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ABSTRACT

The Foundational Approaches in Science Teaching (FAST) is an interdisciplinary science program that began as a curriculum reform effort in the mid-1960s. This historical study provides insights into the FAST project and contributes to an understanding of the dynamics of survival of curricular and instructional innovations. Data collection methods included document analysis, interviews, and observations. Topics highlighted in the results include resources for curriculum development and professional development, the FAST curriculum development process, FAST professional development strategies, and FAST and educational reform. It was concluded that in effect, the FAST project survived because it had the organizational support of an extremely stable lab school research-based unit, steady state funding, highly qualified personnel, and time to plan and craft finely tuned innovative curriculum materials for middle school students and teachers. The analysis of the changes made over the past 30 years in the program's curricular and instructional strategies indicate the extent to which the project responded not only to feedback from the teachers but also to various reform movements in science education. The significance of the study is also discussed. Appendices contain curriculum design and conceptual framework. Contains 31 references. (JRH)

AGAINST ALL ODDS: TALES OF SURVIVAL OF THE FOUNDATIONAL APPROACHES IN SCIENCE TEACHING (*FAST*) PROJECT

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Against All Odds: Tales of Survival of the Foundational Approaches in Science Teaching (*FAST*) Project

> In order to go forward, we must look not only forward, but also backward.
> The backward view gives us confidence and helps us to straighten our course.
> —*George Sarton (1952)*[1]

While many science programs developed at the national level during past curricular reforms of the 1950s, 1960s, and 1970s are no longer available from textbook publishers (Klopfer and Champagne,1990; Pottenger, 1976 and 1977; Welch, 1979), the Foundational Approaches in Science Teaching (*FAST*) program continues to survive 30 years after its inception in 1966. What makes the difference? This study of *FAST*, a long-term survivor of reform in science education, seeks to answer that question.

FAST, one of several curriculum reform projects developed by the University of Hawaii's Curriculum Research & Development Group (CRDG), consists of a sequential and interdisciplinary middle and high school science program for grades 6–10. From the mid-1960s through the late 1970s, the *FAST* program was explicitly intended for grades 7–9 in what was then known as the intermediate or junior high school level. Since the early 1980s, the project has responded to the changing organization of schools and modified its program to serve grade 6 in what is currently known as the middle school as well as extend its services to include grade 10 in high school.

During an eight year period from 1969 to 1977, I was intimately involved in the life of the *FAST* project as a teacher, writer, curriculum developer, teacher trainer, field liaison, and evaluation coordinator. It is with an insider's perspective of the inner workings of the project that I explore in this study how the project accomplished most of its goals and why it still evolves, expands, and endures. From an outsider's perspective as a researcher, I raise questions about the project's odds for survival within a framework of current reform in science education.

Before detailing the study, I present background information about the *FAST* project, an innovation that has survived over a span of 30 years. What forces brought the *FAST* project into existence? In an attempt to answer briefly this question, the following sections highlight the history of the *FAST* project as well as describe its present status, activities, and organizational structure.

[1]Quoted in Klopfer and Champagne (1990), p. 133, from G. Sarton's *Horus: A Guide to the History of Science* (Waltham, MA: Chronica Botanica, 1952).

Brief History of *FAST* Project. The *FAST* project began as a curriculum reform effort in the mid-1960s. A community of concerned politicians, educators, academics, scientists, and members of professional organizations in Hawaii conducted deliberations about their vision for science education and took long-term action to create an educational culture that is still evolving in the name of genuine education reform.

A group of nineteen scientists and science educators participated in a curriculum conference conducted by the Hawaii Curriculum Center (HCC) for the Department of Education in June 1966. Participants included elementary and secondary teachers and science specialists from public and private schools of Hawaii; scientists and educators from the College of Arts and Sciences and the College of Education of the University of Hawaii; and representatives of industry. Paul DeHart Hurd of Stanford University served as the group's consultant.

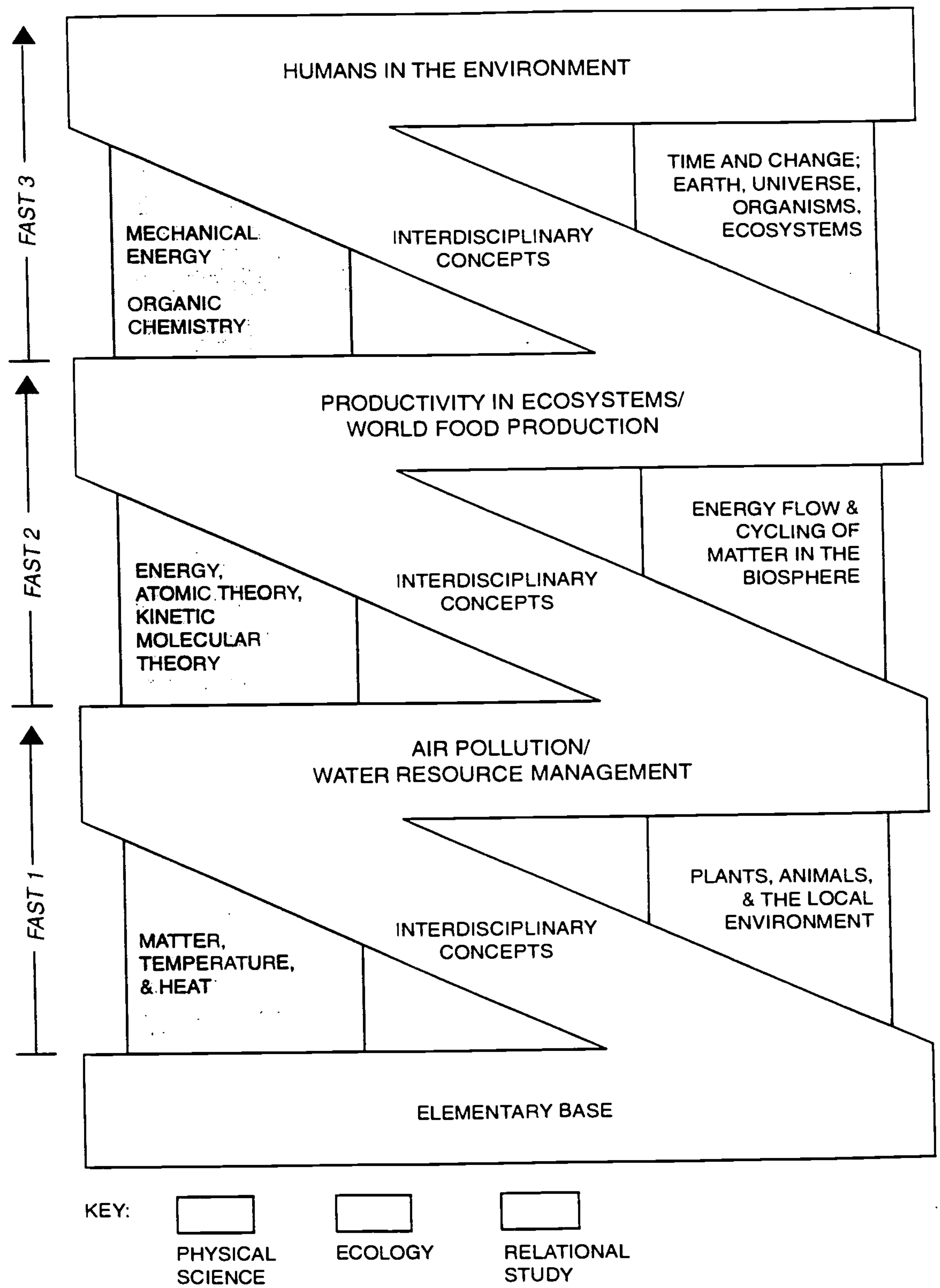
As a result of the group's recommendation, the Hawaii Science Curriculum Council was established in October 1966. The Council in turn sponsored the *FAST* project. A broad outline for the project was completed in February 1967 and development of materials began in the summer of 1967 and continues under the aegis of the Curriculum Research & Development Group.

According to Young and Pottenger (1992), "Since its first pilot trials in 1970, an ever-expanding number of teachers and students have participated in the program. . . . [By 1992] over 500,000 students have taken one or more years of the program. Some of the materials have been translated into Lao, Ilokano, Japanese, [Slovak, Russian, and] . . . is also available in Braille" (p. 1).

Brief Description of *FAST* Program. *FAST* is an interdisciplinary science program that is organized in three strands: Physical Science, Ecology, and Relational Study. The first two strands provide the formal science content while the Relational Study strand integrates the sciences, technology, and society. Principles developed in the Physical Science strand, for example, undergird many concepts in the Ecology strand while biological and earth science principles of the Ecology strand are basic to understanding environmental issues in the Relational Study strand.

Figure 1.1 on page 3 shows the structure of *FAST* while Table 1.1 on page 4 gives an overview of the program's content and sequence. See Appendix A and Appendix B for a curriculum design platform and a conceptual framework, respectively.

FIGURE 1.1 General Structure of the *FAST* Program



Note. From Instructional Guide (Second Edition) (p. 4), by D. B. Young and F. M. Pottenger, 1992, Honolulu: Curriculum Research & Development Group. Copyright 1992 by the University of Hawai'i. Reprinted with permission.

TABLE 1.1 Content and Sequence of the *FAST* Program

LEVEL	PHYSICAL SCIENCE	RELATIONAL STUDY	ECOLOGY
FAST 1 THE LOCAL ENVIRONMENT	**MATTER, TEMPERATURE, & HEAT** Introduction to the properties of matter, change In state, temperature and heat **Examples of concepts:** mass, volume, density, physical and chemical properties of matter, states of matter, pressure, heat, temperature, calorie, vacuum, energy	**INTERDISCIPLINARY CONCEPTS** **AIR POLLUTION** ***WATER RESOURCE MANAGEMENT** **Examples of concepts:** resource management, technology, epistemology, air pollution, environmental use, food production, energy usage, conservation, economics, aesthetics	**PLANTS, ANIMALS, & THE LOCAL ENVIRONMENT** Plant growth, animal care, physical environment, field ecology **Examples of concepts:** ecology, plant and animal growth, weather and climate, field mapping, population sampling, humidity, contour, transpiration, propagation
FAST 2 MATTER AND ENERGY IN THE BIOSHPERE	**ENERGY, ATOMIC THEORY, KINETIC MOLECULAR THEORY** Light and heat; evidence for an atomic theory, a model of matter	**INTERDISCIPLINARY CONCEPTS** ****PRODUCTIVITY IN ECOSYSTEMS** **WORLD FOOD PRODUCTION**	**ENERGY FLOW & CYCLING OF MATTER IN THE BIOSHPERE** Primary production, respiration, the cycling of matter
FAST 3 CHANGE OVER TIME	**MECHANICAL ENERGY** Force, work, and energy **ORGANIC CHEMISTRY**	**INTERDISCIPLINARY CONCEPTS** **HUMANS IN THE ENVIRONMENT**	**TIME AND CHANGE: EARTH, UNIVERSE, ORGANISMS, ECOSYSTEMS** The changing universe, the changing earth, life on earth, continental drift, changing ecosystems

* Unit added to the Relational Study Strand in 1992 edition
** Unit moved from the Ecology Strand (1978 ed.) to the Relational Study Strand in 1994 edition

Note. From Instructional Guide (Second Edition) (pp. 4, 6), by D. B. Young and F. M. Pottenger, 1992, Honolulu: Curriculum Research & Development Group. Copyright 1992 by the University of Hawai'i. Adapted with permission.

Teaching Strategy. The *FAST* program models experiences of practicing scientists. Students, therefore, work in research teams generating theories about phenomena they observe and spend between 70% and 80% of their time in laboratory investigations and field studies. They devote the rest of their time to analyzing data, participating in small group or class discussions, researching the literature, and writing reports.

FAST teachers are research directors who stimulate and facilitate students to probing deeper into problems; they are colleagues on a research team.

> The *FAST* research team approach can tolerate misconceptions because the contexts of investigation are carefully sequenced so that hypotheses and conclusions once developed are constantly retested. . . . Students learn that science proceeds through a process of constant reconstruction of explanation in the light of new findings (Young and Pottenger, 1992, p. 7).

Instructional Materials. A distinctive feature of the *FAST* student book is that it is not a textbook but a guide that contains background information, problem statements, procedures to guide investigations, and summary questions that focus on students' generalizations of each activity. Students keep a running log in their notebooks of data, observations, hypotheses, and conclusions; in essence, they write their own textbooks.

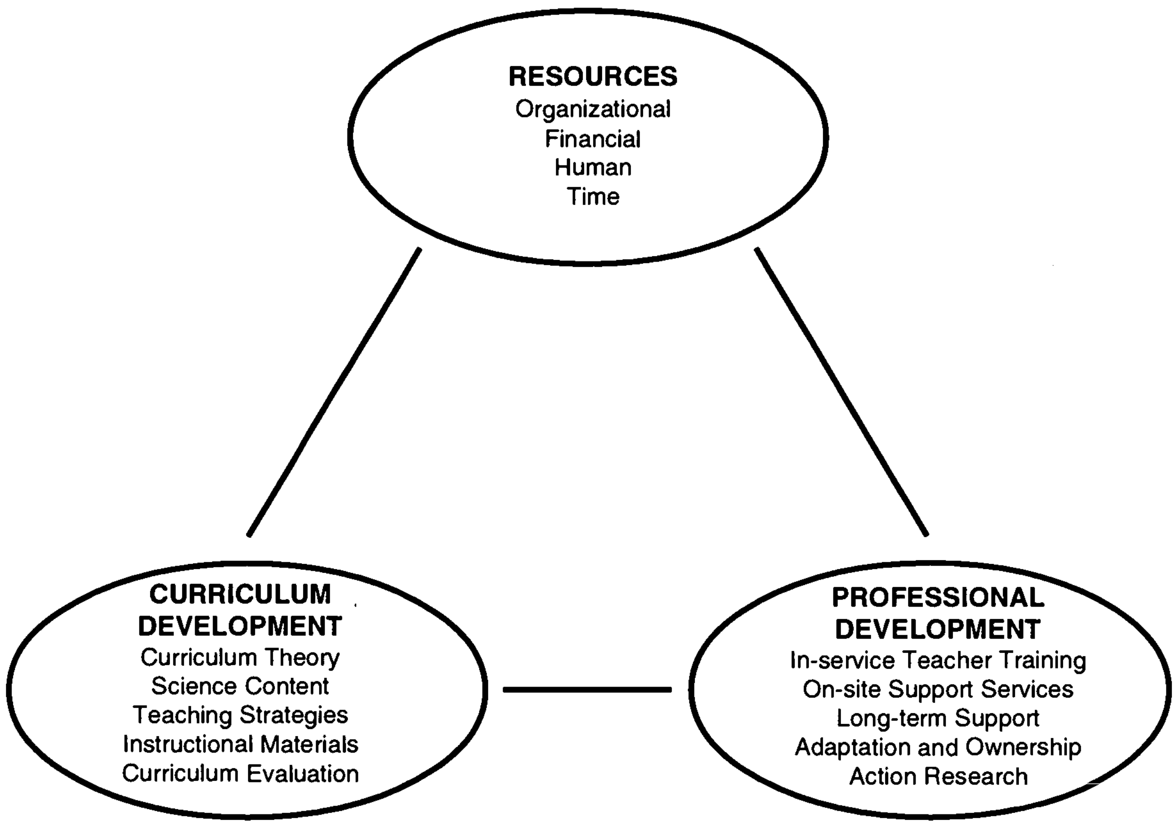
A classroom library of reference booklets provides supplementary information related to some of the investigations described in the student book. It is also intended to give students practice in using reference materials. The *FAST 1* reference booklet on *Air Pollution*, for example, discusses various ways of measuring pollution, examines technologies for controlling pollution, and lists federal laws pertaining to pollution.

For teachers, there is a comprehensive and practical guide that is organized around the investigations in the student book. It explains the relationships among the investigations of the three strands, provides teaching tips, lists equipment and supplies for each investigation, suggests scheduling of units, and gives other helpful information for using the program. In addition, an instructional guide for teachers explains the philosophy of the *FAST* program.

Purpose of the Study. The purpose of this historical study of the *FAST* Project is to provide insights about and contribute to an understanding of the dynamics of survival of curricular and instructional innovations. Key research questions guiding this study include (1) How did the Foundational Approaches in Science Teaching (*FAST*) project survive over the past 30 years? (2) What elements are essential for long-term survival of an innovative science program? (3) Why did the project continue to survive amidst several waves of educational reform?

Conceptual Framework. The aim of this conceptual framework is to guide this study in searching for an explanation of how an innovation that purports to reform and improve science education survived. The core of my framework is based on the premise that the odds of survival of curricular and instructional innovations are increased by the extent to which (1) resources for curriculum development and professional development, (2) curriculum development processes, and (3) professional development strategies are not only incorporated into but also interdependent within a project. The framework is also based on an understanding of the dynamics of change; it considers how and when project developers respond to internal and external forces by what decisions they make and implement in subtly shaping the program. Figure 2.1 shows the links among key elements of a project.

FIGURE 2.1 Conceptual Framework



General Design of Study. In an attempt to understand the conditions under which the *FAST* project survived, I analyzed its resources, curriculum development processes, and professional development strategies. In trying to understand the dynamics of change, I compared key components of the *FAST* project to their counterparts in past and current educational reforms.

Methods of Data Collection and Description of Data Sources. For this study, the main methods of data collection were document analysis, interviews, and observations. Most data were acquired on-site at the *FAST* project's headquarters at the University of Hawaii Curriculum Research & Development Group.

The first method of data collection, analysis of documentary evidence, provided not only background information but also generated issues to explore and identified tales to tell about key components of the project. Sources of documentary evidence included: letters, memoranda and other communiques; minutes of meetings and other written reports; administrative documents; student materials; teacher materials; teacher trainer materials; formal studies and evaluations of *FAST*; and project newsletters.

A second method of data collection was the focused interview, conducted either on-site, via telephone calls, or through electronic mail. The main sources of data came from key project personnel, consultants, and *FAST* teachers. Data in the form of interviewee responses were recorded on paper and/or on tape.

Observation was a third method of data collection. Data sources included logs of field observations conducted in Hawaii and California.

Methods of Data Analysis. Multiple methods of collecting data—documents, interviews, and observations—and multiple sources of data were used to seek evidence of links between resources, curriculum development processes, and professional development strategies. Documents were primarily analyzed for evidences of (1) the continuation or existence of the *FAST* program over a long period of time relative to other programs developed in the same time frame, (2) endurance of the *FAST* program's original vision over time, and (3) adaptation of the *FAST* program to address internal forces such as research conducted by project personnel and/or external forces such as expansion to locations beyond its pilot field-test site and changing visions of educational reformers over time.

The interviews and field observations were then used to corroborate documentary evidence and gain further insights into the *FAST* project's longevity, fidelity of it's program components to the project's explicitly stated values over time, and flexibility to address and adapt to various educational reforms.

RESULTS

According to the conceptual framework for this study, odds for improving science education through curricular and instructional innovations are increased by the extent to which resources are tightly coupled with specific strategies of curriculum development and professional development. I examined such couplings to gain insights into how the *FAST* project survived through several generations of educational reform.

Resources for Curriculum Development and Professional Development

Financial Resources. Curriculum materials development projects are characteristically large undertakings wherein federal agencies such as the National Science Foundation (NSF) and U.S. Department of Education are major sources of funds for developing and disseminating science programs. Welch (1979) cites, for example, NSF funding for precollege curriculum development activity:

> Between 1956 and 1975, more than $130,000,000 was appropriated by NSF for course content improvement projects. During this same period, an additional $565 million was used to support various teacher-training activities. The goal of many . . .teacher-education efforts was the implementation of the new curricula (p. 282).

FAST did not receive financial support from any federal agency for curriculum development. Instead, almost all of its funding for curriculum development came from the State of Hawaii through the university's budget. As Pottenger (1977) and others pointed out, "The *FAST* project total developmental budget of $377,000 [over a span of 10 years] in a period of high inflation, contrasts markedly with the massive budgets of first-generation national science curriculum projects, which often ranged in the millions" (p. 15; Hinze, Rodgers, & King, 1977, p. 22). Additional monies for specific purposes that related to the project were obtained in small lots from a variety of sources: utility companies serving the project's area contributed several hundred dollars toward conference expenses, community health agencies donated funds or materials toward research projects conducted by students, and state agencies awarded funds for educational efforts related to environmental issues.

The *FAST* project did receive funding from NSF, however, for teacher-education. It received $41,000 in 1970 and $40,000 in 1971 for training pilot teachers during summer institutes in the use of *FAST 1* and *FAST 2*, respectively. Additional federal funds for teacher education were received from what is widely known as Eisenhower grants.

In its initial request for monies in 1967, the *FAST* project did not receive funding for its NSF proposal. Pottenger was quite disappointed and wondered if he would ever realize his dream of improving science education through a disciplinary approach to curriculum development. Nearly three decades later, in commenting on the money situation, he confided that not being funded was a "blessing in disguise." How so? In an interview, Pottenger (personal communication, November 1, 1995) answered:

> For *FAST*, a major economy came in its relative anonymity. The early curriculum projects from their inception engaged in massive information dissemination efforts which were forced, it can be conjectured, by the educational concern of the time and their style of testing and dissemination. This activity was exceedingly draining of time and talent. *FAST*, being developed from University funds, was out of the spotlight and could concentrate most of its energies on development. This is not to say that there were no demands for accountability, but such demands were relatively easy to handle in the close community of the [Hawaii] State Department of Education, the University, and the State Legislature."

In effect, federally funded projects were under pressures of specific deadlines for completing their work. Unknown then was the extensive amount of time necessary to develop and disseminate curriculum materials. The lack of funding from a federal agency, therefore, meant no pressure from outside sources for *FAST*. This situation effectively allowed the project to spend sufficient time to develop and thoroughly test quality materials and services.

For the *FAST* project, the positive feature of the university as its primary funding source lay in its commitment to permanent staff positions within the CRDG organizational unit. Unless changes occurred in the structure of the university, the project had a stable staff with long-term personnel.

<u>Human Resources and Time</u>. Another distinctive feature of curricula developed during the federally funded era of the late 1950s and early 1960s was the collaborative effort of large groups of scientists, administrators, and teachers. Harvard Project Physics, for example, listed the names of 295 contributors to the program (Welch, 1979). Another feature of curriculum development processes of these projects was a summer writing conference where writers produced a product and then left the site to return to teaching or conducting research. This meant lots of materials were developed in a short time span.

In contrast, the rate of developing products was much slower for the *FAST* program than federally funded projects; writing for *FAST* was done by a small team of permanent staff members of a curriculum research and development group working together throughout the year. Part of the team worked together for at least five years. At its peak, the project staff consisted of five curriculum developers. In essence, this meant that the staff took a much longer time to complete writing the program than it took for other projects with large teams of writers (Pottenger, 1976).

The small size of the team of key personnel working together over a relatively long-term period seemed to have led to efficiency and economy in operation. With so few team members, everyone shouldered more and varied responsibilities than if the group were larger; as a result, team members assumed and understood complementary roles in the overall scheme of curriculum development and professional development. The multiple roles and overlapping responsibilities of key *FAST* personnel included: teaching students in laboratory school trials; designing activities; producing laboratory equipment; training teachers; and writing, evaluating, and revising curriculum materials.

In terms of personnel, *FAST* has had a project staff that is balanced among the disciplines of biological, earth, and physical sciences; and has a clear understanding of Hawaii's environment and single state-wide school system. Having a well qualified team is not in itself unique. Having a team with members who remained either with the *FAST* project or on other science projects at CRDG for 20 or more years is very unique.

Longevity of a small project staff suggests another possible reason for the project's survival; the collective memory of a group that stayed largely intact and performed multiple roles contributes to a project's stability and continuity in both curriculum development and professional development. Memory of things that did not work means the team does not have to repeat its mistakes; people typically focus on working toward solutions and basing them on lessons learned from things that did work.

Organizational Resources. Federally funded projects were typically large scale enterprises not only in terms of personnel but also large scale in their field/trial testing in large samples of schools. In contrast, a distinctive feature of the *FAST* curriculum development strategy was its small scale testing: project staff designed and tested materials in a single university laboratory school setting before conducting pilot tests in a small sample of public and private schools in Hawaii. Not only was the initial testing, but also the pilot testing, done on a small scale. As Pottenger (1977) recounts:

> There was a constant interplay of theory, practical school experience, and the clear, cold light of the reality of classroom trial. From 1967 to the present, the content of the program has been shaped and tested and reshaped in a continuous succession of laboratory school trials. The design, the ordering of experiments, the language, and the mathematics employed were all molded in this process. Materials were recrafted and retested from three to ten times before pilot testing (p. 14).

FAST Curriculum Development Process

A Theory of Curriculum Practice in Action. The "discipline theory" of curriculum as posited by King and Brownell (1966) in *The Curriculum and the Disciplines of Knowledge: A Theory of Curriculum Practice* is explicitly credited as the theoretical base for the *FAST* program. Pottenger (1976) translated King and Brownell's theory into premises that guided the development of the *FAST* program:

> 1. Science as we know it has been generated out of the discourse of disciplinary communities.
>
> 2. The structure of the scientific disciplines has been reasonably well identified in the works of the historians and philosophers of science.
>
> 3. The very existence of the scientific disciplines is founded on their instructive character, or capacity to transmit their operational structure from one generation of disciplinarians to the next.
>
> 4. Therefore, a science curriculum modeled after the structure of the scientific disciplines should give students an authentic view of science and have a high probability of instructional success (p. 3).

This theory of curriculum practice values intellectual activity in the context of a community of discourse. It also presumes that scientists intentionally produce their knowledge and their ways of generating new knowledge for transmission from one generation to the next. This discipline-based theory was put into action in the design and structure of the *FAST* program "to capture within the classroom the community experience of the scientist" (Pottenger, 1977, p. 14).

It is significant that over a period of almost thirty years, the values guiding the *FAST* project's decisions have remained remarkably stable. It is not surprising, however, since King and Pottenger have—from 1966 to the present—remained as Director of CRDG and Director of the *FAST* project, respectively.

Because of their insistent and consistent reliance on the history of scientific disciplines as a basis for designing project materials, the *FAST* developers use of a discipline-based curriculum theory remained stable. Unless the scientific community's view of the heritage of its disciplines shifts, odds are that the *FAST* curriculum materials will continue to remain stable.

Content Selection and Sequence. During the first year of development, *FAST* curriculum planners selected content from disciplinary structures that were clearly delineated: physical chemistry (thermodynamics and the particle model of the structure of matter) and ecology (interaction of biological organisms with the physical environment). They moved from a plan to design two distinctly separate but parallel sequences to a plan that called for co-projects where foundational concepts and skills taught in physical chemistry would be "instrumental" to concepts taught in ecology (Hawaii Science Curriculum Council, 1967).

In 1967, the *FAST* curriculum planners expanded their co-projects design to incorporate a three-strand approach: Strand 1 - foundational ideas in ecology; Strand 2 - foundational concepts of classical physical chemistry; and Strand 3 - comparative study of ecology and physical chemistry to reveal the structure of the interdisciplinary nature and the processes that characterize the particularity and generality of the composite scientific enterprise (HCC, 1967, p. 7). By 1968, the physical chemistry strand was reconceived as physical science and the comparative study strand as relational study. The *FAST* curriculum content had evolved beyond the disciplines of science by 1980 to include investigations of environmental issues (CRDG, 1980).

See Table 1.1, Content and Sequence of the *FAST* Program, on page 4 for current examples of content selected for all three grade levels. A careful analysis of the content point to a sequential organization in the Physical Science Strand that moves from macroscopic to microscopic in scale of events studied; from the observation of direct evidence to making inferences based on indirect evidence to generating mental models of physical phenomena; and a gradual shift from concrete to abstract thinking. In the Ecology Strand, content is organized to move from emphasis on the biological and physical aspects of the local environment to the flow of energy in the biosphere to inquiring about the origins of life and the universe; the ecology content also moves from simple to complex concepts. The Relational Study Strand initially focuses on the similarities and differences in the kinds of inquiry characteristic of the physical sciences and biological sciences; it highlights the strategies in which information that is generated in the physical sciences can be used in ecological studies. The sequential organization of the Relational Study Strand also shifts from the study of the historical and philosophical aspects of science to contemporary environmental issues.

In summary, the content selection and overall sequential organization points to a historical and philosophical development of the disciplines of physics, chemistry, biology, and earth science. They reflect intellectual values in the context of a community of discourse.

Here is a teacher's reaction to the science content of the program. A. Tuney Kannapell, a FAST teacher since 1982 who has taught in Kentucky and in the state of Washington, wrote in a letter of support to University of Hawaii President K. Mortimer:

> I have personally found . . . (CRDG) a source of information, program, and networking that seems rather unique and unparalleled.
>
> I have taught science for thirteen years. I continually search for curricular programs that suit the needs of my vision of a science education for Middle School students. I had tried other programs and looked extensively, when I happened upon the *F.A.S.T.* program from CRDG.
>
> That program struck me as ideal then, and with years of teaching it, and continually eyeing other possibilities, it still strikes me as a rather elegant and flexible program, clearly in the range of excellent. It is full of philosophy, ideology, and practical methodology.
>
> One characteristic of the *F.A.S.T.* program has always astounded me. Despite its initial creation in the sixties, it carries an amazing array of current educational theory, and continues to grow and develop, connecting to the cutting edge of theory today. (Personal communication, September 7, 1995)

<u>Teaching Strategies</u>. Since the *FAST* program seeks to give students a sense of the operations of a scientific community by directly involving them in typical processes of inquiry and research, the teacher serves as a research director and a colleague to students. The teacher facilitates probing into problems by providing anomalous events, asking research questions, or by identifying the kind of problem they are investigating, formulate hypotheses to explain anomalies, and conduct experiments to check the adequacy of their explanations. Students investigate physical, biological and ecological phenomena and report their findings for critical review by their peers.

<u>Instructional Materials</u>. See page 5 for a description of instructional materials.

<u>Evaluation of Student Performance</u>. In the *FAST* program, evaluation is multidimensional and a dynamic part of teaching. It helps teachers communicate to students their expectations of performance and helps students gain information about what is valued in the way of knowledge and skills. Dialogue between teacher and student is intended to help the student assess strengths and weaknesses and identify what needs to be learned. In essence, evaluation builds on student strengths as learners, is ongoing and continuous. The ongoing formative evaluation process includes

observation of student participation in class and small-group discussions, critiques of student projects and performance of laboratory investigations and tests, interviews, and self-rated scales completed by each student (Young, 1991).

The summative evaluation of student performance consists of a Concept and Skills Inventory whereby both the teacher and student assemble evidences of mastery or non-mastery and jointly make as fair a statement as possible about what the student has learned (Pottenger, 1988). According to Young and Tamir (1977), the Concept Inventory was a "new approach to evaluating what students know" in that the evaluation instrument directly asked students what they understood about "concepts considered important in the program" (p. 27). This feature of self-evaluation by students was considered unique in 1977 and remains unique today (Tamir, personal communication, March 5, 1996).

Periodic use of the Concept and Skills Inventory gives a detailed profile of progress and is included in each student's file. Since progress is measured on a four-point scale, grades are not recorded; if grades are required, the teacher can translate the summative report into a traditional letter grade (Pottenger, 1988).

A Class Progress Record was designed to support the Concept and Skills Inventory and help students track their accomplishments while keeping both teachers and students informed of specific concepts and skills students are expected to master in the *FAST* course. As students master each concept or skill, they check off the item on the Progress Record. These items are keyed to a series of performance and paper-and-pencil tests. By maintaining this record, students and their teacher have at all times, a profile of the students' accomplishments. Periodically, students will fill out their personal Student Progress Record to indicate their level of mastery (Pottenger, 1988).

The four levels of mastery of the rating scale on both the Class Progress Record and the Student Progress Record reflect the notion that the disciplines of knowledge are uniquely structured for instruction. The levels of mastery are as follows:

1. I have not encountered the concept (skill).
2. I understand the concept (skill) but cannot explain (perform) it.
3. I can explain (perform) the concept (skill).
4. I can teach the concept (skill) to someone else (Pottenger, 1988, p. 9).

Levels 1 and 2 indicate a novice member of a community of discourse. In contrast, Levels 3 and 4 reflect how experienced community members transmit the knowledge they have produced and their ways of generating new knowledge from one generation to the next. Having attained Level 4 mastery, the most experienced members are able to teach novices in their community. In essence, this model of evaluation in the context of a community of discourse makes students party to shaping their own instruction. The model also reflects the values of the intellectual realm as the basis for developing the *FAST* program as espoused by its framers.

Evaluation of the *FAST* Curriculum. Young and Tamir (1977) noted that from the perspective of curriculum developers, data from student responses to the Concept and Skills Inventory may be used to evaluate a curriculum by revealing "strengths and weaknesses in the program's presentation of various concepts." They also stated that the data may be used to indicate "which parts of the program are and are not being used in the classroom." In addition, Young and Tamir suggested, "Such information is invaluable in revising materials and planning new programs" (p. 28).

Changes in *FAST* materials reflect feedback from field teachers and staff experiences with Lab School classes. Major changes in *FAST 1* include an extensive use of reference booklets in Ecology and a revised teacher's guide in Physical Science. Project staff make sure experiments and activities "work" and are always very responsive to feedback from teachers.

Twelve years after its decision to adopt *FAST*, a school district in Washington State still uses the program. When asked why he thought *FAST* survived two six-year cycles of textbook adoption, John Pauls—a former middle school teacher—replied:

> The ultimate reason [is that] a program will not survive unless it actually works! And so school districts like that have had it for ten or fifteen years would not still have it if it were not for the fact that it is in fact effective with real teachers who have all of the skills and lack of skills and attitudes and lack—good and bad attitudes—and good and bad days, real teachers working with real kids. In our district, we have inclusion, full inclusion—no special education rooms—and it has to work with our best students and our most challenging students. It just simply has to appeal to the kids and it has to convince the teachers that it's actually moving the kids toward greater scientific literacy and skills (personal communication, May 15, 1996).

FAST Professional Development Strategies

Although reforms are sometimes mandated by leaders at the national and state levels, teachers at the local levels are the ones who must actually bring the curricular and instructional innovations into the classroom. Unless teachers are thoroughly informed and prepared, they will not be able or willing to modify their practice. Recognizing that teachers are the chief agents of instructional improvement, it makes sense to engage them in staff development as a way of bridging the gap between the vision of reformers and practice in the classroom.

In recognizing that intermediate school teachers' backgrounds are often general and marginal, the advisory council linked the *FAST* curriculum with professional development by explicitly stating in the proposal: "The program should provide a complete teacher training package" (HCC, 1967, p. 3).

I recount here a tale of a search for funds. Whether the project received any funding is not the main point of the story; that the Council and curriculum developers felt so strongly about the significance and importance of the link between teacher education and curriculum development is significant.

In early December of 1967, a proposal was hand-carried to Washington, D.C. In speaking about his visits to NSF and the Office of Education, Pottenger reported that despite uncertainty of funds, officials were generally impressed with what *FAST* had undertaken, especially with regard to the teacher education section. Pottenger's comments as they were recorded in the minutes of *FAST* Joint Steering Committee, January 12, 1968: "Mr. Pottenger stated that the general reception of the *FAST* proposal was found to be encouraging with the agreement that the teacher education section should be the central idea." Pottenger also noted that Dr. L. Binder of the precollege science curriculum program of NSF suggested repackaging of the teacher preparation section of the proposal for the purpose of reducing the scale of the grant request: one proposal to address curriculum development and the other to seek funds for teacher education. The curriculum council, however, "felt that since the teacher training section was the very substance of the whole program it would not be advisable to separate it [proposal] at this time." (Minutes of the HSCC, January 8, 1968)

The perception of the advisory committees to the *FAST* project that the curricular and instructional innovation they were advocating was based not only on a unique interdisciplinary approach to content but also on tight linkages between curriculum development and professional development might have cost them funding. Senta Raizen, an official with NSF, commented to Sister Edna Demanche that:

> The whole project was too rich for our blood. We have no means for supporting such an ambitious project. In addition, when a project is that ambitious, even if we had the money to support it, I think we would hesitate to support and carry out this project (personal communication, April 3, 1968).

In hindsight, two proposals seemed to have been a reasonable alternative; NSF was in the business of supporting precollege science curriculum development and the Office of Education was in the business of supporting teacher education. Two proposals on smaller scales than the original proposal would certainly have increased the odds of receiving some funding. So, "against all odds," why did the framers of the proposal insist on keeping the original large scale proposal? What was the effect of not receiving funding on the survival of the *FAST* program?

The proposal framers may have been experienced in curriculum development but inexperienced in writing proposal grants. They were also in the early stages of designing an innovation about which they and many others were excited. Holding very high ideals and perceiving that two proposals in someway might be seen as a compromise in their values, they stuck with their original proposal without realizing that practical realities might have called for separating the ideals from the practice of obtaining grants.

The value premise that a complete in-service training program was an essential component of the reform agenda espoused by the *FAST* project was based, in part, on the experiences of proposal framers with various curricula reform projects. They "recognized that the success of any new curriculum rests heavily on the degree of understanding that the teacher has of its philosophy, objectives, and subject matter" (HCC, 1967, p. 11).

<u>A Policy of "Participate to Purchase" in Action</u>. The 1967 Proposal framers declared, "Since *FAST* is conceived as a completely articulated system . . . reliant on the teacher training package, it will not be distributed piecemeal during the pre-publication period," and added,

> Preliminary conversation has been entered into with Tongg Publishing Co. of Honolulu and John Wiley & Sons, for handling the publishable materials of this project. The University of Hawaii Press will be given prime consideration for this task.
>
> Since no project publications will reach final press stages during the first three years, decision on the final disposition of project publications and distribution can be made at a later time. Efforts will be made to ensure use of the materials as a total system involving both teacher training and full student programs (HCC, 1967, p. 26).

The project did not rule out working with publishers since they welcomed inquiries as indicated in a *FAST* Project (1973) newsletter: "Mr. B. J. Smith of Addison Wesley and Mr. Glen Hogan of Harper and Rowe, two representatives of publishing companies, made separate whirlwind tours of some of our schools. There will be others, so keep your [*FAST* classroom] doors open" (p. 4).

Since it could not find any publisher who would support professional development, *FAST* settled on self-publishing and distributing its own materials. It has complete control on editorial matters as well as controlling access to project materials. In other words, the *FAST* project puts into practice its policy of "participate in order to purchase" [my phrase].

The following story illustrates the *FAST* project's policy in action: In order to obtain *FAST* materials for pilot testing purposes in 1984, John Pauls abided by the "participate in order to purchase" policy and attended a *FAST* summer pre-implementation inservice institute. In addition, Pauls repeated *FAST 1* training the following summer; this time he trained to become a certified trainer so that he could conduct an inservice institute for his school district. In an interview, Pauls tells of how curriculum evaluation for the purpose of textbook adoption became a pathway to intensive staff development:

> I think perhaps *FAST* paved the way for other kinds of intensive staff training [in our school district]. In the old days, we used to adopt a textbook and not provide any training at all. That was never even really considered.
>
> The part [process of adoption] that was most difficult to absorb [and manage] was the teacher training. And, that's for two reasons: one is getting everyone trained and the logistics of doing that, and secondly the cost. . . . We had to figure out a way to do that [train everyone]. One idea would be to have summer training for teachers. But the problem there is that not everyone would participate and not everyone could participate.
>
> . . . Our school district did what I thought was a remarkably forward thinking solution and that was to train everybody the last two weeks of school and provide substitutes for every one of the [20] middle school science teachers (personal communication, May 15, 1996).

The cost of adopting *FAST* increased for this school district with its hiring of substitute teachers for two weeks while salaried teachers participated in pre-implementation inservice training. In retrospect, survival of *FAST* in this school district seems to be a result of a combination of conditions: program-specific teacher training; careful evaluation of the curricular and instructional innovations of the *FAST* program; and additional funds for hiring substitute teachers.

In-Service Teacher Training. Initial reactions by prospective *FAST* teachers to the inservice training requirement varied. On the one hand, some teachers—especially those with strong science backgrounds—were unsure about the value of and requirement for attending a teacher training session. So how did one of those skeptical teacher's reflect on the inservice experience? Tuney Kannapell in a letter of support to University of Hawaii's President Mortimer remarked:

> Not only did the CRDG . . . manage to create an enviable curriculum, but it also provides the necessary support to implement it successfully. I had background training in science, as well as in education, and was somewhat skeptical about the need for training prior to it. After participating, I realize the critical role the training plays, and am impressed with the professionalism and multiple levels of education it provides teachers. Background information, teaching methodology, management, safety, and clear goals and objectives are all presented in the well organized training (personal communication, September 7, 1995).

On the other hand, Eugene Wargo, a science curriculum facilitator for a small school district in Pennsylvania who was appointed in 1989 to find a middle school science program that was "state of the art and really taught science to the students" for his school district readily accepted the requirement for inservice teacher training. In his letter of support to Mortimer, Wargo claims, "One of the most important components of the program was the ten day training session. It takes at least this long to change attitudes about science teaching, learn new techniques and practice direct inquiry and Socratic methods" (personal communication, July 27, 1995). He added: "The philosophy and methods used in *FAST* were so impressive that the superintendent required all science teachers, grades 6–12, to take at least one *FAST* training session so that (they) could apply the techniques developed in *FAST*" (personal communication, July 27, 1995).

On-Site Support Services and Coaching. In 1967, the program developers had already realized the importance of providing a "format for effective supervision during the initial year of use of materials at each grade level" (HCC, 1967, p. 65). In other words, they proposed providing follow-up support services for one year. With 25 years of experience, however, they extended the time frame for assistance; now, the project routinely arranges for on-site support services and coaching that last anywhere from the first to third years of implementation and beyond if necessary.

The on-site support services consist of monthly meetings where teachers exchange ideas and experiences on what works, how to solve problems in the classroom, how to refine instructional strategies, and what resources are available to strengthen their content knowledge background. Teachers may elect to receive university credit for their participation in these meetings.

In addition to on-site support services, the project staffs a telephone hotline to answer any questions or concerns about teaching the *FAST* program. It also sponsors a computer network, the Hawaii Network for Education in Science and Technology (HI–NEST) to foster communication among teachers, administrators, local coordinators, and project personnel. The computer network, in essence, "bridges oceans and continents to help *FAST* teachers share student activities [and data] and stay in touch with other *FAST* teachers, trainers, and CRDG staff" (Southworth, 1995, p. 10). By offering a full range of follow-up activities, the project helps teachers implement the curricular and instructional innovations embedded in the program and increases its odds for survival.

<u>Long-Term Support Services , Adaptation and Ownership, and Action Research</u>. Inservice training and on-site follow-up services enable teachers to learn about, understand, and master curricular and instructional innovation. The third component of professional development, long-term support services, helps teachers refine and personalize the innovative program. Teachers adapt the program to meet their students' needs and their school's policies; they also derive a sense of ownership in the process. In addition, teachers engage in a series of professional development seminars and explore areas beyond the everyday use of *FAST* in their classrooms; they "often begin to deal with philosophical issues such as what is worth teaching and what is the nature of science or to research applications such as how can the research on learning styles or cooperative learning or thinking skills help teachers to teach their program more effectively to more students" (Young, 1995, p. 13). Put another way, some teachers conduct action research as part of their course work in a professional development seminar.

Project staff also encourage teachers to participate in the professional network of national or local chapters of educational organizations such as the National Science Teachers Association; it views networking as an opportunity for professional growth and an enhancement of the staff development process.

Project staff recruit teacher trainers from the ranks of experienced *FAST* teachers. The certified trainers have taught the program as well as received leadership training. As a result, a cadre of trainers is now available in various national and international locations.

In retrospect, the program developers were ahead of the times in the early 1970s in their use of experienced teachers rather than university faculty as teacher trainers. It is noteworthy that the current cadre of certified trainers consists almost exclusively of *FAST* teachers with extensive classroom experience.

FAST and Educational Reform

Science Curriculum Reform: A Vision for the 1990s. The National Committee on Science Education Standards and Assessment (NCSESA) proclaimed that U.S. education needs "to make the transition from the 1890s objective of science for some in some grades to the 1990s goal of science for all in all grades, hoping that after 100 years of observation and experimentation, we move closer to getting it right" (NRC, 1993). The committee in its October 1992 working paper rejected the status quo in science education where members of student populations defined by race, ethnicity, economic status, gender, physical or intellectual capacity are discouraged or excluded from opportunities to learn science. Instead, it adopted the visionary goal of Science for All. The NRC reported its efforts to achieve this goal in its recently published *National Science Education Standards* (NRC, 1996):

> This nation has established as a goal that all students should achieve scientific literacy. The *National Science Education Standards* are designed to enable the nation to achieve that goal . . . (and) make scientific literacy for all a reality in the 21st century. . . . They emphasize a new way of teaching and learning about science that reflects how science itself is done, emphasizing inquiry as a way of achieving knowledge and understanding about the world. . . . The *Standards* make acquiring scientific knowledge, understanding, and abilities a central aspect of education, just as science has become a central aspect of society. (p. ix)

Equitable Access to Opportunities in the *FAST* Program. A major aim of reform efforts since the mid-1970s is equity in science education. The National Research Council (1996) defines equity as equitable access to opportunities for all students to achieve current national standards in science "regardless of sex, cultural or ethnic background, physical or learning disabilities, future aspirations, or interest in science" and includes "those who traditionally have not received encouragement and opportunity to pursue science—women and girls, students of color, students with disabilities, and students with limited English proficiency" (p. 221).

In their report, Clewell, et al (1987) identified *FAST* as an exemplary middle-school science program serving minority and female students. In a study commissioned by the University of Arizona to identify exemplary programs for at-risk students, Gore and Pogrow (1991) cited *FAST 1* as one of only two programs designated as exemplary or "best able to develop the science problem-solving skills of all middle school students, including educationally disadvantaged students in urban environments" (p. 1). The nomination process included a review of the literature and consultation with education experts across the nation. The selection process engaged a panel of three esteemed science educators in screening nominated curricular materials. In addition, researchers conducted site interviews with teachers using the recommended curricula.

Wheelock (1992) cited the *FAST* program as an exemplary program for students in heterogeneous classes and a major contributor to the "untracking of schools." A vignette of the *FAST* program in Kennebunkport, Maine describes mixed-ability classes where students "learn more readily from *doing* than from seeing or hearing alone." According to one of the teachers: "*FAST* is great for all kids. I have kids with retardation working with gifted kids. All of them open up to the lab experiments because everyone can be involved in a different role. What happens is that they all take more responsibility" (p. 174).

The Center for Gifted Education at the College of William and Mary conducted an independent review of science programs deemed appropriate for high-ability students and reported its recommendations in the *Consumer's Guide to Science Curriculum* (Boyce, et al, 1993). *FAST* was recommended for use with high-ability learners based on its reviewers' ratings of curriculum design, classroom design, exemplary science content, exemplary science process, and appropriateness. The reviewers noted that the *FAST* program is especially strong in science process: there is "high involvement that the program provides through investigations, discussion, and group work [that] makes it particularly successful with students of low socioeconomic status and girls who might otherwise avoid science" (p. 41). The reviewers also noted that according to Sears (1990), the *FAST* program materials are gender-neutral and seem to be free of bias.

Promising Practices in Science Education. In the past, *FAST* has been recognized as an exemplary educational program and listed by the U.S. Department of Education's Office of Educational Research and Improvement (1989 and 1994a) in *Science Education Programs That Work: A Collection of Proven Exemplary Educational Programs & Practices in the National Diffusion Network* and in *Mathematics, Science & Technology Education Programs that Work: A Collection of Exemplary Educational Programs & Practices in the National Diffusion Network,* respectively.

An independent nationwide search for programs that meet the new standards for science education, recently conducted under the aegis of the U. S. Department of Education's Laboratory Network Program, identified *FAST* as one of the top 20 multidisciplinary K–12 programs in *Promising Practices in Mathematics & Science Education* (U.S. Department of Education, 1994b). The *FAST* program, in effect, met the standards set by the National Center for Improvement of Science Education (NCISE). Is *FAST* still innovative? *FAST* is still currently acceptable. The studies indicate that *FAST* is very much still with us, surviving and thriving.

National Science Education Standards and the FAST Professional Development Program. To evaluate the *FAST* project's teacher education program, I interviewed two teachers in a San Jose, California, school district about their experiences with the inservice teacher education workshops and also observed a class being taught by one of the teachers. I used the professional development standards of the *National Science Education Standards* as a framework for finding answers to these questions: To what extent does the professional development component of the *FAST* project contribute to what science teachers (1) know about science? (2) know about teaching science? and (3) know to be lifelong learners?

Marilyn Bliss first participated in a *FAST 1* workshop in 1978 in Hawaii. She had accepted a teaching position at a school on the basis that it required the newly hired teacher to attend an inservice institute. Three years later in 1981, Bliss led an inservice workshop under the supervision of a project staff member and became a certified trainer. She also participated in the *FAST 2* institute the following year and subsequently became a certified trainer in that level. (Personal communication, May 16, 1995)

In 1989, Gene Gallock was part of a team charged with creating an integrated science course for high school students. One of his colleagues had attended the NSTA's national conference in Seattle, Washington, and received information about the *FAST* program; the team agreed that this program fit their needs and Gallock organized an inservice summer institute for 85 teachers in the San Jose area. (Personal communication, May 16, 1995)

Both Bliss and Gallock teach *FAST 2* to ninth graders. Gallock, however, teaches only one class as he spends the rest of his time as the science supervisor for his school district. Bliss is co-chairperson of the science department at her school.

The following comments are summaries of the interviewee' responses pertinent to the National Science Education Standards for professional development:

1. Professional Development Standard A: Learning Science Content. Both teachers commented that they learned pertinent science content through the inservice workshop. Bliss was stimulated by her *FAST* teaching experiences and enrolled in university classes to supplement the content knowledge she learned in the workshop while Gallock mentioned that the workshop provided his first experience in learning about density in the context of buoyancy. He seemed comfortable with his knowledge of ecological concepts. The comments from the two teachers seem to indicate that the *FAST* inservice teacher education program provides adequate opportunities for learning science content .

2. Professional Development Standard B: Learning to Teach Science. Bliss and Gallock both commented that the teaching of science as inquiry was modeled in the inservice workshop. "The instructor," noted Gallock, "accepted all responses and answers from participants even though they were not the 'correct' answers." He was impressed by the use of chart paper to keep a record of hypotheses generated by the class and referred to at different times to track any changes they made as a result of further experimentation.

Prior to attending the workshop, Bliss felt that a teacher should "know all the answers." She learned from the workshop that the teacher is a facilitator of learning and that it was okay to "learn along with the kids." Bliss felt that one of the most important and useful teaching strategies modeled in the workshop was of the instructor using anomalies or discrepant events to introduce a concept to not only stimulate interest but also to assess the "baseline" of students' understanding of concepts.

Both teachers expressed that the teaching of science as inquiry was a new way of teaching for them and the modeling by instructors in the workshop was significant in learning to teach science. Their having experienced being "students" taught them the value of inquiry teaching as they began to experience "teaching for understanding" of science concepts.

3. Professional Development Standard C: Learning to Learn.
Voluntarily participating in a *FAST* teacher institute seems to indicate that the teachers already had a disposition toward learning to learn. Indeed, both teachers could be considered lifelong learners prior to attending the workshops. They not only learned about teaching a new program but both also used their teaching experience to move forward in other areas of their professional life, i.e., Bliss is now science department co-chairperson and Gallock is the district science resource specialist. Both mentioned that they gained self-confidence with their *FAST* teaching experience and, as a result, sought out leadership roles.

In general, the NSES professional development standards seem to be reflected by the *FAST* inservice teacher education program.

According to Berman and McLaughlin (1978), "More expensive projects were generally no more likely than less expensive ones to . . . elicit teacher change, improve student performance, or be continued by teachers" (p. vi). In essence, their findings indicated that financial resources were not a condition for a project's survival. Instead, Berman and McLaughlin found that implementation strategies related to professional development were key to putting an innovation into practice. They noted that "these strategies could spell the difference between success or failure, almost independently of the type of innovation or educational method involved; moreover, they could determine whether teachers would assimilate and continue using project methods or allow them to fall into disuse" (pp. iv–v). They also concluded that professional development strategy of a one-shot, pre-implementation teacher training session was frequently *ineffective* because it was "not consonant with the conditions of school district life or with the dominant motivations and needs of teachers (p. v). Berman and McLaughlin claimed that the following professional development strategies were effective, particularly when applied in concert with local materials development:

- Concrete, teacher-specific, and extended training.
- Classroom assistance from project or district staff.
- Teacher observation of similar [innovations] in other classrooms, schools, or districts.
- Regular project meetings that focused on practical problems (p. v).

In summary, although financial resources are not a necessary condition to survival of an innovation, it seems that staffing resources are essential. The professional development strategies that work are people-intensive; they engage teachers in a variety of activities and they require leadership of staff trainers and facilitators for professional development activities. Chances for an innovation to survive are increased if locally developed materials are used in conjunction with professional staff development.

CONCLUSION

This historical analysis shows that the *FAST* project survived over the past 30 years within the University of Hawaii's CRDG/Lab School unit supported by a steady source of State funds and a relatively small but stable staff of highly qualified project personnel. It identifies salient features of the curriculum development process of the *FAST* program:

- Formulating a theoretical base that values development of students' intellectual capacities as the platform for curriculum research and design.

- Use of a school environment with a student population reflecting Hawaii's demographics as a research laboratory in a university setting for designing and testing innovative curricular materials and instructional strategies.

- Field testing of innovations on a small scale with a small sample of schools in a unique single statewide public school system which provided feedback about the program.

- Time to change, redesign, and revise the curricular and instructional innovations in response to not only formative evaluation results but also to external forces such as changing reform policies in science education.

What is remarkable about the *FAST* project is the stability of its vision of science education over the past 30 years and how it is consistently reflected in its curriculum. The changes over time in materials developed for students and for teachers were analyzed to determine the salient features of the *FAST* program. The key characteristics:

- An interdisciplinary program consisting of foundational concepts of physical, biological, and earth sciences; and the history and philosophy of science. It also demonstrates connections between and among sciences, technology, and society.

- Inquiry as content: an understanding of scientific inquiry as a way of generating knowledge; and inquiry as process: use of scientific reasoning and critical thinking skills to investigate and explain phenomena.

- Teaching and learning strategies that model a community of practicing scientists in which teachers are research directors working with students in research teams to generate theories about phenomena in a laboratory or field setting. Students, therefore, spend between 70% and 80% of their time conducting laboratory and field investigations.

• Comprehensive, coordinated, and cohesive package of student and teacher materials for *FAST 1*, *FAST 2*, and *FAST 3* whose costs are in line with textbook programs for the same grade levels. In addition, the materials make the *FAST* program more teacher friendly than other science programs.

Tracing and analyzing the changes in professional development strategies of the *FAST* project over the past thirty years, this historical study identified the main elements of the project's professional development strategies:

• A platform that valued teachers as key change agents in reforming science education. In practice, teachers were required to participate in pre-implementation in service training as a condition for purchasing curriculum materials.

• Developing and using a cadre of experienced FAST teachers as teacher trainers in inservice institutes. Likewise, curriculum developers who were experienced in designing the program and teaching it to Lab School students conducted the pilot inservice institutes.

• Testing of various models of inservice teacher training and follow-up support services on a small scale with a small sample of schools in a unique single statewide public school system.

• Time to change, redesign, and revise the professional development program in response not only to formative evaluation results but also to external forces such as federal funding.

In general, one organizational characteristic of the teacher education program is that institutes and seminars are conducted at sites that are as close to participating schools as possible. In further analyzing the history of the *FAST* project's professional development program, I identified its key components:

• A pre-implementation inservice teacher training institute that provides teachers with experiences as a learner of inquiry not only as content but also as process; experiences as a learner of concepts of the *FAST* program; extensive modeling of instructional strategies; understanding the philosophical and theoretical bases of the program; and tips for classroom management. Most participants find this training teacher-friendly.

• A full range of on-site follow-up and support services consisting of monthly meetings where teachers exchange ideas and discuss their experiences; visits from local coordinators; a telephone hotline to project headquarters; and a computer network for communicating with others.

• Long-term support services including professional development seminars; assistance in adapting curriculum materials to needs of students or in response to district policies; and action research opportunities.

• Professional growth opportunities such as teacher trainer training and leadership training for local coordinators and facilitators.

In effect, the *FAST* project survived because it had the organizational support of an extremely stable CRDG/Lab School research-based unit, steady State funding, highly qualified personnel, and time to plan and craft finely tuned innovative curriculum materials for middle school students and teachers. An analysis of the changes made over the past 30 years in the program's curricular and instructional strategies indicate the extent to which the project responded not only to feedback from teachers but also to various reform movements in science education. This historical analysis shows currency in most of the materials of the *FAST* project relative to the *National Standards*. Put another way, *FAST* was ahead of the times in its vision and its curricular and instructional innovations.

In the context of professional development, the *FAST* project survived because it had the support of the CRDG/Lab School unit in obtaining funding for inservice teacher training from external funding agencies such as NSF, Hawaii Department of Education, and U.S. Department of Education; providing internal funding whenever necessary; and negotiating with schools and school districts to pay for training. In addition, many school districts relied on Eisenhower grants to fund professional development activities.

The project engaged its curriculum developers in teaching inservice institutes; recruiting and training experienced *FAST* teachers as inservice trainers; coordinating inservice institutes; and leading professional development seminars. Most importantly, the *FAST* project involved teachers as key change agents in reforming science education; the teachers are not and have not disappointed. In using the *National Science Education Standards* as a framework for analyzing currentness of the *FAST* project's teacher education component, this historical study shows that *FAST* was ahead of the times in its vision of reform and its professional development strategies as a way of implementing curricular innovations and changing science teaching practices.

Significance of Study. In the past, curriculum reforms have called for improvements in science education albeit for different reasons. Traditional curricula based on textbooks have survived most reforms while many innovative exemplary curricula reflecting reform values tended to have short life spans. Innovative curricula developed with funds from the National Science Foundation in the 1950s and 1960s, for example, were not widely implemented and few lasted beyond the 1970s.

In contrast, innovative curricula developed by the *FAST* project survived over a period of three decades. The significance of the study lies in what it teaches us about some of the conditions necessary for long-term survival. For educators charged with evaluating, designing, or implementing science curricula, this historical study of the *FAST* program teaches lessons about how to select or design curricula that are likely to survive. For policy makers and school administrators, there are lessons to learn about the interrelationships among resources, curriculum development processes, and professional development strategies. For researchers, there are insights into the dynamics of how a curriculum project "against all odds" survived.

This study reveals that the *National Science Education Standards* can provide a useful framework for revising and improving the *FAST* curriculum. The project staff has addressed the Content Standards in its document, *Alignment of the Foundational Approaches in Science Teaching (FAST) Program and the National Science Education Standards: Grades 5–8* (CRDG, 1966). Since the target group consists of young adolescents, for example, the developers might well consider whether science content standards related to personal health, reproduction and heredity, and regulation and behavior—the main topics of concern and interest for many middle school students—should be incorporated in a revised edition of the curriculum or developed as supplementary units. Project staff might also want to consider the content standards and incorporate units on electricity and the transfer of electrical energy in the context of currently living in an age of electronic information.

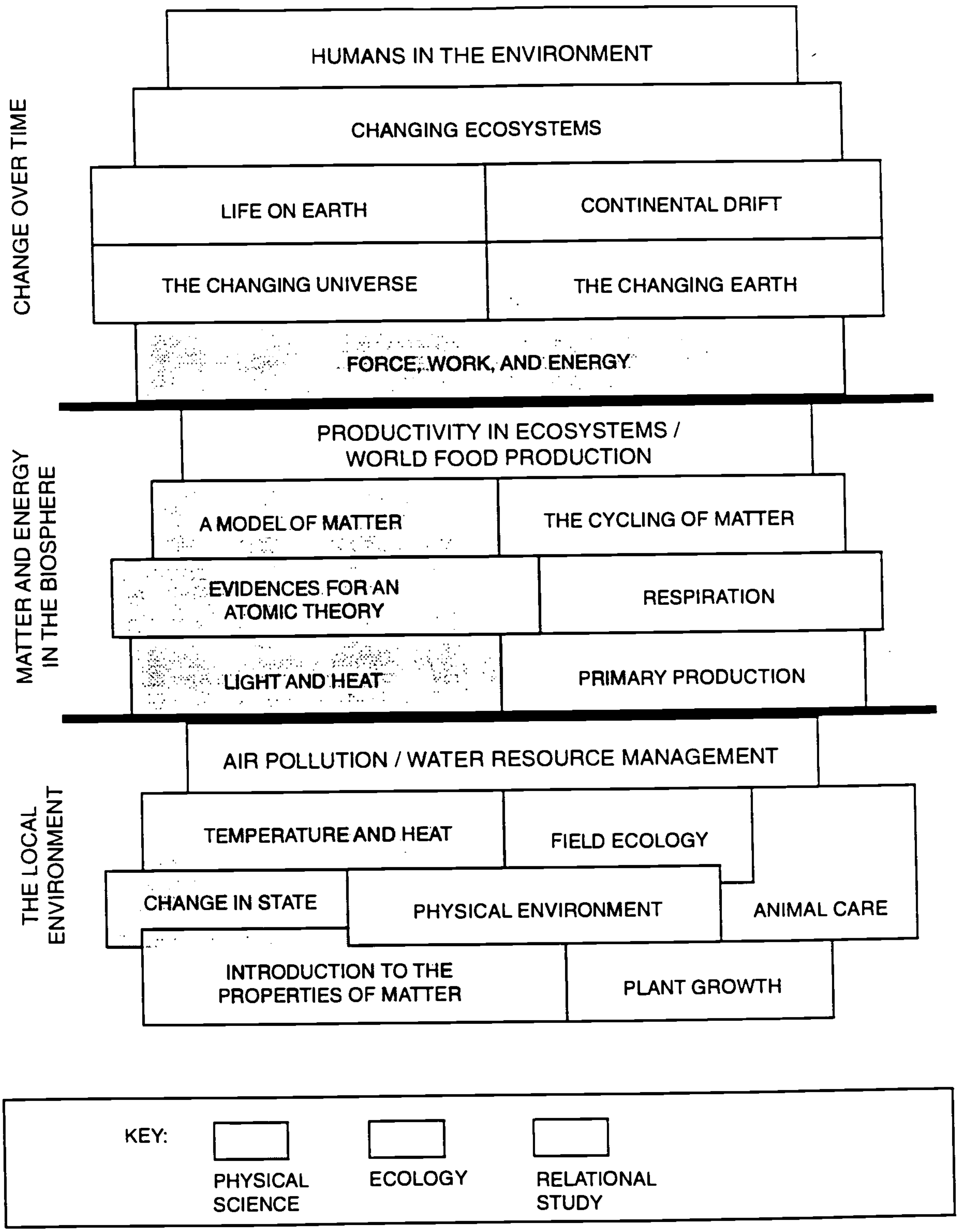
Lessons learned from the *FAST* project about a teacher education and support program that works can be applied to designing and providing professional development programs that help teachers accomplish the *National Standards* for reform in science education. In other words, learning the lessons of survival contributes to our understanding of the elements needed for achieving the goal of excellence and equity in science education in the 21st century.

APPENDIX A: CURRICULUM DESIGN

The *FAST* program is organized into three strands: the Physical Science and Ecology strands provide the formal science content and the Relational Study strand integrates the sciences, technology, and society. (See Figure A.1 on the following page.) According to Young and Pottenger (1992),

> Scientific content has been selected for interdisciplinary utility and social relevance. Principles developed in the Physical Science strand constitute the foundations of science and undergird the Ecology strand. The biological and earth science content of the Ecology strand is basic to understanding major environmental issues. The Relational Study strand uses the teaching strategy of reinforcing basic concepts through interdisciplinary work. That is, concepts and skills developed in one science are used or applied in another, thus linking all areas of science. The Relational Study strand also confronts students with the problem of how technologists, social planners, and citizens can use scientific knowledge in making decisions affecting environmental quality.
>
> The content of the Relational Study is drawn from the philosophy and history of science. It weaves the many parts of science into a meaningful whole. The Relational Study points our the inherent similarities and differences in the kinds of inquiry characteristic of ecology and physical science. It focuses on the historical parallels between work developed in the *FAST* laboratory and work done by the investigators who first grappled with the same concepts. It shows the connections between the sciences, the technologies, and the everyday world of citizens. It also exposes the limitations of scientific knowledge in the arena of social decision. Through this approach, students see scientific knowledge as but one of many factors (moral, ethical, aesthetic, political, etc.) that must be weighed in making decisions affecting society.
>
> *FAST* provides common foundational experiences in the concepts and methods of science for students in . . . [grades 6–10]. . . . *FAST* has been crafted to capitalize on the unique developmental characteristics of adolescents. Students at this age show an increasing capability for abstract thinking; they can inquire into and reflect on the significance of their activities. This is also a time of commitment, when attitudes, habits, and intellectual styles that will strongly influence the remainder of their schooling and adulthood solidify. *FAST* seeks to help students develop positive attitudes toward science and useful problem-solving approaches by providing them with a variety of activities relevant to the world unfolding before them (p. 5).

FIGURE A.1 Units of the *FAST* Program



Note. From Instructional Guide (Second Edition) (p. 6), by D. B. Young and F. M. Pottenger, 1992, Honolulu: Curriculum Research & Development Group. Copyright 1992 by the University of Hawai'i. Reprinted with permission.

APPENDIX B: CONCEPTUAL FRAMEWORK

The *FAST* program is organized into three levels: The Local Environment; Matter and Energy in the Biosphere; and Change Over Time. (See Figure A.1 on the previous page.) The concepts developed in the Physical Science, Ecology, and Relational Study strands of each level are described in this appendix.[2]

The Local Environment (*FAST 1*)

The unifying theme of *FAST 1* is the local environment. To gain understanding of their own environment, students conduct laboratory and field investigations to identify its components—plants, animals, and physical factors—focusing on interrelationships among them. They do laboratory activities to find explanations of the physical factors.

Work in the laboratory and field capitalizes on the excitement of discovery and engages students in activities characteristic of a modern scientific community. Investigation requires careful attention to planning, executing, and interpreting experiments and community validation of results.

In the Physical Science strand, students first investigate basic concepts of science, including mass, volume, and density, as well as the relationships between density and buoyancy. In so doing, they work with all three states of matter—solids, liquids, and gases—and use their knowledge to explain everyday phenomena. By the end of the first unit, they can define matter as having mass and volume and the derived property of density, and they know that matter exists in three states. It is here that students also begin to learn basic laboratory skills.

Next they investigate the melting, freezing, boiling, and condensing of pure substances and mixtures and use their knowledge of change of state to identify unknown substances. They also conduct experiments on fluid mechanics—the capacity of gases and liquids to transmit pressure and to be compressed or attenuated. They measure vapor pressure using student-made manometers and refine their definitions of *change of state* by considering the effects of pressure.

Throughout their investigations of buoyancy and density and change of state, students find that some form of heat or energy is involved in change. Investigations in the final Physical Science unit focus on energy relationships. Students invent heat-measuring devices and derive the calorie as a standard unit of heat measurement. All these physical science concepts are applied in study of the environment.

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[2]From Instructional Guide: *FAST*, Foundational Approaches in Science Teaching (Second Edition) (pp. 9–19), by D. B. Young and F. M. Pottenger, 1992, Honolulu: Curriculum Research & Development Group. Copyright 1992 by the University of Hawai'i. Reprinted with permission.

Concurrently, in the Ecology strand, students investigate plants, animals, and the physical environment, in the laboratory and in an outdoor class study area. In the Plant Growth unit they develop an understanding of experimental design in investigating the effects of scarification on the germination of seeds with hard coats. They then design their own experiments to investigate environmental effects on plant propagation. The units emphasize experimental design and communicating findings orally and in writing.

In the Animal Care unit, students raise an animal from the class study area through one life cycle. They learn about life needs, behaviors, habitats, and niches, as well as interactions with other organisms. They study the interactions and movements of water through the soil, air, and plants in the Physical Environment unit. They build their own instruments for analyzing soil-water interactions, collecting weather data, collecting and measuring raindrops, and measuring transpiration. In the final activity of the unit, they trace the water cycle from their investigations.

The Field Ecology unit is designed to unite all of the Ecology strand into a whole. It focuses on the interactions and interdependence among plants, animals and the physical environment in the class study area. Students build field-mapping instruments and make a detailed scale map of their study area. They also conduct quadrat studies of environmental change over time and learn how to estimate population sizes by using sampling techniques. In the last investigation, they conduct their own research of an ecological problem within the study area.

Through the Relational Study strand, students focus on the interrelationships of their studies in Physical Science and Ecology. For instance, their knowledge of buoyancy is applied to explaining floating and sinking objects in the environment, the floating of clouds, and the working of their soil analysis apparatus. Similarly, their knowledge of change of state and specific heats enables students to explain weather phenomena, ocean and air currents, air pressure, and the movement of water in the hydrologic cycle.

In addition, the Relational Study strand contains two units that call for students to draw on what they have learned in both Physical Science and Ecology during the year and apply their knowledge and skills to the study of a community environmental issue—either air pollution or water resource management.

One of the major objectives of *FAST* is to develop skills in measurement and in laboratory practice. Students learn to manipulate standard laboratory equipment such as metersticks, balances, glassware, graduated cylinders, thermometers, overflow cups, and heating devices. They learn and practice safe laboratory procedures.

FAST also emphasizes research skills such as planning, designing, and executing valid experiments, collecting and organizing data, constructing and using graphs, and communicating results. *FAST* investigations develop thinking and problem-solving skills as well as manipulative skills.

In addition to science skills, *FAST* fosters and enhances interpersonal skills. Most work is done in small collaborative groups where students share leadership as they share data, ideas, and inventions. The ability to get along with others, cooperate, and get a job done is cultivated through example and practice. All these skills are considered foundational for general education and scientific endeavor.

Matter and Energy in the Biosphere (*FAST 2*)

The unifying theme of *FAST 2* is the transfer of matter and energy through ecosystems. Student investigations establish that the processes of photosynthesis, respiration, and decomposition are carried on by living organisms; that there is conservation and cycling of matter in the biosphere; that solar radiation entering the biosphere eventually leaves the system as heat. The role of humans as controllers of forced ecosystems is also studied. From these investigations emerges the realization that all organisms are part of a complex interdependent biosphere.

FAST 2 gives students a realistic perspective on human beings as environmental manipulators in a world of finite matter and energy. Students investigate the pressing problems of overpopulation and worldwide shortages of food and fuel. *FAST 2* develops the theme that humans can and must plan for the world of the future. Since humans are decision makers and agents of change, they must consider the technological, social, economic, and ecological implications of their actions. *FAST 2* is based on the assumption that students must understand the processes and interactions of the ecosystems of the planet, make a commitment, and take responsibility for environmental quality as they become citizens of the world.

Physical Science investigations support ecological studies. The Physical Science strand begins with an inquiry into the Newtonian physics of light. Students investigate the nature of light (including measurement of the solar constant), absorption, transmission, reflection, refraction, diffusion, color, and the spectrum. They define energy as anything that can be converted into and measured as heat and explore the relationship between light and heat. (This is an older definition. *FAST 3* develops the more modern definition that energy is anything that can produce work.)

Students then search for evidence of the existence of atoms by analyzing and synthesizing various compounds. These investigations provide good support at the molecular level for the assumptions of conservation of matter made in the Ecology studies. In a brief review of the history of chemistry they search for further evidence to support an atomic theory. Finally, they investigate the kinetic molecular theory of matter and apply it to explaining various molecular phenomena.

The Ecology strand focuses on matter and energy transfer in ecosystems. Students first investigate the interaction of plants and light. Through a series of laboratory and field studies, they identify the process of photosynthesis and generate a model of a producer. Then they investigate respiration as a process of matter and energy conversion in both plants and animals. Out of this study, they develop a model of a consumer. They study the special group of consumers called decomposers by making compost and observing the process of decomposition. They compare the processes of photosynthesis, respiration, and decomposition. They develop the concepts of interdependence of all living organisms, the cycling of matter in ecosystems, and the flow of energy through ecosystems.

In the Relational Study strand, students apply their knowledge of the transfer of matter and energy in ecosystems to a real system that they design, either field garden plots or microecosystems in gallon jars. By manipulating components of the system, they create a forced ecosystem that maximizes the production of one or more products.

In the unit on world food production, students develop a realistic perspective on humans as capable of manipulating the pathways of matter and energy use in ecosystems to meet their desires. They analyze one or more of the energy problems facing the world, such as the shortage of food or fossil fuel. Students engage in decision-making situations in an attempt to confront these global problems and seek solutions to them.

FAST 2 students build on the skills learned in *FAST 1*. *FAST 2* assumes that students know how to handle standard laboratory equipment and provides additional practice.

FAST 2 emphasizes research skills. Students design many more of their own experiments, paying careful attention to controls, replication, and other features of valid experimental design. They are increasingly responsible for identifying problems, formulating hypotheses, designing tests, conducting experiments, preparing data tables, collecting data, and communicating the results of their work. Increasingly they rely on reading as a method of gathering needed information. Further opportunity for developing interpersonal skills is also an integral part of the skills development of *FAST 2*.

New research tools are added to the students' expanding repertoire. In *FAST 2* they learn . . . chromatography to separate and identify substances; to generate and identify various gases; to analyze compounds by heating, blowpiping, electrolysis, and acid analysis; to test for the presence of carbohydrates, fats, and proteins; and to measure energy as heat. They learn valuable horticultural skills in preparing their garden plots.

Systems analysis is introduced in *FAST 2* as a technique to simplify complex problems and to account for components of a system. Students use systems analysis extensively throughout Physical Science and Ecology for cataloging what they know about a system and for visually summarizing relationships.

Change Over Time (*FAST 3*)

The unifying theme of *FAST 3* is change over time. The course relates the concepts of physics, chemistry, geology, and the life sciences through the study of changes in the earth, living things, the solar system, and the universe. By studying change in different parts of the environment, students learn about events that are happening now or have happened in the past, then use their knowledge to predict events in the future. The concept of time is extended back 15 billion years to the hypothetical formation of the solar system, then forward to the era of students' own adulthood and beyond.

Students begin their study of physical science and the earth sciences by measuring force, gravity, work, and energy in laboratory investigations. These concepts are basic to interpreting the interactions of matter and energy, which they investigate in studies of mountain formation, weathering and erosion, theories of the origin and structure of the universe, the evolution of stars, the formation of Earth, and plate tectonics.

In their study of ecology and the life sciences, students advance hypotheses that suggest conditions necessary for supporting life and develop an operational definition of life itself. They identify the structure of organic molecules characteristic of life, explore alternative theories of molecular evolution, and investigate the probabilities of changes in life forms over time.

They then shift focus, examining changes in ecosystems and the effects of living organisms on their environments. By investigating how living things interact with their environments and with each other, they gain insight into how organisms and ecosystems change over time.

In the Relational Study strand, students explore the interactions of science, technology, and society. They consider the history of humans as they have gained control over increasing amounts of energy, first as hunters, then as agriculturists, and finally as industrialists. The course concludes in a series of simulations in which students take the roles of decision makers coping with problems of resource depletion, overpopulation, energy consumption, and other forms of environmental stress.

FAST 3 students continue to use basic lab skills developed in *FAST 1* and *FAST 2*, getting further practice in applying them as they develop their interpersonal skills.

In addition to gathering data through experimentation, students increasingly rely on the work of practicing scientists to build models of how Earth and its environments have changed over time. Communication of ideas becomes increasingly important. Prediction of future events based on knowledge of past and current events is further cultivated. Students come to see scientific "fact" as tentative and changing in the light of new evidence or new interpretations of old data.

APPENDIX C: LIST OF INTERVIEWS

Bliss, M. Interview by author, notes. San Jose, CA. 16 May 1995.

Gallock, G. Interview by author, notes. San Jose, CA. 16 May 1995.

Pauls, J. Telephone interview by author, tape recording. Palo Alto, CA. 15 May 1996.

Pottenger, F. M. Interview by author, tape recording. Honolulu, HI. 1 November 1995.

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