another approach to multidisciplinary learning is for students to enroll in more than one major, or more commonly a major and minor. Although a major and its imbedded course requirements are required for graduation, the pursuit of a second major is at the discretion of each student. A number of students at UNL include a minor in International Agriculture along with their preferred major study area. A small number of students seek a double major, such as Agronomy and International Agriculture. Although this strategy would appear to be a logical way to accumulate a broad range of experiences, in reality this is not often recommended by advisors nor is it valued highly by employers, according to a survey conducted in spring of 2003 at UNL (Schneider et al., 2005).

D. Individualized Programs of Study

Several colleges and universities employ programs that allow individual students to design their own graduation requirements. In most institutions, the programs are called individualized or integrated programs of study. Individuals design a set of component courses into a curriculum designed to fit their personal interests and needs for graduation. The student chooses a sponsor to help design a curriculum for graduation that meets the requirements. In the Individualized Program of Study (IPS) at UNL, students are encouraged to develop a theme, such as International Sustainable Development, as a basis for constructing a plan of study. Courses are selected that satisfy the interests and needs of the student, and are usually multidisciplinary.

Case Studies

The aforementioned methods for system-level and multidisciplinary learning have been implemented by some universities. The following case studies illustrate the application of integrative methods.

A. Agroecosystems Analysis Course, UNL, ISU, UMN

An intensive week-long experiential travel course for students to learn about agroecosystems through study of alternative farming systems has been conducted for six years in the Midwest (for a report on the first two years see Wiedenhoeft et al., 2003). The course is directed by an interdisciplinary team of faculty from several universities. After a month's preparation with readings in agroecology and reflections on personal experiences with farming systems, students assemble for eight days of farm visits, comprehensive group work, and both oral and written team presentations on what has been learned. Student teams evaluate the productivity, economics, environmental impacts, and social viability of several farms based on their interviews with farmers and families. Students also submit a learner's document that summarizes their thoughts and reflections throughout the course.

Our experience has shown this to be a unique and intense learning environment that brings together experiences of students, faculty, and farmers. Students are exposed to the complexities of working farms and the multiple goals of farm families. Faculty and students travel, eat, and live together for eight days, providing a stimulating environment for co-learning, with instructors as catalysts of the learning process rather than the authority figures found in conventional classrooms. Students mention faculty mentoring in Agroecosystems Analysis as one key factor in their educational experience, and often say they learn more in this week than in a semester of normal classes. Further, students take major responsibility for the process, from choosing their own indicators for evaluating the farms to organizing and summarizing information according to their criteria of importance and relevance to system performance. They quickly realize that evaluating complex systems such as farms is itself a complex process.

B. Water Quality Strategy, UNL

A model for interdisciplinary learning is illustrated by the senior-level Water Quality Strategy course that is cross-listed in eight departments at UNL. Diverse methods and perspectives are included to help students understand water resources and how they are used. Focused on the multiple sources of pollution and multiple demands on water resources today, the highly participatory course addresses economic, political, social, and physical impacts on water management priorities. Attracting students from various majors, but with a target of four students from any single major, the course brings together a wide student experience base that is shared and focused on problem solving with a major student project each semester. It is limited to 25 students per semester.

Brief lectures and prior reading prepare students for in-depth discussion of current issues in water use. Methods are introduced for evaluating different approaches to looking at water quality issues on farms and watersheds, and the implications to society of adopting these contrasting approaches. Most time is spent in large-group or small group discussions, and major projects are used each semester to help students approach real-world challenges in water use. Examples of these projects include: (1) Reducing nitrate concentration from non-point sources in Nebraska, (2) Success of the Nebraska erosion sediment control act and compliance system, (3) Strategies to reduce surface and groundwater contamination from land application of animal feedlot operation wastes, and (4) Water quality strategies for preservation and restoration of habitat in the middle Missouri River.

C. Ecology of Food Systems, NOVA University, Norway

An interdisciplinary course focused on complexities in the total food system has been conducted for the past five years in southern Norway. The semester-long course is based on principles and experiences developed in a series of interdisciplinary graduate courses designed and taught by an international faculty as part of the Nordic Forestry, Veterinary and Agricultural University (NOVA) (Lieblein et al., 1999). One basic principle is that students come with a wide range of academic and practical experiences, and that integrative courses should build on this prior experience rather than starting from an assumption of zero knowledge. Another principle is that students are ultimately responsible for their education, and will thus learn more when given the opportunity to explore and make independent learning decisions. Finally, the course helps students make use of their existing experience and knowledge through active learning, based on the idea that there is often a larger gap between knowledge and action than between ignorance and knowledge (Francis et al., 2001). In these modules we define agroecology as “the ecology of food systems” (Francis et al., 2003).

The first 8-week module in this course involves the study of production systems on conventional and organic farms, and the strengths and differences among different farming strategies. Student teams are organized as consulting groups that visit a farm where the family is interested in converting from conventional to organic production practices. After multiple visits to the farm and extended discussions, the team develops a proposal for conversion that is presented to the family for their critique and finalized as a comprehensive written report. The second 8-week module involves the rest of the food system, including processing, marketing, and consumer issues. The major project involves working teams of six to eight students that visit one county in Norway and conduct a food inventory of current production and consumption. Visiting farmers, processors, marketing outlets, and government officials at different levels, and interviewing consumer focus groups, the teams develop a rich picture of the local food system, while incorporating information from previous studies in the region (Torjusen et al., 2001). The team designs and recommends a strategy that will help the county substitute local production for a share of what is currently imported, representing a potential economic gain to local farmers as well as others in the food system for that location.

D. Hawkesbury Model, New South Wales, Australia

A practical systems learning approach was introduced two decades ago in the undergraduate agriculture program at the Hawkesbury campus of the University of Western Sydney, New South Wales. Based on the observation that students were receiving a good technical education and useful skills, but were unable to apply these with confidence in real world problem-solving situations, the faculty set out to work with farmers to offer an alternative approach to learning. Students were assigned to specific farms to learn the practices and systems on those farms, and to analyze the operations and come up with alternative recommendations to improve the production, profitability, and environmental circumstances on each farm (Bawden, 1991; Bawden, et al., 1984.; Sriskandarajah et al., 1991). With multiple working visits to the farms and close communication with the farm managers and families, students could assess the natural and capital resource base, the current operation of the farm, and the potentials for introducing innovations. A farm report was submitted to the farmers for evaluation. Farmers became both the subjects of the study as well as co-educators with the faculty on campus in the students' new learning environment. This model has been studied and adapted for use in numerous other locations around the world, including multiple methods and participatory approaches (Checkland, 1989; Pretty, 1995).

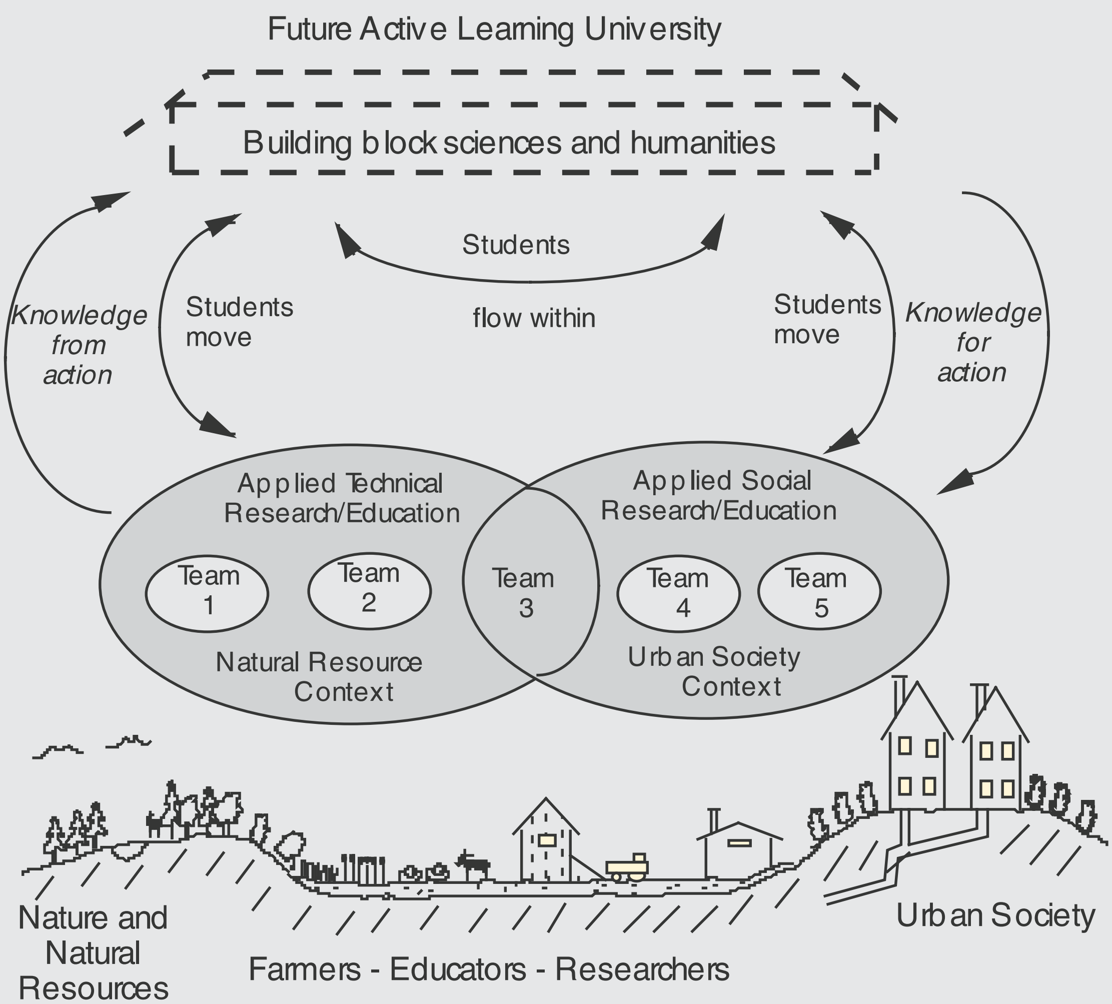
E. Slippery Rock University, Pennsylvania

The Robert A. Macoskey Center (RAMC) offers an example of action education and applied technologies for sustainability. An 83-acre education and research facility houses Slippery Rock University's Master of Science in Sustainable Systems (MS3) degree, plus other environmental and science-oriented academic programs. This demonstration site shows a variety of systems and emerging technologies that apply concepts of sustainability. The Center promotes and supports a societal shift towards a mutualistic relationship with ecological systems. Students and graduate assistants can work on existing systems, or may submit proposals for their own unique projects. The RAMC offers students applied, field based, systems learning with practical applications.

F. Problem-Based Learning, McMaster University and University of Delaware

McMaster University in Hamilton, Ontario has created an interdisciplinary PBL program at the institutional level. Students from any major may elect to enroll in the program on overload. Courses, seminars, and research internships are offered within Theme Schools that each deal with a specific problem or real-life challenge. Beginning at the sophomore level, seminars and workshops about PBL, problem solving, groups skills, and self-directed-interdependent small group learning are given. Courses follow the small group self-directed problem-based format, with instructors and tutors serving as facilitators. Theme school courses are taken concurrently with required courses in the students' major areas. A recent theme school topic focused on “New Materials and Their Impact on Society”. A total of about 35 students from English, Biology, Physical Education, Nursing, Chemistry, Mathematics, and

Figure 3. Idealistic structure of future universities designed for active learning and research, with movement of students, faculty, and information, and a close integration of natural resource, agroecosystem, and urban environments (from Lieblein, Francis, and King, 2000; reprinted with permission of Journal of Agricultural Education & Extension, Wageningen, Netherlands).



Engineering were involved. In this program, the breadth of knowledge originates from students representing different academic areas.

The University of Delaware has a university-wide problem-based learning program. In 1992, a core group of science faculty wrote a proposal to the National Science Foundation (NSF) to transform introductory courses in biology, biochemistry, chemistry, and physics into PBL classes. Upon approval, courses in introductory geology and political science were added as well. A few years later, the Institute for Transforming Undergraduate Education (ITUE) was formed with the intent of spreading the word about PBL. The ITUE is now an integral part of faculty development, with 230 ITUE Fellows, 150 courses using problem-based learning methods, and over 4,000 students exposed to this learning style in the year 2000 (Duch et al., 2001).

Both the McMaster program and the University of Delaware program provide working models of PBL in the undergraduate setting that can be applied to food systems education and research. The systems approach would be highlighted in theme schools addressing various topics and challenges in agriculture. Students from Agronomy, Horticulture, Animal Science, Sociology, Economics, Natural Resources, Community and Regional Planning, Family and Consumer Sciences bring varied, useful knowledge to the table in problem-based, small-group courses. The theme school concept could easily develop into a collegiate minor. For instance, if the theme school were based on various food system issues, an Agroecology minor would be appropriate.

Models for Future Universities in Agriculture

Based on the arguments for increasing systems-level and multidisciplinary opportunities for learning, we recognize that the organization and structure of departments by discipline is often not conducive to integrative education. The identification and isolation of courses by department tend to segregate people, methods, and ideas in one area from those in another, complicating the quest for integrative learning. Figure 3 represents one model of a university of the future, an interactive learning organization with most departments dissolved, people working together, and many of the learning activities taking place off campus (Lieblein et al., 2000). In this model, the basic sciences and humanities are explored on campus, with one eye on the world outside for examples, applications, and challenges. Most practical application courses are conducted off the primary campus, in natural resource areas, on farms, and in communities with people who are working on current challenges in agriculture and food systems. The concept of faculty is broadened to include professionals in government, business, non-profit sector, farming, or wherever ideas are found and people are seeking practical solutions to contemporary challenges (Francis et al., 2001). The flow of information is two-way, with questions continually coming from the field and shaping the content and presentation of courses, and the courses feeding innovative ideas into practice as recommendations for farmers and others in the food system. We believe this type of university will foster connections between interdisciplinary learning and the real-world challenges that graduates will face after completing their formal education. It is likewise easy to imagine a more seamless transition from study at the university into the work force of creative people who will design and implement food systems for the future (Francis, 2000).

Summary

We conclude from individual experiences, examining models and case studies, and considering study of system-level and multidisciplinary learning that there are multiple paths to discovering the whole. The university provides several mechanisms for bringing interdisciplinary perspective to the classroom. A comprehensive educational plan at the university level, core requirements of colleges, majors and minors course in departments, and several strategies in individual courses provide useful options. Integrative models include team teaching with careful and seamless integration of topics and threads that join topics through the semester or quarter, problem-based learning that provides challenges with real-world situations in a local context, multiple majors or major/minor combinations, and individualized programs of study. Case studies illustrate the applications of these integrative principles in current curricula.

The structure of the current university promotes segregation of disciplines and lecture-based courses. The methods and models for integration presented here are still the exception, and are scarcely available to all students. Further, the low numbers of students who avail themselves of the opportunities for a broader curriculum bring into question the incentives for the current approaches to systems learning. More courses could offer a broader view of their subject matter, and provide the students with context for specialized topics. As the complexity of agriculture and food systems increases, the scope of interest of graduates from agricultural university programs must also widen. The tool kit needed to approach problems today and in the future must include both disciplinary and multidisciplinary knowledge for successful system-level problem solving.

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