Developing Interdisciplinary Units: A Strategy Based on Problem Solving

Jean J. McGehee
University of Central Arkansas

While the benefits of the interdisciplinary unit are well documented, it presents a complex challenge to teachers in the natural and social sciences, mathematics, and humanities. Teachers must become active curriculum designers who shape and edit the curriculum according to students' needs. This paper describes knowledge for teachers as curriculum designers and a framework for interdisciplinary unit development. The framework addresses a metacurricular process (problem solving) that will be the unit centerpiece, the development of this central process related to the learner, and the tasks that teach explicit learning and thinking skills attached to the central process. An example of the framework in action is also described. As the faculty and curriculum coordinators for an innovative summer academy for minority students in northern Arizona have used this framework, they have evolved from a group that created a good idea to interest students with parallel subject development in separate classrooms to humanities/mathematics/science teams united in one team/classroom, in which content is integrated through the actions of the problem solving process.

The literature on interdisciplinary curricula is rich with creative examples integrating mathematics, physical and life sciences, and the humanities. The benefits to student motivation and self-esteem are well documented (Rothenberg, 1994; Schroth, Dunbar, Seaborg, & Vaughan, 1994). The curricula meet a need to actively show students how different disciplines influence their lives and allow them to explore the strength of each discipline perspective in a connected way (Jacobs, 1989).

However, the interdisciplinary approach is not without its problems and challenges. In general, Schroth, et al. (1994) claimed that these units present a complex challenge to teachers, because teachers must do more than share and coordinate content. In planning for the interdisciplinary curriculum, teachers usually choose central themes and develop a web of concepts and topics from content in the discipline areas. Jacobs (1989) identified two problems in content selection. The "Potpourri Problem" is the tendency to make an interdisciplinary unit a sampling of knowledge from each discipline. Teachers may feel challenged when a particular theme requires them to contrive material that seems connected to it. Also the interdisciplinary approach can force teachers from their comfort zones as they go against traditional practices of prescribed content sequences often dictated by the textbook. This discomfort would in part come from what Jacobs described as the "Polarity Problem," caused by teachers' seeing interdisciplinary study and disciplinary study as an either/or polarity. To overcome these problems, teachers need to be active curriculum designers who shape and edit the curriculum according to students' needs.

The primary focus of this paper is to describe knowledge for teachers as curriculum designers and a framework for interdisciplinary unit development. The developmental process of a curriculum project in action will also be presented as an example of the framework.

Knowledge for Teachers as Curriculum Designers

As teacher teams develop curriculum material, the teachers from each content area must clarify their own philosophy of knowledge and methods for that particular discipline (Rasch, 1994). Teachers need to know what they can bring to the planning table and develop during the project. First, working definitions are established to lay the groundwork for teacher interaction as follows:

Discipline Field: A specific body of teachable knowledge with its own background of education, training, procedures, methods, and content areas (Piaget, 1972).

Interdisciplinary: A knowledge view and curriculum approach that consciously applies methodology and language from more than one discipline to examine a central theme, issue, problem, topic, or experience (Piaget, 1972).

Teacher knowledge in a discipline field: A teacher is a member of a scholarly community who must understand the structures of subject matter, the principles of conceptual organization, and the principles of inquiry that help answer two kinds of questions in each field: What are the important ideas and skills in this domain (discipline)? And How are new ideas added and deficient ones dropped by those who produce knowledge in this area? (Shulman, 1987, p. 108)

Schulman distinguished three categories of content knowledge. *Subject matter content knowledge* is consistent with Piaget's definition of knowledge in the disciplinary field and includes an understanding of processes that construct this knowledge. *Pedagogical content knowledge* separates the teacher from others who practice the discipline. While a mathematician, natural scientist, or social scientist understands and uses representations of concepts to solve problems, the teacher must also use representations as learning tools. A discipline practitioner works toward developing an expert's knowledge structure. The teacher also develops an understanding of a student's or novice's knowledge structure and must make instructional decisions that allow enhancing that structure or amending misconceptions.

A teacher who has a well-developed *curricular knowledge* has an understanding of the big ideas in a subject area from a vertical point of view through the grades and can employ an alternative curriculum model to the conventional paradigm. Ackerman and Perkins (1989) described the conventional paradigm as a pervasive orientation to the "3Rs" and a domination of content topics based on the basic skills of a discipline. They framed an alternative model throughout the grades using two levels: the *curriculum* and the *metacurriculum*.

> The *curriculum* is about important topics and ideas, and instruction aims to make these ideas come alive in a manner appropriate to children of different ages, developmental stages, and degrees of background knowledge....The *metacurriculum* is comprised of learning skills and strategies selected on the basis of their value in helping students (1) acquire the curriculum content being taught and (2) develop the capacity to think and learn independently. (pp. 9,10)

In fact, the combination of metacurriculum with curriculum is where integration across subjects may take place, because together the two levels can pull the disciplines to the center of the continuum of integration described by both Huntley (1998) and Roebuck and Warden (1998). The integration becomes an infusion of methods from one discipline into another, as opposed to an infusion of content (Huntley, Watanabe, & McGinnis,1995).

The following is a summary of some of the advantages of this model (Ackerman & Perkins, 1989):

- There would be acquisition of vital learning skills enhanced by reinforcement and refinement through a range of applications.
- Students would be given a far more coherent set of learning experiences and would know better how to make sense of curriculum content.
- Teachers from different departments could work toward common goals without sacrificing their own subject matter concerns. They compare and contrast learning skills to show how they can be used to learn different subjects.
- "Process" and "content" goals would be unified and would not compete against one another.

These advantages address both the Potpourri and Polarity Problems cited earlier (Jacobs, 1989).

In the metacurriculum, participation is a fundamental factor unifying the goals of skills and content. In describing the Middle School Mathematics through Applications Project, James Greeno (1997) explained how participation in practices of inquiry, understanding, and reasoning is fundamental in the process of learning mathematics. Any discipline can be substituted for "mathematics" to see that skill and content come together so that students can participate in authentic practices of the discipline. "Emphasizing educational aims involving participation also supports a focus on students' development of personal identities as learners, knowers, and users of [the discipline] " (p. 1).

In summary, at the interdisciplinary planning table, teachers need to bring knowledge of process as well as content, an understanding of learning, and an openness to see the bigger picture in the curriculum. A planning framework is needed to keep teachers anchored as a team in a metacurricular process, while allowing individuals to explore the contributions of their discipline field. The framework for the unit will address (a) a metacurricular process that will be the unit centerpiece, (b) development of this central process related to the learner, and (c) tasks that teach explicit learning and thinking skills connected to the process.

A Framework for Interdisciplinary Unit Development

If an interdisciplinary unit is to be successful for the core disciplines, it demands a common goal that keeps the teachers in mathematics, the sciences, and the humanities working in concert rather than in isolation. A planning phase requiring only the coordination of the discipline areas will produce a multidisciplinary approach in which teachers use parallel lessons and instruction. Solving a real-life problem is a common goal that uses the metacurricular process of problem solving and moves the planning beyond mere coordination, because it calls forth the active processes within each discipline so that true interaction and interdependence are possible. Woodbury (1998) described problem-based integration as Alberty's Type-Four Core of core curriculum organization. Teachers can draw on all pertinent fields of knowledge "to illuminate, clarify, and provide data for solving common problems of living. No preconceived bodies of subject matter are set up to be 'covered'" (p. 306).

Problem solving has been a central topic in mathematics education and an essential process standard (National Council of Teachers of Mathematics [NCTM], 1989, 2000). However, it is *not* the sole property of the mathematics discipline. Problem solving influences all disciplines' curricula as there is a decreasing emphasis on procedures, memorization, and traditional skill testing and an increasing emphasis on critical thinking, concepts, and alternative assessment.

When examining why problem solving is the cornerstone of school mathematics, one can see how the problem-centered approach applies to other disciplines. Consider the following position statements from *Principles and Standards of School Mathematics* (NCTM, 2000) without the word, "mathematics":

> Without the ability to solve problems, the usefulness and power of...ideas, knowledge, and skills are severely limited. Students who can both develop *and* carry out a plan to solve a problem are exhibiting knowledge that is much deeper and more useful than basic skills and fact....Problem solving is also important because it can serve as a vehicle for learning new...ideas and skills. A problem-centered approach to teaching...uses interesting and well-selected problems to launch...lessons and engage students. (p. 182)
>
> To meet new challenges in work, school, and life, students will have to adapt and extend whatever...they know. Doing so effectively lies at the heart of problem solving. (p. 334)
>
> [Students] should have opportunities to formulate and refine problems because problems that occur in real settings do not often arrive neatly packaged. Students need experience in identifying problems and articulating them clearly enough to determine when they have arrived at solutions. The curriculum should include problems for which students know the goal to be achieved but for which they need to specify—or perhaps gather from other sources—the kinds of information needed to achieve it. (p. 335)

This call for problem solving is consistent with the advantages of the metacurriculum listed by Ackerman and Perkins (1989). Problem solving creates richer student experiences. In fact, it is the active, experiential, and reflective nature of problem solving that makes it ideal for an interdisciplinary unit.

The general classroom activities that seem to occur in NCTM's description are launch; seek out information; explore, experiment, and apply; and summarize. It is no accident that they fall into four phases—not unlike Polya's four steps in problem solving: understanding the problem; devising a plan; carrying out the plan; looking back. Since their introduction in *How to Solve It* (Polya, 1957), these steps from this classic work have become a foundation for problem solving in the classroom. Unfortunately, if problem solving is taught as a unit from a textbook, the steps can be trite and algorithmic. However, if problem solving is considered a pervasive process in all disciplines, these steps form a flexible, useful first layer for a planning framework.

The four steps also connect to a second layer, the learning framework. None of the wonderful student learning from process or problem solving occur if students do not first engage in the problem situation. Failure to engage students results in their not knowing what steps to take or why they are trying to solve the problem. They simply look to the teacher to prescribe the solution steps. The 4MAT activity cycle (McCarthy, 1990) is ideally suited to the problem solving steps and relates learning to these steps. Both problem solving and learning require active and reflective moments. Similarly, problem solving and learning both occur with concrete and abstract phases. McCarthy's model develops around the active/reflective and concrete/abstract axes. The model presented in Figure 1 shows McCarthy's progression on the inside and the corresponding problem solving steps on the outside. The simple model of a circular chart allows teachers to consider diverse learning styles, flow of content, and relationships to problem solving.

McCarthy's primary purpose in devising this scheme has been to provide learning tasks for diverse students. The innovative concrete/reflective learners of the top right quadrant want a reason to learn and connect to personal experience. The analytic abstract/reflective learners in the lower right quadrant need facts and

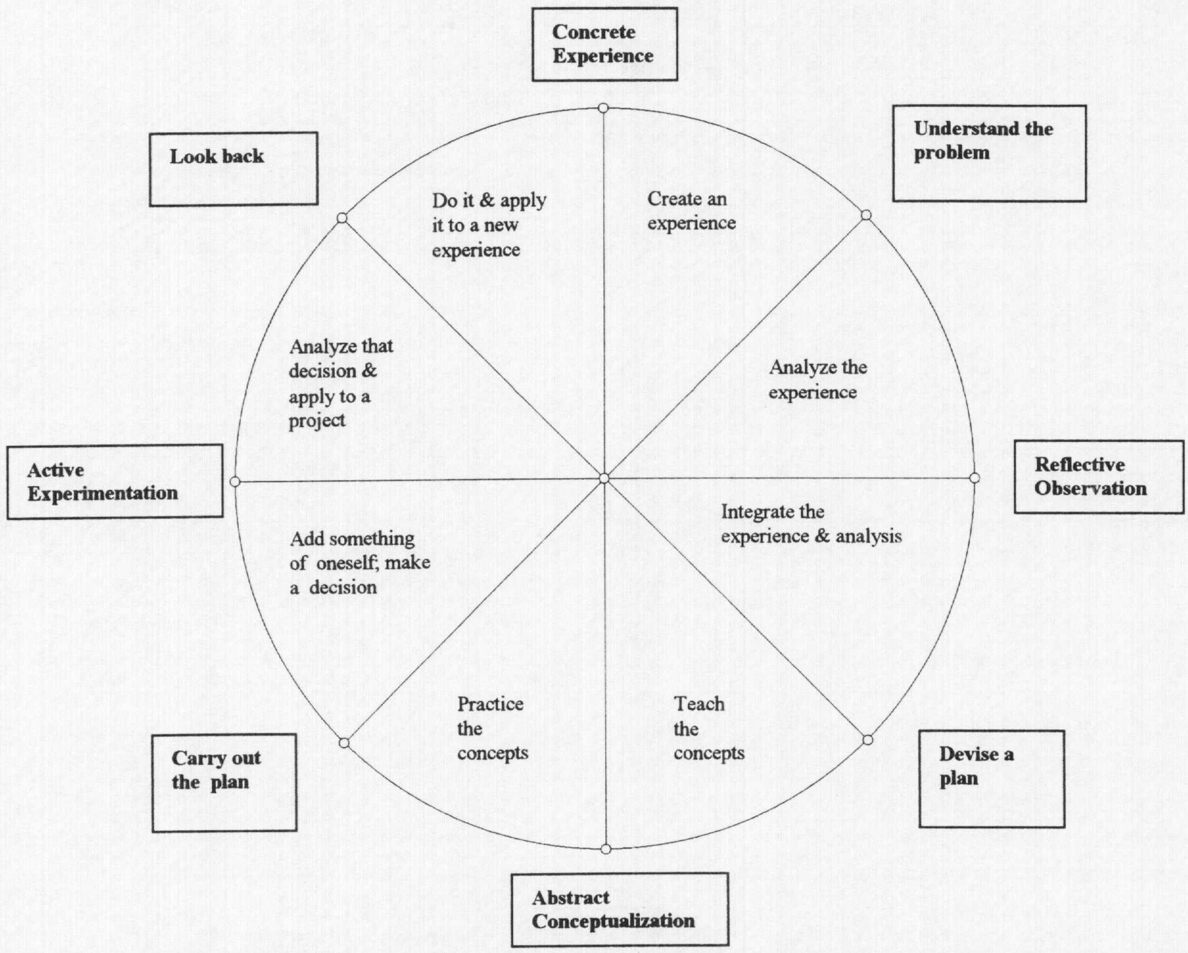

Figure 1. *The 4MAT Model layered over Polya's Four Problem Solving Steps. Start in the upper right quadrant and read clockwise.*

skills, while the common sense abstract/active learners of the lower left quadrant want to investigate how things work. Finally the dynamic abstract/active learners in the upper left quadrant will analyze their creations for relevance and originality. Each type of learner is essential to the problem solving process and can make a valuable contribution.

The third layer of the framework involves the tasks to explicitly teach learning and thinking skills that will help students deal with the not so neatly packaged problem. Students face the situation and assignment with uncertainty. They know the ending point but do not know how to get there. The instructional team's challenge is to help them recognize, formulate, and then study the different disciplines' contributions in the situation. This layer provides four task phases common to the process for all disciplines: describe the situation; study then refine the descriptions of the situation; collect, represent, and analyze the data; make convincing arguments for solution proposals, and extend to new situations.

These tasks relate to the problem solving steps and the quadrants of learners. They also provide an easier way for teachers to make connections to content than the generic problem solving steps.

The Developmental Process of Interdisciplinary Curriculum Project in Action

The Upward Bound/Nizhoni Academy is a 5-week summer college preparatory program held at Northern Arizona University (NAU) for high school sophomores and juniors, with priority given to students from rural high schools or potential first generation college students. In the program are approximately 110 students, with a balance of gender but a majority of Native American students. Upward Bound students also participate in a school program focusing on study skills and counseling for school success. The summer faculty consists of 12 teachers chosen from a pool of NAU graduate students and secondary teachers in northern Arizona, with four teachers each in the disciplines of

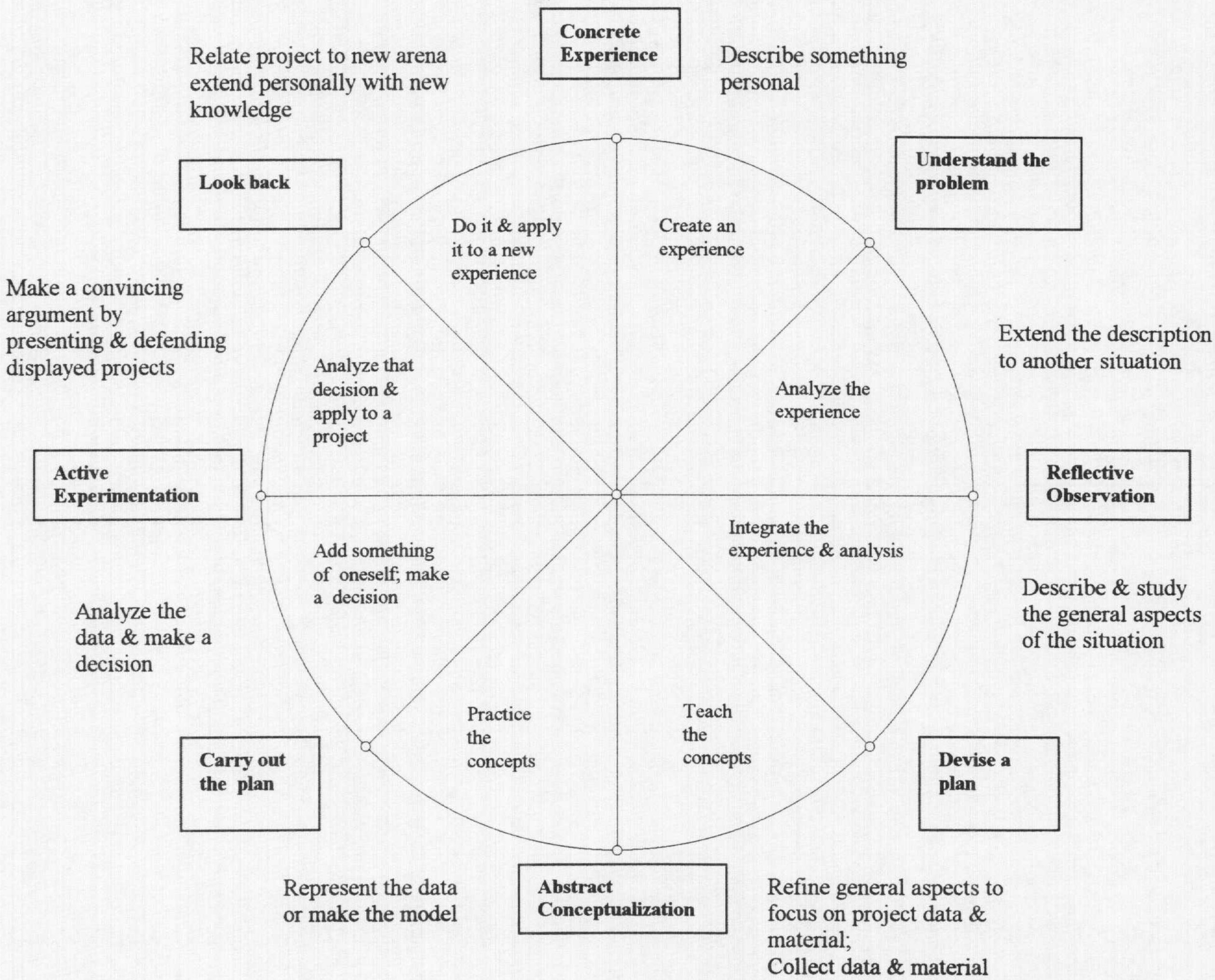

Figure 2. *The Three-Layered Interdisciplinary Model: Polya's Four Steps, the 4MAT Model, Process Tasks*

mathematics, sciences, and humanities. The teachers are usually not associated with any of these students during the school year. The criteria for faculty selection is a demonstrated predisposition to accept nontraditional material and the ability to use innovative pedagogy and curricula.

In 1993, program directors decided to offer students a unique study experience, as opposed to classes remediating skills in each discipline. They adopted an interdisciplinary approach focused on the study of environmental problems in the Verde River area near Cottonwood, Arizona. Students were assigned to write an environmental impact statement about a proposed housing project. The area, rich in the history of Native Americans, pioneers, and mining developments, made study in the humanities a natural part of the curriculum. The riparian ecosystem provided a good basis for scientific study, and the data collection required a study of statistics. Students were divided into three teams with one teacher from each discipline. Teachers had their own separate classrooms and implemented their own versions of the written material in the curriculum. As a result of the isolated classroom experiences, the students wrote papers with separate historical and scientific sections, while adding little mathematics with a few statistical graphs. The students had not seen a meaningful interaction and interdependence of the disciplines, and without a model for this kind of teaming, their performance was not surprising.

The planning group for the summer of 1994 realized that teaming in every aspect of development and implementation should be emphasized in a focus on a unifying metacurricular process, problem solving, as well as learning issues to promote better student engagement. The writing team created a realistic simulated problem situation that would be fertile ground for the study of concepts in all three disciplines and planned for the discipline teachers to teach as a team in the same room. In 1995, a second problem was created for Year 2 students. For each problem the team created a general

5-week timeline of instruction and developed a curriculum resource notebook of related readings and both discipline specific and integrated activities. Some of these activities were original, while others were pulled from the best curriculum materials available. While studying the teaming process (as defined in Johnson & Johnson, 1994) in a full week of teacher training, teachers made norms for instructional team operation and fine-tuning the curriculum details in their notebooks.

Teacher teams learned about student strengths and weaknesses from a study skills and content pretest given during student orientation. However, teachers did not plan instruction to remediate a weak skill or teach for mastery. In a typical day students met for four morning hours with their instructional team of teachers, and in the afternoon each group had a computer lab, tutoring session, and break time. In the morning each teacher team decided how to divide individual discipline instruction and integrated instruction. The discipline instruction focused on making problem-related topics accessible to the students, and integrated instruction focused on problem-solving and teaming processes, as well as applying the discipline topics to the projects. There were also two field trips for each project.

The Upward Bound/Nizhoni Summer Academy Problem is described as follows:

Cottonwood is a city located on the Verde River approximately 60 miles south of Flagstaff. This fertile area has been home to the Anasazi and Yavapai tribes, farmers, ranchers, miners, and numerous plants and animals. Cottonwood is now growing quite rapidly. Fun-In-The-Sun Land Co. (FITS), a group of developers (Year 1 students), has made a proposal to the city board to build a new housing district on the Verde River. FITS owns a large inholding in the Prescott National Forest (PNF) and proposes a land swap of that land for part of Dead Horse State Park, situated in Cottonwood. If this were to occur, FITS could build on land that is suitable for construction, while PNF would gain additional riparian area and be able to protect a large stretch of river and watershed.

The land swap would give FITS river-front real estate to develop into a recreation/retirement community (housing in the form of apartments, condos, and townhouses). The new community would double the population in the Cottonwood area and provide public recreation in the form of one new golf course, 20 tennis courts, one softball field, a multipurpose athletic center, three restaurants, housing, and a bar.

Citizens Active in Restoring the Environment (CARE) filed a suit in federal court to require PNF and FITS to file an Environmental Impact Statement (EIS). CARE claims that the land swap would result in significant damage to the environment, specifically damage to the quality of water in the Verde Valley and the riparian ecosystem. The court has agreed with CARE that PNF and FITS must complete an EIS and hold a public hearing before the land swap can occur.

PNF and FITS jointly decided upon hiring an outside environmental consulting firm, Year 2 Nizhoni/Upward Bound Students (NUBS), to prepare the EIS, which will research the predicted effects of the proposed action. The EIS will address current problems that may be amplified due to the swap and increase in population. The EIS will make an estimate of the long-term environmental implications of the proposed land swap. Finally, the document will suggest possible alternatives to the action (including no action) each of which may have different environmental consequences.

Year 1 Student Assignment: The design teams in FITS must have models and brochures ready for a housing fair by 8 AM on July 12. Bids will be made for the projects. Project designers will then represent FITS at a public hearing on July 13 for the final approval of the project.

Year 2 Student Assignment: The NUBS consulting firm must have the EIS completed in 3 weeks by 8 AM July 11. Following the preparation of the EIS, a public hearing will be held on July 13 at 8 AM. Representatives of the NUBS firm will present the EIS to the Department of Environmental Quality hearing officer. At this open forum members of the public and special interest groups also will be allowed to present testimony. When the hearing is complete, the hearing officer will make a recommendation to the city board.

The outlines for each program are given in the layered 4MAT models in the following section.

For both Year 1 and Year 2, understanding the problem occurs in the first quadrant when students are engaged in description and data collection at a personal level, then at a broader level with study of the Verde Valley. In the second quadrant teachers introduce key content components that contribute to devising plans for the projects. While this situation is heavily science driven in its study of a riparian ecosystem, water chemistry, and solar energy, the problem-based nature of the situation makes mathematics more prominent than a series of graphs. In Year 1, students deal with budgets and apply geometric and measurement concepts to design model homes and contoured site models. In Year 2, they study a food web graph of animals in the riparian system, counting vegetation in transects, representing water chemistry data, and data modeling of

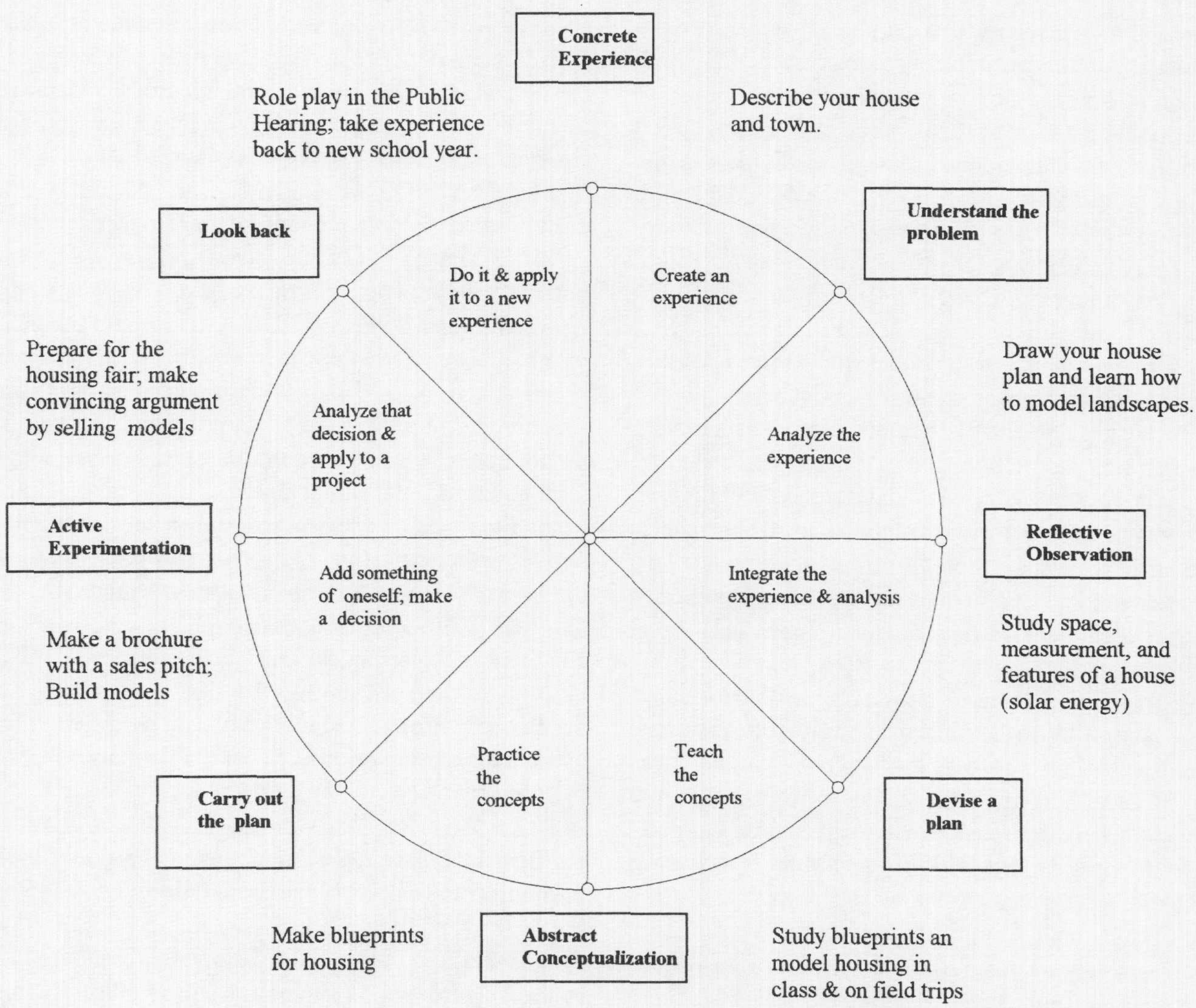

Figure 3. *The Three-Layered Interdisciplinary Model:Year 1 Curriculum*

population growth. Students experience both technical and biased writing in various reading, journal, and essay assignments. Year 1 students are introduced to the history of past environmental impacts in the area and study community design and architects such as Frank Lloyd Wright and Paolo Soleri, while Year 2 students study the history and impacts of the past groups in detail.

Plans are carried out during the 4th and 5th weeks of the program, as teachers and students devote their time to the capstone projects. By the 2nd week students in both levels have been divided into project groups of five or six. Teachers choose groups according to learning styles and diverse strengths. Year 1 student groups finish their contoured model of the site, build three model homes, and produce a brochure complete with budget details for a bid. Year 2 student groups write and present an EIS so that each group demonstrates technical, unbiased arguments to support a position for or against the housing community. The housing fair and the public hearing take the intense focus off completing group projects and help students look back at the unit experience as Year1/Year 2 students interact. At the fair Year 1 students not only display their creativity but they also have to sell energy efficiency, economical budgets, and design features. The public hearing requires role-playing and debates with biased points of view from the developers (Year 1 students), a scientific team, an environmental group, and the ranchers and farmers. Oddly enough, the hearing often ends in support of the housing project, because housing designs address environmental issues, and EIS investigations show the data do not support a detrimental impact.

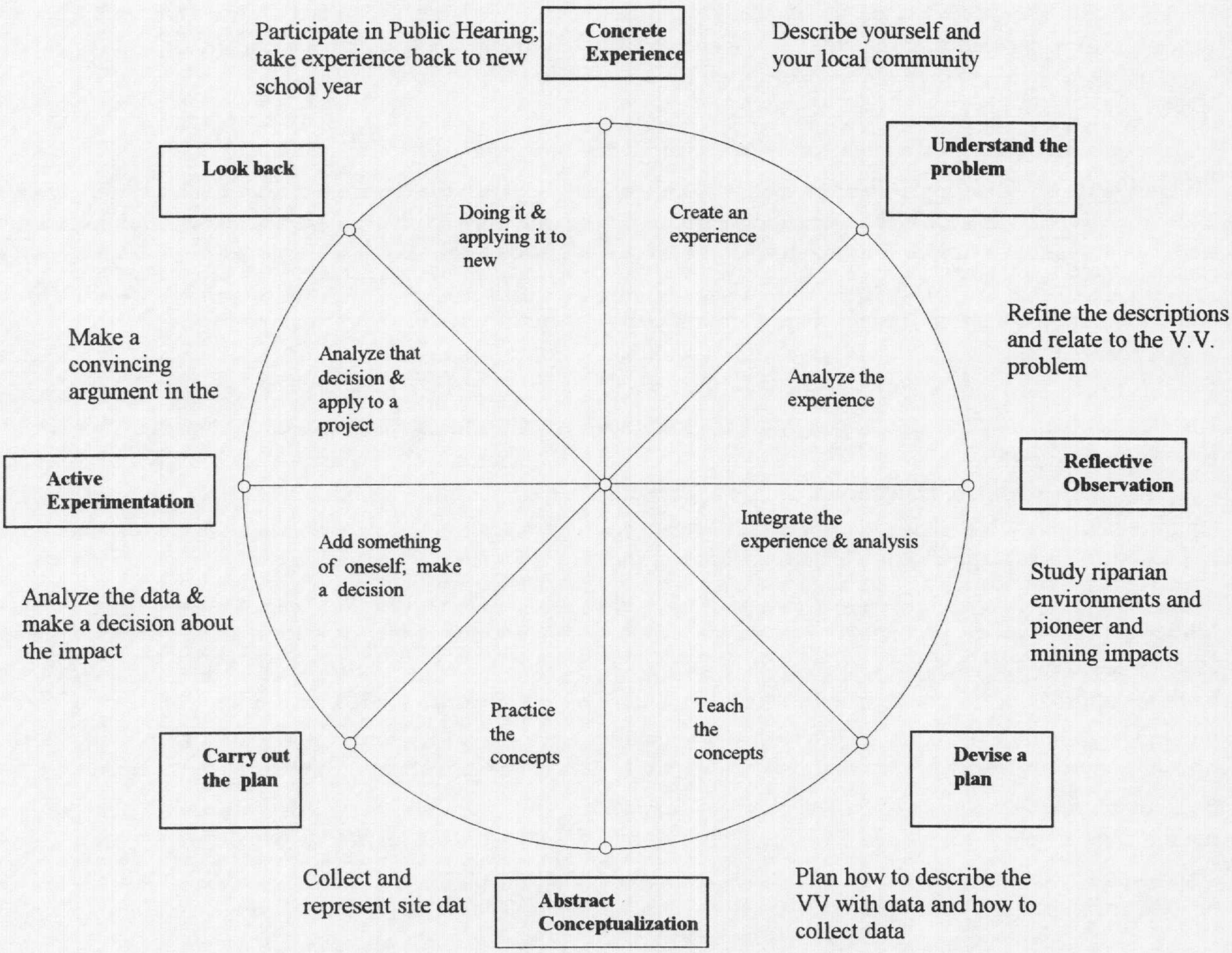

Figure 4. *The Three-Layered Interdisciplinary Model: Year 2 Curriculum*

Effectiveness of the Interdisciplinary Curriculum Project

As the faculty and curriculum coordinators developed the material, they evolved from creating a good idea to interest students with parallel development in science, mathematics, and humanities to teaming in one classroom and integrating content through the actions of the problem solving process. In dealing with their own teaming issues and problems of integration, teacher teams learned firsthand how to explicitly help students work as a team and work through the project problems. In the beginning of a summer session, teachers often dealt with colleagues who would dominate the stage or isolate a discipline. A mathematics teacher described a science teacher as follows: "He often begins lessons with, 'Today in science . . .' He separates his subject." Later in the program a tutor described this same teacher: "He often participates in others' lectures by adding concepts or examples. He works daily towards integrating the curriculum." There were content challenges as well as teaming issues, but often the challenges produced good results. A social studies teacher said, "I need to integrate math more. This is my least comfortable subject, but I am learning." She also said, "In this situation, I can't believe how many teaching moments there are that we don't even plan for." A science teacher said, "At first I didn't like the journal time, but now I see what I can learn about my students with it." The intensity of the projects' culmination seemed to break down remaining barriers between disciplines. Humanities teachers helped students write about graphs; mathematics teachers critiqued brochure descriptions; science teachers examined historical summaries that supported a scientific argument.

While this study focused on the teachers' development and implementation of curriculum materials, significant student gains were documented on a study skills and content pre/post test. Students better understood the final projects and were more self-directed than in the 1st year of the program. The display of final group projects showed that the Year 1 students could combine their artistic talents with their study of scale and proportion in the housing models and could apply budget data and energy efficiency study to the project brochures. Year 2 students could use water data graphs, scientific site descriptions, historical impacts, and community interviews to support arguments.

The project has encouraged students to pursue similar programs. Several students completing 2 years in this curriculum have continued their studies with the Four Corners program at NAU. Students also have enrolled in other Upward Bound programs on both the east and west coasts.

The framework has transferred to other teaching situations. In 1995, NUB invited public school teams to participate in its faculty training and to observe the program. One teacher observed, "Now I see the possibilities instead of all the problems." This middle school teacher realized that as her faculty was adopting a teaming approach she could benefit from the NUB units. The planning structure of the EIS and housing project units were generalized to meet needs in studying Arizona history and environment. Her team used regular subject class periods to teach related content and the team period to implement the problem solving process for interdisciplinary projects.

A NUB mathematics teacher took the Year 1 housing curriculum to a small school district in northern Arizona for adaptations with his middle school. Another mathematics teacher used the framework to develop special units for a private school in northern Arizona.

Summary

Every state or region has an area of particular interest in social and natural history. If an interdisciplinary faculty team can create a simulated problem about this area, then they can use the problem-solving metacurricular process layered with the 4MAT model for learning and the processes of description, data collection and analysis, and proposal argument.

The challenge of the developmental process of the interdisciplinary unit is that it takes time and reflection on content knowledge, as well as logistical considerations. The reward for the teacher is honing higher level thinking skills in the content area and learning more about other disciplines. The reward for students is that they engage in a challenging problem and have an opportunity to develop what Polya (1963) called "know-how." They experience the usefulness and power of knowledge and skills because they are formulating, solving, and reflecting critically on a problem.

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Editors' Note: Correspondence concerning this article should be addressed to Jean J. McGehee, University of Central Arkansas, 201 Donaghey, Conway, AR 72035.

Electronic mail may be sent via Internet to jeanm@mail.uca.edu