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ABSTRACT

A study described the dynamics of integrated mathematics-vocational-technical education learning initiatives in high schools and postsecondary institutions that have adopted the National Council of Teachers of Mathematics (NCTM) standards. A national survey of secondary and postsecondary sites engaged in linking mathematics and vocational-technical education was conducted to identify and select four promising programs (three high schools and a community college) for in-depth case studies. Protocols were developed and used for interviews and focus groups with administrators, mathematics/vocational instructors, and students. A protocol for classroom observations was also developed to document instructor and student activities during the 2-day site visits. Case studies were conducted to examine program development and the extent to which the NCTM standards guided local efforts. Findings suggested that linking the NCTM standards to emerging career-oriented curriculum was not a simple process requiring pedagogical changes only. It was a far-reaching enterprise challenging educational leaders to engage in serious comprehensive restructuring involving curriculum, instruction, and assessment systems. Implementing NCTM standards required the following steps: managing change; moving toward integrated, "authentic" instruction; building institutional and community support; and fostering interdisciplinary teacher collaboration. (Appendixes contain 48 references and the 4 case studies.) (YLB)

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LINKING THE NCTM STANDARDS TO SCHOOL-TO-WORK REFORM

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EXECUTIVE SUMMARY

An unlikely equation is in the making. The premises underlying both mathematics and vocational-technical education reform movements present a historical opportunity for developing integrated curriculum guided by the National Council of Teachers of Mathematics (NCTM) Standards. The common grounds provide great opportunities for collaboration. Both movements aim at providing *all* students with challenging curriculum and learning required in today's world. The questions are "What are the characteristics of promising programs engaged in bridging these two reform movements?" and "What can we learn from these programs to inform the development of rigorous integration efforts?" This study addresses these questions by building a comprehensive understanding of integrated program development and approaches to linking the NCTM Standards and mathematics/career curricula. Through a national survey of programs featuring mathematics/vocational-technical integration, four promising programs were identified (three high schools and a community college). Case studies of these promising sites were conducted to study program development and the extent to which the NCTM Standards guided local efforts.

Study findings suggested that linking the NCTM Standards to emerging career-oriented curriculum is not a simple process requiring pedagogical changes only. It is a far-reaching enterprise challenging educational leaders to engage in serious comprehensive restructuring involving curriculum, instruction, and assessment. Organizational and management changes are also necessary to support more active collaborative efforts and shift from traditional ways of thinking about educational systems. Consistent with research on organizational restructuring, the following findings highlight a framework for linking the NCTM Standards to curriculum featuring mathematics in realistic contexts.

Managing Change

- Assessing institutional and student performance is essential in order to make informed decisions about improvements and their relation to shifting students' learning from traditional tracking systems.

- Leadership styles that promote more democratic participation in decisionmaking appear to be more successful in facilitating shared understanding of needs, purpose, and working toward changes to improve the quality of learning for *all* students.

- Another basic requirement for successful implementation at early stages is setting a clear definition of achievement expectations for students and roles of instructors, administrators, and other internal and external supports.

Moving Toward Authentic Instructional Practices

- Instructors must commit to implementing changes in pedagogy that match high expectations for student achievement. For this purpose, integration formats and collaboration arrangements have to satisfy local needs. Models and guidelines outlined in related literature provide an excellent frame of reference for successful integration.

- Career contexts provide great opportunities for the development of nonroutine problems featuring significant mathematical concepts. Through these problem scenarios, core SCANS and NCTM Standards skills (e.g., problem solving, communication of ideas, and knowledge applications) can be effectively emphasized.

- To guide decisions on the development of authentic, integrated, NCTM Standards-based instruction, a shared understanding of criteria for high authenticity is required to match high expectations for achievement and career goals for *all* students. The NCTM Standards vision along with relevant ideas supporting emerging vocationalism should be taken as a flexible guide, not as a step-by-step framework.

Building Institutional and Community Support

- Creating an institutional climate is critical for establishing the organizational capacity that will sustain integrated work. The goal should be to foster a sense of community where avenues for democratic input in decisionmaking are understood and used.

- Early promotion of interdisciplinary collaboration in decisionmaking through working groups, councils, and other forms of participatory management are suggested to foster shared understandings, empower participants, and facilitate work toward common goals.

- Instructors should be encouraged to take responsibility for designing their own professional development plans grounded in individual and program needs to acquire specific preparation for implementation of suggested improvements in curriculum, teaching, and assessment.

- Channels for continuous dialogue and discussion of important institutional issues affecting all stakeholders are also helpful in creating a sense of professional community. It is important to shift from bureaucratic, compartmentalized systems precluding multiple manifestations of collaborations and open exchanges of opinions.

Fostering Interdisciplinary Teacher Collaboration

- Interdisciplinary collaboration helps break down the walls between instructors. Fostering teamwork and exchanges between mathematics and vocational instructors is helpful for dispelling stereotypes and building an appreciation for each other's contributions to the educational enterprise.

- Bringing mathematics instructors closer to vocational work provides likely and valuable exposure to external supports (e.g., business and industry) that may be taken for granted by vocational instructors. This exposure can contribute to a greater understanding of the complexity of supports needed for establishing career curricula and to an opportunity to identify significant mathematics applications.

- Awareness of issues, government regulations, and requirements of mathematics/ vocational reforms perspectives is a desirable condition for establishing a holistic understanding of common undertakings and to shift from turf protection that is prominent in traditional settings.

Survey information suggested that the extent and nature of efforts linking the NCTM Standards and school-to-work reform are weak and slowly evolving. This process appears to be very complex, requiring deep changes and radical shifts from traditional practices supporting education systems. However, drawing from the experience of case study sites, we were able to identify a promising framework for development of effective integrated efforts featuring mathematics in occupational contexts. This framework is supported by related research on the restructuring of educational organizations and can be useful for practitioners, administrators, and policymakers.

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BACKGROUND

Recognizing the importance of mathematics literacy, the SCANS report (Secretary's Commission on Achieving Necessary Skills, 1991, p. xvi) considered mathematics and computational skills essential since virtually all "employees will be required to maintain records, estimate results, use spreadsheets, or apply statistical process controls as they negotiate, identify trends, or suggest new courses of action." The Society for Industrial and Applied Mathematics (SIAM) agreed. In 1996, SIAM reported an overwhelming prevalence of mathematics applications in a variety of industrial settings including materials processing, automobile design, medical diagnosis, development of financial products, network management, and weather prediction. It also attested to the pervasive role of mathematics in real-world problems and noted that in many instances it is not even explicitly labeled as *mathematics*. Most importantly, SIAM outlined desirable employee qualities that aligned closely with the SCANS skills, including "formulating, modeling, and solving problems from diverse and changing areas; interest in, knowledge of, and flexibility across applications; knowledge of and experience with computations; communication skills, spoken and written; adeptness at working with colleagues ('teamwork')" (p. 2). SIAM and SCANS both concluded that workers lack these skills and called for students to acquire a deeper understanding of real-world applications of mathematics.

In today's rapidly advancing technological world, knowledge of mathematics is imperative. However, it is clear students are still experiencing traditional curriculum and instruction and are ill prepared for the realities of the 21st century. The challenge is to break traditional molds of curriculum and instruction and shift toward a holistic approach that emphasizes knowledge and skills that connect students with the world around them and build powerful understandings of both mathematics and its applications (Newmann, Secada, & Wehlage, 1995; Romberg, 1992; Rothman, 1995). In the early 1980s, the National Commission on Excellence in Education (1983) concluded that serious educational reforms were necessary to prepare future generations with problem solving, higher-order thinking, and communication skills as well as to help students develop an understanding of academic knowledge grounded in real-world situations. Further, the National Education Goals Panel (1992) set the goal of American students becoming "first in the world in mathematics and science achievement by the year 2000" (p. 101). But we are far from successfully implementing education reform and realizing such an ambitious goal.

Reacting to these issues, mathematics educators understood it was time to revisit current mathematics curriculum and teaching practices. Concurrently, vocational-technical educators embarked on a similar journey in response to new demands in workplace skills requiring rigorous applications of academic knowledge. The potential for linking mathematics and vocational education reforms was, for the first time, a promising equation.

Tuning Mathematics Education

Proponents of mathematics education reform have argued that teaching and learning practices must be revisited and that the development of mathematics education that addresses the needs of the modern student is long overdue. They argue that students have been shortchanged in traditional classrooms by viewing learning as a process of absorption, rather than construction, of knowledge. Thus, mathematics reform suggested content revisions focusing on *all* students "doing" mathematics through active participation in worthwhile problem-solving activities including the use of calculators and computers (Romberg & Carpenter, 1986; Rothman, 1995).

The National Council of Teacher of Mathematics (NCTM) has played an active role in promoting these ideas and developing a framework for much needed changes. NCTM developed a vision for implementing mathematics reforms in a set of documents proposing standards for curriculum and evaluation, teaching, and assessment for K-12 school mathematics (NCTM, 1989, 1995). This vision for curriculum and evaluation standards suggested that *all* students should learn to value mathematics, reason and communicate mathematically, develop confidence in their mathematical understandings, and become problem solvers (NCTM, 1989). To further guide teachers in designing a variety of assessment practices, a complementary document outlining relevant standards was published by NCTM in 1995. These standards provide ideas to weave assessment practices as an integral part of the teaching-learning process.

The American Mathematical Association of Two-Year Colleges (AMATYC) followed suit and released a report in 1995 describing standards for introductory college mathematics before calculus. These standards reflected, in general, the same vision of the NCTM Standards while focusing on college needs and proposed to enhance the career

development for all students, heavily emphasizing mathematical applications in realistic contexts featured in technical programs.

School-to-Work Reform Movement

In response to new realities encountered in the workplace, vocational education legislation laid the foundations for serious restructuring early in 1990s. Most importantly, there was a call to integrate vocational and academic education and no longer instruct for narrowly defined skills and preparation for specific trades. Schools were encouraged to emphasize transferable skills that would enable students to function effectively in a diverse and competitive world of work. The goal was to make academic knowledge contextually relevant to *all* students while learning all aspects of an industry (see Grubb, 1996; SCANS, 1991; Stasz, Kaganoff, & Eden, 1994; Wirth, 1992).

The School-to-Work Opportunity Act (STWOA) of 1994 refined this movement by making explicit that *all* students should benefit from programs facilitating school-to-career transition. It also included work-based learning opportunities and connecting activities with postsecondary institutions to enhance students' academic/vocational preparation and career development. Broad guidelines suggested curricula featuring college preparation courses integrated with technical education to provide both academic and practical skills so that students could pursue further education or work. Fueled by these calls for change, Tech Prep, youth apprenticeship, career academies, and magnet school initiatives were promoted to deliver these educational promises (Grubb, 1996; Pauly, Kopp, & Haimson, 1995; Phelps, 1992; Rosenstock, 1991; Smith, 1995). This has been a remarkable movement that is challenging a well-rooted system resting on 80 years of vocational education void of strong connections with academic learning.

A Framework for Integrated Learning in the Works?

Coming from two different perspectives, both mathematics and school-to-work reform movements shared common grounds: a belief that all students should benefit from improved and challenging curriculum and teaching practices and the need to make learning relevant to the requirements of today's world. The concept of integration bridged these two

movements by linking realistic learning experiences with the power of reasoning, problem solving, and communication skills across the disciplines. The linkages between mathematics and vocational-technical education, however, have been weak. The mathematics education sector has conducted its reform efforts as an internal movement involving comprehensive reforms in curriculum, teaching, and assessment. In contrast, vocational-technical counterparts have promoted curricular changes involving integration with academic disciplines but changes in instruction and assessment appear to have been ignored.

The NCTM vision and ideas derived from school-to-work reform can provide an excellent framework to link mathematics/career curriculum, instruction, and assessment. This converging framework clarifies ideas for the development, implementation, and evaluation of authentic, integrated, standards-based learning. However, producing curriculum based on this framework is not easy and mathematics/vocational-technical instructors continue to call for specific examples. Packer (1995) offered some practical hints. In a typical high school algebra class, he indicated that students may be asked to solve the following problem: "Find the speed of the canoe if the paddler is paddling six miles an hour upstream and the current is three miles an hour" (p. 40). He argued that although this word problem reflects a realistic situation and is not about solving merely for x and y, it lacks a significant and important situational context and encourages students to solve it by using a step-by-step textbook method. To break this traditional approach, Packer suggested ways to bring authenticity to integrated mathematics/vocational-technical learning: He offered an alternative example:

> Students would establish specific work contexts for the generic problem of evaluating an equipment purchase. For example, students interested in health care might consider acquiring a new MRI machine at a local hospital. One teaching strategy would put all the data needed on an electronic database so that students, working in teams, could solve the problem in one or two class sessions. Another strategy would make this problem a six-week project, done in cooperation with English and science teachers. Students could collect data to help local administrators analyze the purchase of piece of equipment that the hospital is really considering. They would have to determine how many of the community hospital's pediatricians, neuro-surgeons, and oncologists, typically send their patients for an MRI and in what proportion. They would have to find out what Blue Cross pays for an MRI exam, how much it costs to buy an MRI machine, and how the purchase might be financed. Students would use e-mail and the Internet to obtain data, and use computer spreadsheets to simulate alternative scenarios. Finally, they would write a report containing graphs and charts that the hospital administrator would read and act on. (p. 40)

In this scenario, students use algebra concepts in the context of decision making in hospital administration. Several SCANS competencies are addressed and instructional processes are aligned with the NCTM Standards. From High Schools that Work program experience, Bottoms and Sharpe (1996) also identified a number of ways to learn how to integrate mathematics. For instance, investigating garbage as an environmental issue, students use mathematical functions, solve problems, and study technological applications. Students are required to analyze "data on the amount of garbage generated each year and the availability of landfill space to calculate the extent of the nation's waste disposal dilemma" (p. 23). NCTM (1989) also provides examples of students' work connected to real-world situations.

An examination of these examples reveal that there is no universal model for integrating the learning of mathematics with knowledge in other fields. Integration can take many forms depending upon the level of commitment and resources available (Bottoms & Sharpe, 1996; NCTM, 1989). The NCTM vision and the framework for authentic, integrated instruction provide broad guidelines for developing problem situations that feature mathematics in realistic contexts.

But, Does Integrated, Standards-Based Learning Work?

The benefits of providing students with realistic learning experiences through situated learning have been documented (e.g., see Brown, Collins, & Duguid, 1989). Proponents argue that, in situated learning, students develop deep understandings of applications because they participate in activities that simulate real-world situations while using the assistance of mentors or expert practitioners. However, skeptics contend that most studies refer to isolated instances within certain disciplines and offer limited evidence of successful formal integrated coursework involving mathematics. They suggest caution in endorsing full-force promotion of integrated curriculum and continue to ask for hard evidence of its value (e.g., see George, 1996).

The premises underlying an integrated approach are promising, though, and there are hints of evidence suggesting a variety of benefits, other than gains in scores, associated with mathematics learned in context. For instance, by asking students to participate in simulations that depict real-life problems in assembly and manufacturing operations

(Scribner & Stevens, 1989) and building experiences (Verzoni, 1996), elementary and junior high school students demonstrated that it may be possible for schools to promote active learning through mathematics problem solving in realistic contexts. Hall and Stevens (1995) have further suggested that active learning in contextual scenarios produce great opportunities for exhibiting competencies often overlooked in traditional curricular activities. By comparing mathematical practices in architectural design, they found that teamwork produces various forms of learning whereby *novices*' competence is shaped by interactions with *expert* individuals and experiences beyond the classroom. These are experiences that would normally be lost in traditional curricular activities. Others have confirmed that realistic mathematical tasks requiring multiple-solution strategies and representations are crucial in building students' reasoning abilities (Stein, Grover, & Henningsen, 1996). However, we are far from moving in that direction because instruction still focuses on rote memorization of information (Romberg & Carpenter, 1986). This and other problems still seriously inhibit the implementation of education reforms.

Barriers for Rigorous Curriculum Integration

The barriers for change are many and deeply rooted in strong beliefs about traditional teaching practices involving paper-and-pencil calculations, administrative reliance on standardized tests, and parental expectations on rote homework (NCTM, 1989; Romberg & Carpenter, 1986; Scholz & Niess, 1995). Collectively, these factors create a political framework in which policy decisions shaping the nature and scope of school changes are made. Hence, the decision to implement radical changes in the schools aligned with current reforms is not an easy one (Gray & Herr, 1995; NCTM, 1989; Newmann, 1991; Wirth, 1992).

Bridging traditional academic/vocational turfs is another problem magnified by reliance upon segregated professional development practices that inhibit a sense of community (Kruse, Louis, & Bryk, 1994; Little, Erbstein, & Walker, 1996; NCES, 1996; Newmann & Wehlage, 1995; Schmidt, Finch, & Faulkner, 1992). Further, models and strategies for integration have already been identified, but practitioners seem to use them without regard to local circumstances and needs. This indicates a lack of big-picture understandings and confusion about the meaning and applications of integration (Bottoms & Sharpe, 1996; Grubb, 1996; Stasz et al., 1994). Therefore, it is not surprising to see the

proliferation of commercial curriculum products and the lack of locally developed, NCTM Standards-based, integrated mathematics curricula. Commercial texts may be helpful in complementing integration efforts but can not substitute internal and external collaboration, understanding of specific curriculum needs, and the nuances of everyday implementation that only a sense of community can provide (Kruse et al., 1994; Stasz et al., 1994). A related issue concerns the preservation of curriculum rigor. Some educators fear increased standards will produce higher dropout rates, increased enrollment in remedial and basic courses, and watered-down curriculum (Gray & Herr, 1995; Porter, Kirst, Osthoff, Smithson, & Schneider, 1994; Wirth, 1992).

Collectively, these issues and concerns suggest that linking the NCTM Standards to emerging career-oriented curriculum is not a matter restricted to the mere development and implementation of integration efforts. The implications are far reaching, ranging from school restructuring notions to the more mundane classroom problems. While integration of mathematics and career curricula appears a natural evolution of both educational reforms, there seems to be a limited number of promising systemic efforts currently underway at both the secondary and postsecondary level.

PURPOSE OF THE STUDY

The purpose of this research was to describe the dynamics of integrated mathematics-vocational-technical education learning initiatives in high schools and postsecondary institutions that have adopted the NCTM Standards. The objectives were to produce insights regarding the links between vocational education and mathematics in secondary and postsecondary settings, develop an understanding of how instructors collaborate and are supported to implement integrated work based on the NCTM Standards, and identify implications for effective implementation of integration practices featuring mathematics in realistic contexts.

The phrase *linking the NCTM Standards to school-to-work reform* was used to denote a comprehensive process for connecting two reform movements. The goal was to build a comprehensive understanding of how these two movements were linked through integration efforts and how the NCTM Standards vision served as a bridge for establishing

curriculum connections. By using the NCTM Standards framework to select programs, it was possible to study approaches involving vocational-technical and mathematics instructors working collaboratively and illustrate the use of mathematics in solving problems found in workplaces and other settings.

To further position the reader in understanding the material presented in this document, it is also important to define integrated and authentic learning. *Integrated learning* refers to vocational-technical and academic instructors linking their courses and teaching content grounded in a broadly-defined career field (Bottoms & Sharpe, 1996). "Mathematics integration" and "integrated mathematics" were used interchangeably to reflect these curriculum and instruction connections between mathematics and career-oriented disciplines. High-quality *integrated* mathematics/vocational learning should address learning mathematical concepts grounded in worthwhile problem scenarios involving important career concepts and a variety of real-world applications (NCTM, 1989; SCANS, 1991). Likewise, *authenticity* of learning and instruction connotes experiences reflecting engagement in higher-order thinking, in-depth understandings of concepts, productive interactions inside and outside the classroom, and realistic interdisciplinary connections (NCTM, 1989; Newmann & Wehlage, 1995).

METHOD

The research design was conceived under a case study format to allow the examination of programs of interest and develop an understanding of specific practices or problems in all their dimensions of complexity (Stake, 1994). When interested in a particular situation happening in multiple settings, Stake (1994) suggested a *collective* study design to characterize similarities across contexts, and gather the experiences of stakeholders operating under different circumstances. Thus, a collective case study was designed and guided by three research questions: (1) How did school reform focusing on integration of academic and vocational education get started? (2) What is the nature and scope of integration efforts linking mathematics and vocational-technical education? and (3) To what extent are the NCTM Curriculum and Evaluation Standards for improving teaching and learning emphasized in pedagogical practices? A national survey of secondary and

postsecondary sites engaged in linking mathematics and vocational-technical education was conducted to identify and select four promising programs for in depth case studies.

Identification of Promising Sites

Selected national officers of teacher organizations, directors of mathematics and vocational-technical education, and state education department consultants were contacted in the spring of 1995. They were asked to nominate schools and two-year postsecondary institutions that were implementing the NCTM Standards and engaged in integration practices linked to occupational contexts. A total of 86 program nominations were received during the search, including 80 high schools and six two-year college programs.[1] To determine the general nature and extent of integration efforts, a survey was conducted during the fall of 1995 asking site representatives (mathematics-vocational teachers and program coordinators) to describe integration formats, extent to which NCTM Standards were being implemented, activities supporting integration, and demographic information describing the institutional profile. Survey instruments were based on work conducted by the National Center for Research in Mathematical Sciences Education and designed to examine how schools were implementing mathematics reforms (Secada & Byrd, 1993). After two follow-up reminders, a total of 41 sites returned surveys (47.6% return rate). This return rate was influenced by the fact that some sites were indeed integrating mathematics and academic education but not emphasizing the NCTM Standards. In contrast, a number of sites were using the NCTM Standards in their mathematics program but had no integration efforts. These sites did not return surveys because they did not feel qualified to participate. Thus, the 41 respondents including 37 high schools and four two-year colleges were considered as the pool of programs offering the best framework for selecting promising sites.

The majority of respondent sites were public high schools (78%) located in rural settings (43.6%) and serving an average student population of 1,302 students. On the average, high school students were predominantly Caucasian (82.8%) with a small representation of African-American (10.4%), Hispanic (3.8%), and other ethnic groups (3.0%). Also, the majority of high schools reported high compartmentalization of

[1] This is a proportional rate of participation reflecting the extent of efforts occurring in the educational system at large where the bulk of activity is more prominent at the secondary level (see Stasz et al., 1994).

instruction. About 76% of high school programs had both mathematics and vocational-technical education departments with 40.6% of all faculty teaching either math or vocational courses.

Two-year colleges were all public institutions located in either urban or suburban areas with an average student body of 23,583. Overall, respondent colleges reported a more diverse student population with 48% Caucasian, and 22.2% Hispanic, 13.2% African-American, 9.4% Asian, 4.7% American Indian, and other ethnic groups (2.5%). Given the nature of postsecondary institutions, departmental lines were a bit blurred but at least half had both departments clearly defined. In general, colleges reported that 46.3% of all instructors taught either mathematics or technical courses.

Given the small sample of two-year colleges, no statistical comparisons were possible. Thus, the intent was to describe in general terms the state of implementation of integration practices conducted by respondent sites as a preliminary step for developing four case studies of promising efforts. The analysis relied on basic descriptive statistics (e.g., frequencies and averages) to represent response patterns for each question or sets of related questions.

Case Studies

Case study sites of interest involved four communities with robust experiences in linking mathematics and vocational-technical education: Cocoa High Academy for Aerospace Technology (CHAAT), Fairdale High School Magnet Career Academy (FHS), Mt. Hood Community College (MHCC), and Swansea High School (SHS). The combined efforts of these sites to emphasize the NCTM Standards and integrate mathematics in education-for-work curriculum were in the top tier when compared to their counterparts in the survey pool. Collectively, all selected case study sites favored interdisciplinary collaboration and program-wide commitment to integrate mathematics and vocational-technical education, had spent more time in formal integration work, and showed higher than average commitment to emphasize the NCTM Standards. Further, selected sites had their integration efforts connected to school reforms and had met more frequently per semester to discuss integration strategies and student assessment issues. Case study

instructors were also more informed about mathematics reform and school-to-work literature than the average instructor surveyed when considering all respondent sites.

Procedures

Protocols for data collection were based on research questions to clarify and characterize practices and processes involving evolution of integration efforts and commitment to implement school reforms, extent of mathematics integration, and approach taken to emphasize the NCTM Standards vision. Probing questions for each area of interest were constructed based on previous research aimed at describing innovative programs featuring school-to-work principles, mathematics reforms, and NCTM vision (Hernández-Gantes, Phelps, Jones, & Holub, 1995; NCTM, 1989; Secada & Byrd, 1993). Protocols were used for interviews and focus groups with administrators, mathematics/vocational instructors, and students. A protocol for classroom observations was also developed to document instructor and student activities.

Case studies were developed over a five-month period and included a review of the literature on the sites of interest, clarification of site information over the phone, and on-site visits. Two-day site visits were conducted by a team of two researchers in the spring of 1996. Researchers toured site facilities to become familiar with the physical and social environment of the setting. Prior to each interview or focus group, all participants were informed of the purpose, content, meeting procedures, and intended use of the information. Protocol questionnaires were treated as semi-structured guides susceptible to ad hoc modifications based on the nature of the information and experiences shared by participants.

Analysis

Upon completion of site visits, the research team compared notes guided by one question: What are the major events and characteristics of the site? Personal notes, information from print materials, and transcriptions of interviews and focus groups were summarized to build a profile of each site. The next step involved identification of patterns, key issues, processes, and practices emerging across sites. The results of the analysis were organized into three categories. The first category describes common circumstances and reasons leading to the implementation of educational reforms and commitment to building a climate fostering instructor collaboration. The second category addresses strategies taken

for integrating vocational and academic education with emphasis in mathematics. The third category illustrates the collective emphasis on teaching and assessment practices aligned with the vision of the NCTM Standards.

It is important to note that because of the short duration of site visits, it was not possible to observe a wide range of learning experiences across classrooms and other relevant settings. Thus, to address potential bias embedded in data collection, the analysis relied on triangulation techniques and verification of information from various sources (i.e., interviews, observations, and review of literature) and consensus building between visiting researchers to decide on relevancy of findings. A set of implications for implementation of professional development were derived from the analysis of site profile components (see case studies in the Appendix).

FINDINGS

The findings are organized in two sections. The first section presents survey results from the overall respondent pool to set the larger context of the current status of mathematics integration. The second section presents findings derived from the case studies that were designed to address the dynamics leading to a commitment to restructure and integrate vocational-technical and academic education curriculum with particular focus in mathematics, approaches to implementation of integration practices, and the extent to which the NCTM vision is driving instruction. In general, the case study of the two-year college featured in this research conformed to general patterns observed in high school programs. Hence, the narrative of findings reflects collective findings including clarifications only when patterns between high schools and the two-year college experiences are not parallel.

Setting the General Context: Survey Findings

Extent and Nature of Integration Efforts

Overall, the majority of the high school programs (51%) showed that mathematics and vocational-technical instructors were either working alone or collaborating informally with colleagues in their own department to integrate mathematics and vocational curriculum. Efforts to establish more complex forms of collaboration (e.g.,

interdepartmental teamwork and program-wide approach) appeared small in comparison. In contrast, the colleges' commitment to interdepartmental and program-wide collaboration appeared to relatively higher than that for high school programs.

Respondent programs reported an average of 7.3 years of primarily informal work on general integration practices involving mathematics and vocational-technical education (e.g., instructors integrating on their own). Formal integration efforts connected to current school reform and supported by an interdisciplinary school/program-wide committee had been conducted for only one year in high schools and two years in colleges. Integration efforts were most frequently grounded in architecture and computer aided design (CAD) programs in both high schools and two-year colleges. Other vocational-technical areas popular at both institutional levels included electricity/electronics, health, and technology applications (e.g., industrial technology and manufacturing).

Implementing the NCTM Standards Vision

In general, there appeared to be little to moderate emphasis on linking the NCTM Standards to career curriculum at both the secondary and postsecondary levels. Efforts seemed to concentrate in emphasizing processes (i.e., problem solving, communication, and connections) rather than specific content standards (e.g., discrete mathematics and applied study of trigonometry) in problem situations found in career contexts. This strategy appeared to help strengthen the identification of connections within mathematics and applications beyond the classroom, especially at the postsecondary level where instruction was grounded in broad technical areas.

Instructional practices supporting the NCTM Standards can be described as an attempt to respond to mathematics and vocational education reforms. However, respondent sites did not appear to be doing a good job conducting formal meetings between mathematics and vocational-technical instructors to share ideas in this regard. For instance, in the first semester of 1995, high schools usually met twice to discuss integration strategies, coordination of content integration, use of calculators for problem solving, and team teaching activities/planning for collaboration. To discuss progress of integrated efforts and use of computers in problem solving, instructors typically met only once. Further, regarding discussions about teaching and assessment issues, both high school and two-year college instructors shared similar levels of meeting patterns. On the average,

mathematics and vocational-technical faculty met only occasionally in the first semester of 1995 to talk about student performance on standardized tests and portfolios of student work. In contrast, they reported frequent meetings to discuss performance on classroom projects and quizzes and tests, questions students ask and the oral explanations they give, and written explanations on assignments.

Overall, slightly more than a third (35.3%) of high school respondents reported they had read the NCTM Curriculum and Evaluation Standards document. A smaller percentage reported they had read other NCTM key documents such as the *Professional Teaching Standards for School Mathematics*, *Addenda* series, and the *Agenda for Action*. A similar pattern was reported by college respondents. About half of high school instructors also reported they had read school-to-work related literature (48.4%), including a variety of documents (e.g., SCANS and state/federal guidelines). However, very few reported reading reports on models of integration, teachers' roles, case studies of early innovative sites, the importance of focusing on high skills, building local programs, and Tech Prep materials. Further, regarding participation in related professional development respondents indicated only occasional participation in workshops, conferences, or institutes relevant to implementing the NCTM Standards and integration issues.

Case Study Findings

Getting Started: Leadership in Action

The process for implementing drastic curricular changes can be described as a restructuring act common to all four case study sites. With slight variations, what prompted institutional changes was a discouraging picture featuring high dropout rates, low academic performance, deficient employability skills, poor student attendance, and lack of parental involvement in educational matters. In some instances, high teen pregnancy rates complicated this picture. Consequently, few students were pursuing enrollment in postsecondary institutions. Students were sorted in curriculum tracks based on their academic performance with frequent over-representation of minorities in low-level and remedial classes. The teaching environment wasn't helping either. Instructors' morale was low and students had a poor attitude toward learning. Collaboration between academic and vocational instructors was practically nonexistent; vocational education was perceived as the dumping ground for low performing students; and instruction was nothing but a

combination of lectures and paper-and-pencil drills emphasizing rote memorization and knowledge reproduction.

The response to this crisis was characterized by a case of leadership in action across all sites. Change was championed by individuals in different positions (e.g., superintendent, principal, and dean) who were convinced teaching and learning needed to improve. These individuals were also willing to fight key stakeholders' resistance to change because of well entrenched traditional beliefs on educational practices. First, institutional leaders set themselves to develop a "big-picture" understanding of principles underlying education reforms to provide direction for local efforts. Second, they recruited support from important stakeholders (e.g., board members and innovative teachers) by sharing with them why drastic changes were required. These actions created seed support crucial to the implementation of subsequent steps leading to restructuring curriculum. Third, an institutional assessment was conducted to determine the state of academic performance, teaching practices, administrative problems, and facilities and equipment. The purpose was to provide a frame of reference for goal setting and progress evaluation of subsequent steps.

The results of institutional assessments confirmed problems previously identified and served as the basis for plans to implement change. With the support of steering committees, working groups, or advisory boards, organizational and management strategies followed a collaborative approach. Instead of dictating change in the traditional top-down management style, site leaders involved stakeholder groups in the design and implementation of plans (e.g., faculty, administrators, parents, and business and community representatives).

Common Foundations for Change

In all instances, through collaborative work (e.g., participatory management, steering committees, and working groups), each site refined the nature and extent of proposed reforms, identified timelines, and built a consensus on the basic underpinnings of their efforts. This strategy created a climate favorable for implementation of change and set the stage for restructuring curriculum tracks, creating staff development programs, and reviewing instructional and assessment practices. A major task was to decide on appropriate curriculum structures upon which to ground proposed reforms. The choice was

shaped by a realistic assessment of site and community resources, extent of instructional collaboration and understanding of reforms, potential impact on students' learning and career development, and public support. In all cases, sites adapted chosen models to individual circumstances and needs. CHS worked toward creating an academy program on aerospace technology to tap into the prominent presence of this industry in the community. FHS opted for a magnet-academy model with focus on public safety in response to a high concentration of area residents working in this field. SHS decided to develop career paths aligned with the Tech Prep initiative. MHCC also chose career paths to improve articulation with feeder high schools under a consortium format. The common ground was the use of occupations contexts to restructure curriculum aiming at improving students' learning and career development.

The next major task was to expand the support of instructors and other stakeholders because the academy, magnet, and career paths formats required the active participation of both vocational-technical and academic instructors. Facilitating interactions between believers and nonbelievers in curriculum changes was key to move forward with proposed plans. Since all sites were basically divided in two worlds, vocational and academic, collaboration had to be nurtured as a bottom-up approach instead of mandated moves. Plans for change involved a visionary strategy aimed at revisiting established curriculum structures, instruction and assessment practices, and instructor collaboration. Second, each site called for grounding teaching in occupational contexts to make learning activities more relevant to students. The goal was to provide students with academic and practical skills in tune with contemporary demands in the workplace. Third, local efforts showed a strong belief that all students can benefit from rigorous learning experiences linking technical and academic knowledge and skills. Finally, across all sites, there was a commitment to improve linkages between high school and postsecondary programs to ensure that all students were also well prepared for further education.

A Test of Leadership: Managing Change

The process of promoting and managing change was not easy. Across all cases, there were accounts of intense negotiations and educational exchanges with institutional, community, and business stakeholders. Professional turf was hard to break, and getting academic instructors to collaborate with vocational-technical peers was sometimes described as "hitting a wall." Another major hurdle was having to overcome stereotyped

perceptions that vocational-technical programs are of low-quality, that they only prepare students for specific jobs. Mathematics instructors were reluctant to join restructuring efforts because they feared the integrity and rigor of the discipline would be lost in integration schemes. Adding programmatic changes to accommodate restructured and integrated curriculum activities to this picture, created a juggling act that could only be managed and maintained with strong leadership, focus, and a deep sense of collaboration.

Implementing Mathematics Integration: A Challenging Process

On the average, case study sites had more than 13 years of experience with integration of vocational and academic education. This experience included slightly more than seven years of formal work supported by federal or state funds and widespread instructor collaboration. The implementation of academy models and career pathways proposed by sites required restructuring coursework to reflect the new curriculum orientation. It also required changes in teaching assignments, scheduling, and instructional collaboration. Further, it involved integrated collaborative instructional work and related professional development.

Restructuring Mathematics Curriculum

Academic disciplines were well entrenched in the traditional educational system at each site and efforts to restructure academic curriculum represented an important undertaking. The following question had to be addressed: How would mathematics be aligned with a series of coherent technical courses while preserving the rigor of content? High school programs eliminated all general and remedial math courses and created a strand of applied mathematics classes (e.g., applied mathematics for the technologies and applied geometry) available to all students. The emphasis of these classes was in grounding mathematics in occupational contexts featuring hands-on, real-world problems relevant to mathematics concepts and skills used in the broadly defined technical fields. For example, at SHS, Applied Mathematics for the Technologies I, recommended for grades 9 and 10, is a "problem-solving course that makes mathematics relevant by showing how mathematics skills are used in the workplace. It teaches problem-solving by hands-on, student-centered situations. The mathematical skills include, but are not limited to, using the scientific calculator, problem-solving techniques, and measurement" (SHS, 1996, p. 25). Similarly, at CHS, the Applied Mathematics III course expected that students will "understand and apply functions, relations and graphs; understand and apply geometric properties to solve problems; and demonstrate an understanding of the structure of mathematics as it applies in

the real world" (CHAAT, 1996, p. 25). Similar descriptions for restructured mathematics courses were found at FHS.

At the two-year college level (MHCC's experience), restructuring was particularly challenging because it entailed a revision of college curriculum along with the development of articulation agreements with feeder middle and high school programs. MHCC's response was the development of an applied, technology-based, one-track (ATO) curriculum linking mathematics and technical areas from middle school through the first year of college for all students (Tech Prep and baccalaureate preparation). As in the high school cases, a series of interactive mathematics courses replaced traditional courses such as remedial mathematics and intermediate algebra (see ATO chart, MHCC case study in the Appendix).[2] The interactive nature conveyed in the restructured courses was laid out by expected core outcomes for all topics included in each course. Students in these college courses were expected to actively interact with teachers and other students in learning mathematics. Further, algebra, geometry, probability, data analysis, and statistics were interconnected in each level of interactive mathematics. Also, applications grounded in technical disciplines were linked to mathematics concepts to bring relevancy to students' learning.

Curriculum Development

Changes in curriculum structures required parallel activities in curriculum development to reflect coherent sequences of courses representing broadly-defined technical fields (e.g., engineering industry, aerospace technology, and public safety) under career paths or academy formats. Course content and complementary activities were then identified along with programmatic and administrative requirements (e.g., attendance, credits, grading, and advanced coursework). This process was characterized by an interdisciplinary collaborative effort of instructors and individuals leading restructuring activities either as an internal process or guided by external consultants. Common across all sites was the gradual development of curriculum and an open attitude for trying out new things. Thus, faculty at each site were willing to experiment and make revisions as things progressed.

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[2] From work completed by the Joint Core Curriculum Team of MHCC, Centennial, and Reynolds teachers as part of the ATO Mathematics Curriculum Project funded by the National Science Foundation Advanced Technological Education Program, draft 5/25/95, p. 1.

Available funds were used to develop *applied* coursework to link vocational and academic education. Technical courses in career paths and academy models were structured and sequenced and curricular activities developed in detail. In the case of mathematics, restructuring helped define applied courses, sequences, content emphasis, and teaching focus. However, the specificity of curricular activities within each course remained sketchy, and instructors still relied on commercially available resources and loosely connected student activities and projects to complement or guide instruction. To a different extent, based on time and resources available, refining curriculum is an ongoing process at each site.

Curriculum development efforts at MHCC were more successful. Led by one of their peers serving as Dean of the Mathematics Division and supported by a federal grant, mathematics faculty built a consensus on expected outcomes for all ATO core curriculum courses along with instructional strategies to facilitate the learning of mathematics. As part of this collaboration, a team of instructors completed a textbook used for Interactive Mathematics III aligned with restructured content, emphasis, expected outcomes, and instructional strategies agreed upon by all faculty. With grant support, MHCC faculty have continued to work on the development of materials and textbooks to meet the specific requirements of restructured ATO courses. The strength of MHCC curriculum development efforts lay in the detailed consensus on outcomes and instructional strategies, its collaborative approach, and commitment to produce full course materials and textbooks for restructured courses.

Integration Strategies

The career theme of each program (e.g., public safety and aerospace technology) allowed faculty to integrate concepts, ideas, and skills across various disciplines. A career theme facilitated the immersion of students in learning experiences linking academic and work skills found in a technical field of interest. For instance, at CHS, math, science, social studies, and technology instructors identified content patterns and overlaps for team teaching purposes. Mathematics content was then integrated with appropriate SCANS competencies relevant to communications, transportation, manufacturing, and other relevant topics in aerospace technology.

Integrated instructional practices grounded in career paths did not have a program-wide approach, but students were partially immersed in activities featuring broadly defined technical fields (see SHS and MHCC case studies in the Appendix). Courses were interconnected within technical fields and related to relevant topics in academic subjects. For example, mathematics topics were linked to money management emphasizing a business career path, geometry was connected to concepts in a manufacturing curriculum, and so forth. Also, across all sites, there were instances of shared integrated activities involving planning and teaching between a team of two or more cooperating instructors. Math instructors collaborated either formally or informally with technical instructors, individually or in multidisciplinary formats, to plan and teach shared concepts (e.g., data collection and interpretation and graphing). Further, all sites threaded problem solving, thinking and communication skills, and knowledge applications across vocational and academic disciplines as a prominent integration strategy. Collectively, integration strategies departed drastically from fragmented structures found in traditional settings where curriculum tracks, lack of instructional collaboration, and paper-and-pencil activities were the norm (see Fogarty & Stoehr, 1991, for a detailed description of integrated curriculum strategies).

The implementation of integration practices presents a number of practical considerations negotiated between administrators and instructors. Course scheduling is a crucial organizational factor that needs to be considered for aligning courses in the academy or career paths models. Also, a flexible teaching schedule has to be negotiated to allow teacher collaboration in team teaching, group projects, and content coordination. Therefore, shared planning time is needed during a typical week to keep mathematics/vocational-technical instructors informed of students' progress, problems, and to prepare future activities. Time management, especially in high schools, appeared to be a challenging issue for implementation of integration practices. Integrated curricula seemed to increase the demand for materials and equipment and more student-teacher contact beyond the classroom. Thus, competition for resources increases and adds another factor in management decisions as stakeholder groups lobby for their share of funds, materials, and equipment. Finally, another challenge is to maintain a climate conducive to productive collaboration aimed at designing nontrivial integrated practices involving mathematics applications in occupational contexts that also adhere to the NCTM Standards while preserving the rigor of the curriculum.

Professional Development

Individuals leading integration efforts were self-motivated and prepared themselves by reviewing relevant literature, attending conferences addressing reform topics, and seeking guidance from research and demonstration institutions. Literature on contextualized learning and documents outlining key principles for school-to-career curriculum and mathematics reforms provided initial ideas for these efforts. Site leaders promoted some strategies for professional development to early cooperative staff to expand the support base for anticipated changes.

Organizations such as the Southern Regional Education Board (SREB) and Coalition of Essential Schools (CES) appeared to be helpful in providing effective guidance and staff preparation in high school programs. In some instances, these organizations provided sites with the philosophical and management foundations of reforms along with training opportunities involving institutes and seminars on curriculum integration, authentic assessment practices, and restructuring issues. Across all sites, the strategy was to expand the support base by involving faculty reluctant to buy into restructuring efforts in these professional development activities. Early on, working in groups and engaging in reflective discussions about areas that needed improvement, faculty began to work toward future collaboration. They also learned important theoretical and practical considerations for implementing reforms since various points of view were openly and forcefully voiced by competing groups. More recently, professional development across sites are flexible programs that allow instructors to develop individual plans or decide as a group what relevant preparation is needed, instead of being required to participate in standard district programs offered to instructors at large. Further, in most cases, new hires are required to have at least one year of experience in applied instruction and be committed to continuous development of integration practices.

Linking the NCTM Standards to Integrated Learning

At a time when reforms in both vocational education and mathematics were taking shape, case study sites were already experimenting with alternative pedagogical and assessment practices. The common denominator in both secondary and postsecondary restructuring efforts was to develop program-wide emphasis on real-world applications.

In Spring 1996, case study sites reported a moderate-to-great emphasis in using the NCTM Standards to guide instructional activities. It was clear, across the board, that sites were more successful in emphasizing process rather than content-specific NCTM Standards, matching the general emphasis on skills called for by the school-to-work movement. Based on problem-solving activities, the goal was to involve students in relevant and challenging curriculum requiring teamwork, reasoning, communication skills, and concept connections. What follows is a description of how process standards were implemented at case study sites, a summary of instructional applications addressing content standards (e.g., geometry, algebra, and statistics), and assessment strategies.

Problem Solving

Authentic, integrated problem solving activities require student engagement in discovery of mathematics applications in technical contexts. The *virtual learning* concept typical of CHS instructional activities represented problem scenarios involving high levels of authenticity. For example, the unit "Working in Space" was based on a real-world problem situation found in aerospace technology. Students visited NASA launching facilities at Cape Canaveral and consequently considered pursuing a career in a related field upon graduation from high school. Thus, the following problem situation statement was very real to them:

> NASA has asked Congress for funding to design, build, and launch a large station into the earth's orbit, and you have been selected to serve as members of the Space Station Task Force. You have committed the next ten years to the preparation of the space station, and you will be among the station's first inhabitants. Launch is tentatively scheduled for the year 2000. (CHAAT, 1996, pp. 1-2)

Several questions requiring the integration of multidisciplinary knowledge could derive from this problem scenario. Similarly, several mathematics applications could also be found. For instance, students were required to calculate the exact distance from earth the station must reach to maintain its orbit around the earth and make a scaled map of the Space Station's orbit in relation to earth. This was a nonroutine problem that caught the students' interest. The problem was nontrivial and provided opportunities for approaching solutions in various ways so that students could investigate and develop understandings of applied functions, relations, graphs, geometric properties and models, axiometric systems, relationships between plane and solid geometry, and transformational and coordinate

geometry. The contextual application was linked to science and technology concepts associated with understanding orbital requirements.

The complexity of this problem was significant and produced additional questions requiring the application of more advanced mathematics concepts (e.g., trigonometric identities and the concept of limits and its applications). Mathematical models were a natural application for determining the orbit of the station.

This problem was contextualized in a genuine, significant problem scenario open to various approaches for solutions. To solve it, students had to research and understand related science and technology concepts, identify mathematical solutions at their grade level and even attempt solutions requiring more advanced mathematics. This approach represented a drastic departure from traditional mathematical problems void of realistic contexts asking merely to solve for x and y or word problems involving trivial situations.

Higher-Order Thinking

To engage students in higher-order thinking (HOT) activities, characterized by tasks fostering inductive and deductive reasoning, NCTM (1989) suggested that highly authentic instructional practices "should include numerous and varied experiences that reinforce and extend logical reasoning skills" (p. 143). An example drawn from a FHS integrated unit of study entitled "The Curious Death of Zachary Taylor" illustrates an integrated problem situation that requires the application of HOT skills.

The problem, grounded in a public safety curriculum, required the participation of students in the preparation and re-enactment of the trial concerning the death of Zachary Taylor. Students, working in teams, played different roles in the trial. To determine the possible causes of Mr. Taylor's death, data analysis and chemistry teams collected blood samples at the "scene of the crime," measured the presence and amount of toxic substances, interpreted data, drew conclusions on a toxicity report, and communicated information at the trial. In a focus group, students indicated this was a highly engaging activity. Playing various roles, students were involved in gathering evidence for different purposes. The data analysis and chemistry teams, in particular, had to identify and test hypotheses involving the presence and appropriate levels of known toxins. Students followed steps simulating real-world procedures to collect, handle, and analyze blood samples, conducting

tests repeatedly to improve reliability. The results of this analysis were complemented by data from test trials on mice to determine toxicity of substances found in blood samples. Based on data presented by the chemistry team, the data analysis team summarized the information, used regression analysis to extrapolate toxicity results to humans, and produced graphs of relevant findings for reporting purposes.

In this activity, students applied inductive reasoning derived from analysis of toxicity data on mice to arrive at logical conclusions about the lethal effects of levels of toxins present in blood samples. The evaluation of available information had to be carefully conducted and conclusions well grounded since a major decision was at stake. Deep understanding of mathematics concepts and their potential applications were promoted since students had to be prepared to answer questions and justify their arguments. In comparison, in traditional classrooms mathematical problems are presented to students by using lower-order thinking instructional activities emphasizing the application of memorized formulas to solutions of problems void of relevance for students.

Communication of Ideas

Opportunities to exchange mathematical ideas and applications with peers and teachers is also central to authentic, integrated NCTM Standards-based mathematics instruction. The *Working in Space* curriculum developed by CHS staff, provide an illustration of instructional activities conducive to facilitating substantive communication of ideas and their relation to other concepts. Students, working in heterogeneous groups (i.e., students with a mix of academic abilities, gender, and ethnicity) were asked to make decisions to staff a space station under the following conditions:

> Use as much of your two million dollar annual personnel budget as you can. You must decide which occupations are most necessary. The list of possible personnel, and the annual salary for each is [available to you]. If your station has a personnel requirement not given, you may add to the list (substantiate need and define salary). You may hire more than one person in a given occupation. Each member of the task force must prepare a different personnel plan, and then the entire team must choose, by consensus, which plan they will use. To devise the plan, each member must create a spreadsheet giving wages and calculation of social security, 8% of annual salary; unemployment compensation, 1.5% of annual salary; federal taxes, 12% of annual salary; and benefits (including health insurance, vacations, and retirement plan), 7% of annual salary. The employee's salary plus each of these additional costs represents the total cost of each employee. The final plan must include each member's spreadsheet. Remember that the entire personnel budget many not exceed 2 million. Including the families of the

> space stations employees, approximately 200 people will live on the station. (CHAAT, 1996, pp. 1-2)

This activity involved mathematics and business concepts requiring computer applications. First, students engaged in extended conversations discussing the need for certain services (e.g., lawyer, mayor, detective, and florist). Once this issue was settled, the conversation moved to the optimal size of staffing for each job (e.g., how many doctors?). Students began to gauge the impact of salaries on budget limits and discuss adjustments. A productive conversation was carried out about staffing, management, and organizational issues connected to budgetary decisions. As students discussed these issues, other related topics began to emerge concerning taxes and estimation of benefits and deductions. The conversation then turned to mathematics applications involving percentages, data management, tabulation systems, and use of computer spreadsheets. Collectively, these exchanges with peers and instructors appeared to help students build shared understandings of business and mathematics concepts and issues involved in payroll management and computer applications. Further, students were expected to communicate their ideas on staffing decisions orally and in writing, requiring the use of appropriate terminology and articulated presentation of information. In contrast, a low authentic instructional activity would reflect lecture formats, individual paper-and-pencil work, and little or no productive interactions in the classrooms.

Connecting Mathematics and Career Concepts

An important goal of the NCTM vision is to provide students with opportunities to develop deeper understanding of connections among mathematics topics and potential applications in other disciplines. Occupational contexts appear to be an excellent vehicle to address mathematics concepts in real-world situations and establish meaningful connections. Across all sites, this was the area where successful accounts were found more prominently, given the fact that students are basically immersed in a thematic curriculum (i.e., public safety, aerospace technology, and career paths). Even in situations where the levels of authenticity in instructional activities involving problem solving, communication, and reasoning skills were not that high, the relevance of mathematics connections was still prominent.

The academy and career paths formats seemed to weave a context beyond individual courses and lessons, carrying interrelated experiences through the curriculum. Thus, it is

inevitable that students develop an appreciation for the value of mathematics applications in occupational contexts and for the ways in which mathematics topics relate to each other in certain situations. For instance, the whole program of studies in aerospace technology becomes part of the students' filter for both vocational and academic education. Under these circumstances, students soon begin to get the idea of *doing* instead of only knowing mathematics. Overall, there appeared to be great student predisposition for making connections between substantive mathematics knowledge and problems and personal experiences grounded in broadly-defined career fields. In contrast, low authentic instructional experiences would be characterized by both disciplines taught in separate tracks precluding meaningful connection of ideas and applied learning.

Assessing Students' Learning

NCTM (1995) defines assessment as "the process of gathering evidence about a student's knowledge of, ability to use, and disposition toward, mathematics and of making inferences from that evidence for a variety of purposes" (p. 3). To monitor students' learning and improve instruction, all sites showed evidence of early development of assessment plans to match changes in instruction. For example, FHS had already been using portfolios for assessment purposes by the time they were required by state law in 1990. With varying emphasis, case study sites use several alternative assessment strategies to monitor students' learning, inform instructional activities, and evaluate students' achievement. A shared belief was apparent in that assessment activities needed to be integrated with instruction since mathematics and vocational concepts had to be clearly identified within a problem situation. Further, because instructional activities were more dynamic and open to greater student exploration of potential solutions to problems, a key concern of instructors was to monitor how students progress toward set goals. The common philosophy encountered across sites was to emphasize communication with students about progress rather than whether they have correct or incorrect answers in absolute terms (learning standard focusing on multiple skills). Also, in most instances, students were presented with problem statements, expected outcomes, and criteria for evaluation (standard emphasizing use of assessment to enhance learning). See, for example, Table 1 listing broad criteria for a situation statement and problem solving activity for the problem on orbit estimation presented previously in this report.

Students may have been required to work individually or in groups, document work in portfolios, engage in classroom exchanges, research information, present reports orally and in writing, justify answers and conclusions, and take traditional quizzes and tests. Based on observations of these tasks, responses to questions, scoring rubrics, samples of work from portfolios, project products, and results from quizzes and tests, instructors informed and adjusted instructional activities to seize the learning moment (standard emphasizing multiple sources of evidence for valid inferences on learning). With variations in approaches, instructors at each site were able to determine whether the mathematics concepts students applied to problem solutions were nontrivial and whether the problem was integrated effectively in a realistic context (worthwhile mathematics standard). Finally, through class observations and exchanges, documentation of individual and group work, and presentations of findings, instructors could gauge the level of student involvement and motivation derived from instructional activities (standard focusing on setting high expectations for all students).

Table 1
Criteria Checklist for *Working in Space*, Problems Involving Orbit Estimation[3]

General Criteria Checklist

- Estimate orbit accurately
- Produce orbital drawing using Auto CAD technology

Criteria Checklist for Applied Mathematics I, II, III, Geometry Honors, Algebra I, Algebra I Honors

- Final drawing completed on Auto CAD
- Show calculations used to determine the orbit of the station. Make a scaled map of the Space Station's orbit in relationship to earth

Criteria Checklist for Algebra II Honors & Pre-Calculus

- In addition to final drawing and calculations provide additional comments. Document where and why your calculations are accurate along with a written proof of your findings

Criteria Checklist for Principles of Technology I & II

- Demonstrate knowledge of orbital requirement (indication of proper definition, and justification of the type of orbit to be used)

Criteria Checklist for Physics I Honors

- In addition to identification of orbital requirements: Demonstrate ability to develop a safe orbit

Note: Students receive full credit by completing both general and course specific criteria checklists.

The purpose and type of assessment strategies practiced at each site can give an idea of the cohesiveness of integration efforts (standard focusing on coherent process). The picture is both a source of encouragement and a reality check. It is encouraging because it is clear that these alternative strategies can influence improvements in instruction and inform curriculum revisions for integration purposes. It also appears to be an excellent framework for gauging the quality of integrated problem situations and the kind of mathematics involved. However, it is a reality check because it shows the difficulties in connecting curriculum, teaching, and assessment in a coherent fashion. Instructors struggled but continue to develop and experiment with scoring instruments and other alternative ways for

[3] This criteria checklist is a sample summary of various requirements listed on relevant content from different courses involved in this activity. See CHAAT (1996).

assessment to account for multiple manifestations of learning elicited by problem-solving activities. Further, it appeared that comprehensive efforts were falling on the shoulders of highly motivated instructors, still a minority in most cases.

A Taste of Reality

Although case study information suggested a trend toward great emphasis in implementing the vision of the NCTM Standards, the reality of efforts may be more modest. There are areas where the NCTM Standards can be naturally emphasized as a result of program-wide integration efforts, while in more course-specific curriculum activities the shift toward the NCTM Standards remains a challenge. Promising practices were found across sites but consistency across the curricula regarding a systematic implementation of the NCTM Standards appears to be questionable. There are hints of evidence indicating that curriculum grounded in broadly-defined career fields can serve as an influential umbrella for providing a sense of purpose and meaning to mathematics learning. The career contexts seemed to facilitate the identification of worthwhile related mathematical tasks in specific integrated course activities and across the curriculum. Because students were immersed in career contexts, integrated activities reinforced the connections with mathematical applications beyond the classroom and added authenticity to learning. Hence, process NCTM Standards (i.e., problem solving, reasoning, communication, concept connections) appeared to be more easily emphasized across the board. However, addressing specific content standards (e.g., algebra, trigonometry, and discrete mathematics) in rigorous ways seemed more inconsistent.

Linking the NCTM Standards to integration efforts is not easy, and there seem to be several challenges to effective implementation. First, identifying worthwhile mathematical tasks involved in real-world problems is more difficult than it seems. Designing nonroutine, nontrivial problem situations, including significant mathematics applications, is not an easy task. Promising examples were found across sites, but they were showcases of exceptions rather than the rule. High authentic instructional practices coexisted with traditional teaching, and even those who were involved in innovative activities may have shown inconsistent pedagogical behaviors. This is perhaps more visible when it came to emphasizing HOT activities through provocative questions and challenging problem scenarios. For instance, instructors may have had trouble discriminating between guided and analytical questioning, thus limiting the quality of HOT tasks. Breaking traditional

molds of instruction and faculty collaboration can be best characterized as a story of fragmented successes.

The lack of specific curricula involving mathematics integration adds to the challenges for implementation of the NCTM Standards. The majority of available curricula is restricted to lessons or units loosely structured and still in the process of development. Thus, it is not surprising to see instructors relying heavily on CORD (Center for Occupational Research and Development) and other commercially available textbook materials to guide instruction. Consequently, alternative assessment strategies are used with restricted purposes and are still evolving in the schools. Also, programmatic challenges (e.g., scheduling and resources), time demands for collaboration and planning, and other institutional issues can all contribute to the quality of emphasis on consistent and systemic NCTM Standards-based practices. It is apparent that linking the NCTM Standards to emerging vocationalism is promising but, at the same time, requires serious restructuring efforts beyond pedagogical strategies.

CONCLUSIONS AND DISCUSSION

Case study findings confirmed earlier reports on the implementation of mathematics reform and the prospects for using the NCTM Standards as a framework for improving curriculum, instruction, and assessment (Porter et al., 1994). Integration efforts did not result in watered down curriculum at case study sites. Students, in general, reported high levels of approval for integrated mathematics reflecting high authentic instructional practices, indicated positive changes in attitudes toward mathematics, and demonstrated better understanding of where it fits in their career interests. Administrators reported that students' scores were similar, if not better, than those participating in more traditional courses. With variations in approach and degree of authenticity, examples from case study sites hinted that it is possible to link the NCTM Standards to integration efforts at both the secondary and postsecondary level. However, it was clear that implementing the NCTM Standards vision is not a mere question of change in instructional practices. It requires participatory leadership and serious commitment to program-wide restructuring involving comprehensive changes: placing students' experiences at center stage; moving toward authentic, integrated instruction; providing institutional support under more democratic and

flexible conditions; and promoting a climate conducive to internal and external collaboration (i.e., developing a sense of community). These findings parallel research on organizational restructuring and support a theory for developing integrated, authentic mathematics curriculum (Newmann & Wehlage, 1995).

Managing Change

At each site local leaders realized that the academic situation and career preparation of students needed to improve. They also recognized the need to shift from traditional tracking systems to more integrated forms such as career academies and career paths. Champions of change were found across sites, individuals providing the fuel to recruit interdisciplinary participation through various leadership styles described elsewhere (see Finch et al., 1992; Moss & Jensrud, 1996). After a careful and comprehensive evaluation of processes, practices, and outcomes, there was a general attempt to build a democratic vehicle for managing change and building a consensus on priorities (e.g., site-based management and working groups). This approach facilitated early collaboration between vocational and academic instructors and created a climate favorable to change. Big-picture understandings of the philosophical underpinnings of change were promoted along with an action plan and a commitment to breaking traditional educational molds. The result was a shared vision for adopting drastic measures involving curriculum restructuring with a student-centered goal: to ground their learning in flexible career structures while preserving rigorous preparation for college.

Shaping the institutional climate in order to guide efforts for improving student learning with lasting results was a key condition requiring more democratic leadership styles also suggested by other researchers (Hernández-Gantes et al., 1995; Little et al., 1996; Newmann & Wehlage, 1995). As a result, particular approaches to integration derived from individual circumstances, needs, realistic assessment of resources, programmatic considerations, and extent of internal and external support. Based on this assessment, the mathematics curriculum at each site was restructured to align with career clusters or academy formats and provide either a series of applied courses or one-track coursework for all students.

Moving Toward Integrated, "Authentic" Instruction

Another lesson learned is that a commitment to curriculum restructuring and integration is not enough. Matching instructional changes in pedagogy and collaboration arrangements have to occur to engage students in rigorous experiences linking significant mathematics and career concepts. There are no quick-fix approaches nor one-size-fits-all models for integrating mathematics/vocational-technical education. Several collaboration formats were identified across sites ranging from informal exchanges to multidisciplinary teamwork where content and instruction had to be carefully coordinated (for details on integration models and strategies, see Bottoms & Sharpe, 1996; Fogarty & Stoehr, 1991; Grubb, 1996). This collaborative climate favored a commitment to linking teaching strategies suggested by the NCTM Standards.

The career context provided great opportunities to emphasize process standards, including problem solving, reasoning, communication of ideas, and making relevant concept connections. In contrast, content standards received less emphasis and were inconsistently implemented as faculty focused more heavily on processes standards. Thus, examples featured here must treated only as promising practices. Across sites, several instances of high authentic instructional activities in a variety of formats were found and it is possible to envision how content standards can also be rigorously emphasized. Statistics and measurement, for example, can be emphasized across various technical fields as students design experiments and collect, organize, and analyze data. Algebra, geometry, and mathematical functions can also be rigorously applied in problems featuring science and technology, manufacturing, and other technical fields in ways hinted by the experience at the Cocoa High Academy for Aerospace Technology.

At any rate, a shared understanding of what constitutes authentic, integrated, NCTM Standards-based instruction is crucial to match high expectations for achievement and career goals for *all* students. To this end, it is critical to understand that the NCTM Standards and related literature should be taken as a guide, not as a step-by-step cookbook, to stimulate change toward authentic pedagogy sustaining integration (Newmann & Wehlage, 1995; Porter et al., 1994).

Building Institutional and Community Support

Consistent with research on school organizational capacity (Kruse et al., 1994; Newmann & Wehlage, 1995), the institutional climate supporting the demands associated with more dynamic instructor collaboration was essential for linking the NCTM Standards to integrated curriculum, teaching, and assessment. A shared understanding of purpose provided the grounds for establishing governance and management structures to foster a democratic climate where administration, instruction, internal/external support were considered all part of a harmonious whole. In this climate, professional development was more likely to be shaped by individual and program-wide needs relevant to communal goals. Unlike counterparts in traditional systems where hierarchical structures and compartmentalized interactions are basically the rule, instructors at case study sites functioned in the kind of professional communities described by research on effective school restructuring and development of career-oriented programs—that is, communities that foster reflective dialogue, peer feedback, development of shared expectations for students, collaboration, and understanding of the philosophical foundations of reform efforts (Bottoms & Sharpe, 1996; Kruse et al., 1994; Newmann & Wehlage, 1995).

Further, because collaboration may involve business and industry partners, mathematics and other academic instructors can gain valuable exposure to these external supports more familiar to vocational-technical peers. Also, collaboration facilitates an understanding of the different expectations for both academic/vocational-technical instructors, help clear stereotypical perceptions, and create an awareness of external influences affecting common goals (e.g., finances, government regulation, and public perceptions). An understanding of the whole picture appears to be an essential component of successful restructuring efforts, integrated mathematics work included (see Little et al., 1996; Newmann & Wehlage, 1995).

Barriers for Change

Based on case study information, it was possible to build an understanding of the kind of organizational dynamics that are conducive to the development of promising efforts linking the NCTM Standards to school-to-work reform. However, survey information suggested that typical integration efforts around the nation can be characterized by low

levels of instructor collaboration, simplistic integration formats, and a rather low emphasis on the NCTM Standards vision. Not surprisingly, few instructors reported familiarity with key documents informing mathematics/STW reform movements. Further, although case study sites reported an optimistic assessment of their emphasis in linking the NCTM Standards to emerging vocationalism, an analysis of the individual nature and extent of these efforts revealed a more modest qualification. Overall, designing worthwhile problems involving significant mathematics along with authentic pedagogy facilitating critical thinking appears to be the main challenge to advancing integration.

Concurrently, programmatic supports (e.g., planning time), relevant professional development, and appropriate resources are needed to maintain instructor collaboration. This is particularly important since at each of the sites negotiating curricular changes with mathematics faculty, in particular, was a challenging task. Mathematics faculty appeared reluctant to embrace the full array of changes across sites. Although they may support some restructuring of curriculum, reluctance to change seemed to grow when they felt the integrity of specific content may be threatened by integrated instructional practices. In all cases, a small group of innovative faculty fueled integration efforts and struggled to gain additional support from their peers.

Considering these limitations, it is not surprising that linking mathematics and school-to-work reform in NCTM Standards-based integrated curricula is evolving very slowly, if at all, both at the secondary and the postsecondary level.

In conclusion, study findings are both humbling and promising. Given the extent of mathematics integrated efforts, it looks as if only a handful of institutions are committed to serious comprehensive reforms linking mathematics/career curriculum, instruction, and assessment. Even organizations with substantial efforts underway appear to be struggling in moving toward authentic, integrated instruction guided by the NCTM Standards. Tying the mathematics and career curriculum with the NCTM Standards vision is a very complex task requiring deep changes bridging disciplinary walls and well-entrenched notions on instruction and assessment. The scope and nature of current efforts reflect this complexity.

What seems promising is the realization that it is possible to make authentic mathematics/career curriculum connections. Ground-breaking experiences and related research can provide a useful frame of reference for advancing current efforts. For

instance, the theory for integrated learning deriving from case study findings is supported by research on organizational change suggesting that effective restructuring should involve a comprehensive focus on student-centered learning, authentic pedagogy, school organizational capacity, and external support.

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APPENDIX

Cocoa High Academy for Aerospace Technology

The Academy is housed at Cocoa High School, a public urban school located in Cocoa, Florida, and integrates academic education and aerospace technology. Approximately 1,250 students are enrolled in the school with the following ethnic representation: 63% Caucasian, 34% African-American, 2% Hispanic, and 1% Asian-American. The academy enrolls 150 students per year and is open to any student in the county. A total of 11 mathematics teachers teach full-time in the school, with one full-time teacher and one part-time teacher assigned to the academy.

Early in the 1990s, instruction across the board at Cocoa High School was based on lecturing and reliant on paper and pencil drills and rote memorization of information. Cocoa High was typical of other schools in Florida, which were tracking heavily and featuring low-level and basic skills classes. Minority students were overrepresented in these classes, even though school demographics indicated only about 10% minority enrollment. The result was low academic performance and lack of motivation to learn. According to the academy coordinator, students kept asking, "Why do I need to learn this? What sense does it make to me?" At that time, she began a research project to see how the curriculum could become more relevant to students. Based on this work, the school began broad integration efforts, including language arts and all vocational-technical courses. The results were so promising that the school decided to consider integrating all of the core academic areas and vocational education.

In 1992, an RFP came from the State proposing a change to a career academy system focusing on technology. Through the leadership of the current school's academy coordinator, Cocoa High School submitted an application based on the concept of Virtual Learning Activities (VLA), using aerospace technology as a hub. The virtual learning concept is based on problem solving. Students are given a real-world problem and they must solve it by researching and integrating multidisciplinary concepts and technical skills. Virtual learning is expected to occur as students solve problems resembling situations they may encounter in aerospace technology. In 1993, funds were awarded to Cocoa High School to create Cocoa High Academy for Aerospace Technology (CHAAT). The strong points of the academy's proposal included the VLA concept, focus on student preparation for school-to-career transitions, emphasis on SCANS competencies and applied technology, and cooperative learning and authentic instructional practices (e.g., emphasis on critical thinking, reasoning, and communication skills). With this framework, integration efforts began immediately. Under these circumstances, mathematics was to be

fully integrated with science, technology, applied communications, and business. Teachers at this site participated initially as volunteers. The group included five teachers who were already implementing integration activities. After receiving the initial grant, a steering committee was formed including district-level administrators, business people, post-secondary instructors, and staff from the academy. Subcommittees included working teams (e.g., curriculum committee), who worked with staff to develop curriculum focusing on integrated VLAs and SCANS competencies. An instructor provided an account of this process:

> Faculty got together with the academy coordinator. We had math, science, English, business, and technology instructors. The five of us sat down with the academy coordinator to start brainstorming for ideas on [virtual learning activities]. We also looked at SCANS competencies and decided what to do in the first nine weeks of school and what we wanted to accomplish. We picked appropriate SCANS competencies relevant to communications, transportation, manufacturing, whatever topic [involved in aerospace technology].

Once VLAs were identified, situational and solution statements along with criteria for evaluating student performance and outcomes were developed as well as program logistics. During the first two years, the academy received funding to support curriculum development and faculty worked full-time during the summer to develop curriculum.

The academy's first years were not easy. Stereotyped perceptions of vocational-technical programs are prevalent in the Cocoa area, and the academy's appeal was not high among students at the beginning. Since admission requirements are not based on grades and enrollment is open for any student in the county, the academy was seen as an alternative program for low achievers and problematic students. However, the academy has a goal of serving all students interested in aerospace technology and was open to all students regardless of grades. An instructor explained this philosophy:

> To say that we're going to take the top-end students and make the best of them is not fair. That's not the real world. We want everyone who wants an opportunity to come in here and make a change in their life. We want to do something for those students. And that's the way the grant is written and we've stuck to that.

To date, the program's philosophy, underlying working principles, and the climate among faculty and students all appear to be paying off. Students and instructors seem to

have formed a unified front and have refined a team concept supported by various integration strategies.

Strategies for Integration

The academy uses numerous strategies to integrate academic/vocational education. To reinforce a holistic approach, the school offers professional development activities tailored to specific needs around cooperative learning and a creative scheduling format. Further, consensus building and open discussions of issues and day-to-day problems remain an important foundation for collaborative, integrated work.

Integration Formats

The academy coordinator described CHAAT's integration efforts as *seamless*. "There are no discrete disciplines," she remarked. The entire curriculum was restructured based on an academy model spanning the 10th to 12th grade, where academic and vocational courses are aligned in a thematic structure featuring aerospace technology. The technology context involves relevant, transferable skills, including engineering, computer applications, technical maintenance, graphic design, computer aided manufacturing, and telecommunications. Traditional mathematics tracks were replaced by an *Applied Math* series, based on a series of sequenced and coherent courses for appropriate grade levels. VLAs, the focus of the integration approach, provide the vehicle for linking academic and vocational content. The unit "Working in Space" exemplifies these VLAs. The unit is introduced with the following situation statement:

> NASA has asked Congress for funding to design, build, and launch a large space station into earth's orbit, and you have been selected to serve as members of the Space Station Task Force. You have committed the next ten years to the preparation of the space station, and you will be among the station's first inhabitants. Launch is tentatively scheduled for the year 2000.

A solution statement encourages students, as members of the task force, to solve problems associated with designing and building a space station. Students must submit various reports describing solutions and are expected to research, critically evaluate available information, draw and build architectural models, and justify their space station proposals. Each contributing teacher is provided with a teacher page outlining specific outcomes for each subject, teacher methodology and related activities, suggested resources and references, and evaluation strategies. In this unit, mathematics integration involves

using scale drawings and maps in two- or three-dimensional shapes; using mathematical formulas to solve problems; and using flowcharts, area/volume concepts, and spreadsheets to manage and analyze data (see example of the teacher's page for Applied Mathematics II below).

Teacher Page

Course: Applied Mathematics II
Date:
Title: Working in space

Outcomes

Perform operations with powers and roots and solve relevant problems

- Use formulas and linear and non-linear equations to solve real world problems
- Solve problems using special right triangles, trigonometric ratios and the Pythagorean theorem
- Demonstrate an understanding of functions, relations, and graphs
- Apply properties of lines, angles, and triangles to problem solving

Teacher Methodology and Activities

- Conduct small-group instruction
- Introduce Virtual Learning Activity (VLA)
- Review spreadsheet and how to calculate formulas on the computer
- Conduct VLA
- Provide individual student assistance as needed

References and Resources

- Science text
- CORD Applied Mathematics Units 16, 17,18, 20, and 24

Evaluation

Students will receive full credit for this activity by:

- Completing Applied Mathematics II checklist
- Completing Criteria checklist

(From CHAAT, 1996)

Each instructor is also provided with a criteria checklist for assessment and evaluation purposes. Other formal and informal integration strategies support academy work ranging from individual efforts to work in teams to integrate specific aspects of VLAs drawn from various fields related to aerospace technology. Internships represent another form of integration, strengthening the connections between school and real-world applications. Students learn relevant on-the-job mathematical applications involved in VLAs. Students who have internships are also responsible for developing VLAs with the help of their mentors. Integrating work-based learning activities into the academy becomes another source of potential VLAs happening in the real world identified from the students' standpoint.

Professional Development

Preparation in cooperative learning, authentic assessment, and applied curriculum are prerequisites for new staff members. The district also provides professional development opportunities addressing these topics for staff who need further training. This includes various local and state staff development workshops with focus on cooperative learning, authentic assessment, and applied curriculum. These professional development activities assure broad-based and uniform familiarity with these topics. In addition to the workshops provided off-site, training in virtual learning is provided at the school for all teachers. A math instructor reported that faculty may spend a summer attending a 60-hour inservice workshop on cooperative learning and applied technology involving mathematics and examining its relevancy to various fields in aerospace technology.

Scheduling

The academy model and the implementation of VLAs require a flexible and creative scheduling system, allow instructors various forms of collaboration, and provide students with time to work in groups and participate in internships. Work is organized in academic rotations or individual learning activities. First, students get together in teams and learn about the objectives for specific components of the day's VLA. Five predetermined groups work simultaneously, each focusing on a different academic/technical aspect of the VLA (e.g., English, technology, and mathematics). They brainstorm ways to address the problems assigned to them and divide the work. They can work as a group or individually until regrouping to debrief and assess progress. Then each team rotates to another component of the VLA to focus on a different academic or technical aspect. At the end of

the fifth period, the students participate in a debriefing session to assess overall progress and to plan for the next day. The rest of the day is spent on elective course work available at Cocoa High School, or students may leave campus to work on their internships or participate in on-the-job training programs. To keep all instructors abreast of common progress, the sixth and seventh periods are devoted to planning meetings. All staff are debriefed about what's going on in mathematics, students' progress, problems they are facing, and whether more time is needed to complete certain tasks.

Institutional Climate and Support

Camaraderie and a sense of family and teamwork seem to be important in maintaining integration efforts at CHAAT, especially if difficulties arise. The thematic context helps establish a climate conducive for collaboration among students and instructors. As one instructor put it: "When you think about it, not only are we an aerospace team, we're also a family. We spend five hours a day with these kids and seven hours with each other as teachers, so we are one big family and we really work that way. We have our problems, but we work through them together." Because of the VLAs' integrated nature, accountability and interdependence among teachers are vital components of the cooperative efforts between different areas and for conducting learning activities. "There might be some occasions that you see somebody putting up boundaries," explained another teacher, "but they fall because we talk about it and it is resolved." During typical meetings, all faculty meet with the academy coordinator and support staff to discuss ongoing work and issues and about how the day went. They identify collaboration on common tasks related to the rotations and talk about disciplinary issues. Decisions are made by consensus, and the academy coordinator's vote has the same weight as everybody else's. This participatory climate is further enhanced by cultural values inherent in teamwork and by student-centered instruction. Thus, instructors refer to each other as facilitators because they do not rely on lecturing. Their goal is to "promote a lot of interactions with the students." This climate among faculty spreads to students, who in turn are encouraged to work in teams with peers of different academic abilities.

Mathematics Integration: Implementing the NCTM Standards

The academy coordinator reported that the NCTM Standards have been addressed as long as math has been integrated at this site. She noted that county performance standards are also very closely linked to the NCTM Standards. In developing curriculum

for the academy, facilitators guided their efforts based on the NCTM Standards, county performance standards, and the SCANS competencies, with a particular emphasis on problem solving activities. Indeed, each VLAs includes a problem statement along with relevant questions requiring researching, data collecting, analyzing data, exploring possible alternatives for solutions, implementing a plan of action, and reporting findings in both writing and verbally. For instance, mathematics concepts can come to life throughout the VLA as students may be required to estimate the exact orbit of a space station, budget for maintaining the station in operation, and draw flow charts of plans of action and blueprints of space station models. Teamwork is emphasized in each VLA through a balanced, heterogeneous grouping of students with different academic abilities and backgrounds. Thus, a great deal of student interactions occur whereby advanced students learn by explaining to peers who may be in lower grade level. Finally, assessment methods range from traditional paper-and-pencil tests to non-traditional strategies. Students are assessed via criteria checklists, teacher communication, rubrics, and portfolios of students' work. "The assessment criteria is not just a checklist that is passed around for signatures," reported one teacher. "It is used to let the students know where they are and what they have to do to complete the activity as they go along. It is like a road map and we're always checking them off and letting them know how they're doing, if they're going in the right direction."

Fairdale High School Magnet Career Academy

Fairdale High School is a public institution located in Fairdale, Kentucky, a rural setting near Louisville. The school serves 1,200 students representing a majority of Caucasian descent (75%) and a minority of African-American ethnicity (25%). About 60% of students participate in the free-lunch program. The school features a Public Safety Academy and employs 12 mathematics and 12 vocational education teachers. The academy is an Advanced National Demonstration Integration site with the Southern Regional Education Board's (SREB) High Schools that Work program.

In 1986, student academic performance at Fairdale High School (FHS) was at a low point, suffering a high dropout rate and low attendance. As a result of the school's location in an economically depressed region, education was given a lower priority by many in the community. The program coordinator recalled that the school was "taking the kids that nobody else would take." The first-year principal certainly had her work cut out for her. However, she was a visionary with a deep commitment to the students, and she invited the faculty to simply find "better ways of doing things." To involve all major stakeholders in a schoolwide collaborative effort, she initiated a participatory management committee consisting of faculty, parents, and community representatives. Seeking further guidance in implementing schoolwide reform, the school joined the Coalition of Essential Schools (CES) shortly thereafter. From the Coalition, the school was made aware of the philosophical underpinnings that would guide and inform the management committee's actions from then on. As a result, the school gained many training opportunities, including the privilege of attending the Coalition's Integrated Curriculum Institute and numerous state, regional and national training seminars and institutes dealing with integration of academic/vocational education, authentic assessment practices, restructuring, and other related issues. Over time, FHS faculty's high participation rates in these activities, the quality of their contributions, and the resultant gains in expertise afforded even greater opportunities for subsequent involvement as presenters. Presently, some FHS teachers have become National School Reform faculty and many serve as nationwide consultants.

Fairdale had already enacted many requirements of the Kentucky Education Reform Act when the act was passed in 1990. Portfolios had been instituted for assessment purposes along with school-based participatory management and academic standards. Writing portfolios, for instance, had been in use for approximately two years before required by law. Further, while the reform act also addressed school-based decision making, the law required inclusion of three teachers, two parents and the principal as

chairperson. At Fairdale, the school-based decision making committee had already grown to a total of 26 members, including eight parents, eight teachers, two (nonparent) community members, four students, one classified staff representative, an ex-officio member of the University of Louisville faculty, and the principal (who was never the chairperson). Other changes already in place included heterogeneous class groupings, elimination of remedial or honors courses (honors credits can be earned in any course), authentic assessment including writing and math portfolios, and student and teacher networking with other restructuring high schools. The reform act, nevertheless, legitimized the school's restructuring efforts and helped further develop what was already accomplished or in the works.

The 1991-1992 academic year, when the district began to restructure vocational education and convert to the magnet career academy system, marked another pivotal period in the school's integration efforts. Since almost 40% of all public safety workers in the county lived in the school's attendance area, it was decided that this site would become a public safety academy. Becoming the Public Safety Magnet School necessitated a unified approach between the vocational and academic faculties. The school held a number of faculty meetings, although at first the program coordinator noted that academic/vocational teachers were divided. At first, the school was basically split in two worlds, academic and vocational, and "even the students were seen as different and did not attend the same school functions." To mend fences, the vocational and academic buildings were merged, so that all classes would be held in both buildings. Students are now bused the short distance between the two buildings, especially in winter, to maintain a mixture of all students in both buildings. This strategy facilitated the promotion of same educational goals, high expectations, and a combination of work-based learning for all students.

Since the 1989-1990 academic year, the school has been a Southern Regional Education Board (SREB) site member. SREB has been instrumental in providing funding as well as a wealth of opportunities in integration and restructuring efforts. Through SREB, Fairdale was awarded a grant to integrate technical and academic subjects. However, instead of implementing the more common practice of pairing two teachers in specific areas, FHS decided that the entire faculty would be the team and would, therefore, have an incentive to work on integrated projects. FHS features a flexible schedule for students, advanced learning opportunities with local colleges, internships for all public

safety seniors, and integrated academic/technical subjects. Because of the quality of these restructuring efforts, the school has received national recognition.

Strategies for Integration

An open, inclusive, and highly focused environment is conducive to integration efforts. This environment is supported by flexible professional development activities designed with direct input from faculty. A creative scheduling format allows students to select courses and teachers to choose teaching slots, a format that appears conducive both to teacher-enhanced collaboration and to student motivation.

Integration Formats

Fairdale's levels of integration encompass a schoolwide approach through a magnet school format. Vocational and academic courses are aligned into a thematic program featuring an occupation (i.e., public safety). Integration is facilitated by three collaborative learning communities in 9th and 10th grades, in which 5-7 teachers on each team provide students with personalized assistance regarding scheduling, instruction, and integrated learning opportunities. Mathematics team teaching is also prominent at FHS. Working in pairs, teams of teachers integrate mathematics with science and occupational contexts. For instance, one team of two teachers representing math and science developed integrated activities as a result of their participation in the CES Mathematics/Science Fellows program. The science instructor described this work, highly popular with the students:

> [In science] we go through the chemical reactions involved in photography. In geometry students go through proportions and ratios and so forth. It is truly integrated. There are days when [the math teacher] teaches and I just sit tight. The students really start to see that this isn't just a chemistry or math class anymore.

Other projects require multidisciplinary teacher collaboration. "The Curious Death of Zachary Taylor," an integrated unit designed in the context of law enforcement, requires students to participate in re-enacting the trial following the death of Zachary Taylor. Students take different roles in six preparation teams, including chemistry, geometry, data analysis, prosecuting, biography, and legal defense. Other students participate in trial team roles including jury, prosecution, defense, reporters, chemical experts, data experts, geometrical experts, and cartoonists. Students apply mathematics and geometry to examine evidence, recreate the scene of the crime, and analyze evidence. Five teachers, representing

English, social studies, science, math, and law enforcement, collaborate on this project. Other collaborative work focuses on problems including design and construction of public safety facilities. Through these problems students are required to plan, design, draw blueprints, and build a scale-model version of their proposed building. Geometry concepts are embedded in all phases of the project.

Professional Development

While some schools are struggling to catch up, FHS has six years of experience with many of the requirements of the Reform Act. Because of this headstart, the school has been able to devote more time to developing and refining professional development activities. Early on, strategies included sending different mixed groups of teachers to conferences, meetings, and presentations to introduce integration concepts to teachers who were not into integration. The academy coordinator remarked that "it was against our principles to spend this money only on one group of teachers or one team, so we took a mixture. Always a mixture." Also, every spring, staff meet and produce a transformation plan. This action plan stems directly from a needs assessment based on student's scores and other data. Professional development activities also stem from this plan, ensuring logical, coherent, site-based training for faculty in integration practices, authentic instruction, curriculum development, teamwork, and other relevant issues and implementation practices. University of Louisville students are also a part of these efforts. They participate in this professional development plan focusing on integration and pedagogical practices aligned with school reform. In an agreement with the University's School of Education, pre-student teaching classes are held at FHS. The content of these classes is common to area schools, but FHS is used as a vehicle of study. In addition to studying specific situations at Fairdale, students are required to perform 30 hours of work outside of class time. At FHS these students teach, rather than observe. University students also are responsible for much of the time consuming work that needs to be done implement a plan. For instance, when the idea of block scheduling came up, university students collected models and interviewed other schools to find the most appropriate format for Fairdale.

Scheduling

Flexible and creative scheduling is a critical piece in integration arrangements. Arena scheduling allows students to select courses and, in most cases, teachers can select

teaching slots as well. Several scheduling models were examined and debated until everybody agreed on a consensus-driven negotiated schedule, which the academy coordinator described as the most complex option:

> We left Mondays and Fridays with a traditional schedule to honor those people who didn't want to change. And then Tuesdays, Wednesdays, and Thursdays we run 80-minute blocks to honor the people who did want to change. And what came out of this is that [now] everybody loves the blocks. Some now want to simplify the schedule by going to blocks every day.

Institutional Climate and Support

The academy coordinator summarized the school climate at FHS: "All of our meetings are open. Any opportunity for travel is thrown out there; the budget is open; nothing about the money is secret." The Critical Friends group, also trained through the CES, exemplifies this climate. Thirty-eight teachers from all areas participate voluntarily in peer reflection. One of these activities is a tuning session in which a diverse group of teachers (10-12) use a protocol to critique a teacher's work. Teachers from different content areas become aware of, and contribute indirectly to, what is happening in other content areas throughout the school.

Collaboration between experienced and novice teachers is a major factor in the perseverance and success of the school's efforts. "One of the greatest benefits of [this open climate] is that we know that there are cycles, and we know that there are stages, and we know that it takes time to get something accomplished," noted the academy coordinator. Under these conditions dialogue can turn into an empowering process:

> Teaching is such a polite profession that there are no norms for civil discourse. We have had faculty meetings where some were sobbing and others had stormed out, but yet we always come back together. We would question top-down directives and we would talk and argue, until the ideas became everybody's ideas.

This method is effective in large part because philosophically, the teachers know they are arguing for change, for a better school, and—first and foremost—for the benefit of the student. These exchanges have empowered participants and have been critical to local integration efforts. The present school administration, although different from that which started the restructuring process, has nurtured this approach and continues to encourage teachers to integrate learning and to seek student success.

Math Integration: Implementing the NCTM Standards

Prior to restructuring efforts, the school had five academic tracks and traditional teaching delivered by lecture. All low-level math courses were eliminated when staff accepted the premise that all students should have same expectations and educational goals. However, integrating mathematics with other disciplines proved difficult. Through participation on the CES Math/Science Fellows program, teachers were trained on effective integration practices and faculty sparked an interest in the problem-based approach that is now common in the school.

Through this coalition participation, teachers have gained exposure to local, state, and national groups who advocate the NCTM Standards. A math teacher believes that all of the mathematics department favors use of the NCTM Standards, so "the math department is a real cohesive group which seems to have common values and philosophies for teaching." The teachers' cohesiveness may be a result of the fact that many of the teachers and new hires have graduated from the University of Louisville. Their teacher education curriculum included the theory and practical use of the NCTM Standards. Their common philosophical background seems to fit in quite well with the integrated thinking of the school. "I was a junior in college when the standards came out," another math teacher recalled. "[The NCTM Standards] were our textbook. Our professor made us get it and we tore that book apart." Thus, University of Louisville graduates come to FHS ready to integrate the NCTM Standards into the classroom lessons and pedagogical practices they develop.

Fairdale High School's emphasis on problem solving and communication is a major factor in their successful implementation of the NCTM Standards. Everyone in the math department helped develop a new curriculum, which incorporated the NCTM Standards and the Kentucky learner expectations. The new curriculum emphasizes communication and problem-solving skills through small- or large-group discussions. Normally, students are given an assignment describing a problem and required (whenever appropriate) to measure and collect data. For a lesson on statistics, for example, students are required to determine independent and dependent variables, draw a scatter plot, analyze and explain data characteristics, plot the data using a calculator, and explain line of best fit. Through these activities students research, exercise critical thinking and communication skills, and engage in problem-solving activities typical of a discovery approach to learning.

Alternative assessment strategies involve portfolios, rubrics, and observations of students' work. Math portfolios have been in use for about four years, allowing students to show their work using writing and multiple representations to describe their solutions. By observing how students work, teachers also learn about instructional practices that may need further refinement such as when students struggle to get involved or do not understand what they are supposed to do. Rubrics are widely used to assess what students are thinking about math and how they go about solving problems. Typical rubrics focus on critical thinking, communication/presentation, and interpersonal skills based on four categories of assessment ranging from novice (basic understanding) to distinguished (exceeding expectations).

Mt. Hood Community College

Mt. Hood Community College is located in Gresham, Oregon, serving students from urban, suburban and rural communities in the Portland area. The college enrolls approximately 12,000 students per year with the following ethnic breakdown: 90% Caucasian, 3% African-American, and less than 1% American Indian. The college has a mathematics division and technical programs in communication and performing arts, business and computers, engineering and industrial technology, and science. The mathematics department has ten regular full-time instructors.

Traditionally Mt. Hood Community College (MHCC) had separate mathematics tracks for technical and academic students. Transfer between tracks was not possible: Students who wished to change tracks lost ground. In general, the technical track acted as a sieve, straining an entire group of students from the pool of those considering future math and science studies. Students with undecided majors typically chose the academic track. The technical math track lacked the depth of conceptual understanding needed for future application in varied settings. Students saw both of these tracks as hurdles to overcome, rather than as the beginning of lifelong learning. Clearly something had to be done. In 1986, MHCC organized a series of meetings between representatives from professional technical fields and all district high schools, faculty, and key stakeholders in the community. The meetings' mission was to find ways for MHCC to establish more productive connections with the feeder high schools. As a result, the Mt. Hood Regional Cooperative Consortium (MHRCC) was formed with local feeder high schools, business, government, and community-based organizations. Its goal was to develop an improved framework for implementing 2+2 Tech Prep programs. The Consortium's first step was to organize articulation agreements and to develop career pathways. In 1995, MHCC reported that "eighty-one written articulation agreements have been established between MHCC and the eight high schools. These agreements cover seventeen different professional-technical areas of the college and all six of the high school Certificate of Advanced Mastery (CAM) areas." Other career pathways under development are arts and communications, business/ management, health services, human resources, industrial/engineering systems, and natural resource systems.

Another critical component of the Consortium's work was to nurture collaboration between faculty, administrators, board members, and support staff from participating district high schools, from the Multnomah Education Service District, and from MHCC. Indeed, administrators reported that much of MHCC's successful collaboration with high

schools is attributed to the quality of these connecting activities. These exchanges involving MHCC and high school faculty are also used to review and update articulation agreements.

A third strategy for articulation was the collaborative development of 2+2 curriculum guides and marketing materials. Presently, curriculum guides have been developed for each of the seventeen professional-technical areas of MHCC. These guides are used by counselors, students, and parents at each of the participating high schools. Creating pathways required drastic restructuring changes to provide a series of coherent courses for all students, from middle school through the first year of college. While a series of technical courses could be aligned with career pathways, academic disciplines such as mathematics were well entrenched in traditional tracks (e.g., remedial, general, advanced). The creation of an Application-based, Technology-supported, One-track (ATO) mathematics curriculum was a bold response to integration of mathematics and technical areas. The curriculum was the result of four years of curriculum revision and experiences with alternative pedagogy and assessment. During this time, the mathematics faculty were supportive of these reform efforts. In 1994, they received a four year grant from the National Science Foundation (NSF) to support the refinement and implementation of the ATO mathematics curriculum. The ATO model provides a "balanced, coherent mathematics program for all students (tech prep and baccalaureate prep) in entry-level mathematics courses. It acknowledges the challenges of education reform in mathematics that are common to all schools that teach the mathematics addressed in the NCTM Standards and SCANS documents." To facilitate mathematics teaching under this model, a series of interactive mathematics courses replaced traditional track courses (e.g., remedial mathematics and intermediate algebra). The interactive nature of the mathematics course is defined in three ways:

> [First,] students are actively involved with other students and the instructor in their learning of mathematics. [Second,] algebra, geometry, probability, data analysis, and statistics are integrated in each level of interactive mathematics. [Third,] applications from other disciplines are incorporated to establish a strong connection between mathematics and the real world.

Under these restructuring efforts, students participating in the 2+2 Tech Prep programs can benefit from advanced placement course work at affordable tuition rates. Based on the Consortium's *1995 Summary Report*, student participation in transcripted credit had increased 1446% since 1986. Additional benefits include potential participation in a manufacturing Tech Prep internship developed in collaboration with the Portland's

Boeing Company and the Consortium. Students interested in careers in retail and hospitality industries can participate in a Management Development Academy to acquire work-based experience in that field. To date, MHCC has focused on developing integrated curriculum, teamwork, realistic applications for mastering academic skills, and work-based learning opportunities for all students.

Strategies for Integration

The MHCC integration approach is supported by strategies facilitating the development of career paths through a series of coherent technical courses. Technical and academic content is also integrated in support of career pathways. In the mathematics program, integration is a department-wide approach nurtured by flexible and focused professional development activities and an institutional climate conducive to effective implementing education reform.

Integration Formats

Prominent in the MHCC integration efforts is the integration of secondary and postsecondary education through career pathways. Students can participate in coherent sequences of technical and academic courses in programs related to the humanities and performing arts, business, health sciences, human resources, technology, and natural resources. The industrial and engineering systems career pathway, for instance, involves the study of "related technologies necessary to design, develop, install, or maintain physical systems. These may include engineering and related technologies, mechanics and repair, manufacturing technology, precision production, and construction" (from MHRCC's *1995 Summary Report*). In alignment with the development of these career pathways, academic departments have attempted to restructure their curriculum by eliminating traditional tracks and integrating academic content into realistic contexts. The English and mathematics departments have worked assiduously to connect with the professional technical groups on campus. A college administrator indicated that integration is occurring in various ways all the time to infuse "academic material into the minds of professional technical people."

The mathematics department's integration approach is characterized by program-wide efforts. First of all, mathematics courses were restructured to serve all students, regardless of their career pathways. This vision is being implemented through a

common-core baccalaureate and Tech Prep course sequence under an interactive mathematics curriculum involving four levels of mathematics. These courses integrate the use of technology and emphasize practical examples of real-world problem situations drawing from technical fields of interest to the students (see MHCC ATO mathematics curriculum on page 64). Under this program-wide approach to integration, all faculty in the mathematics division participate in developing curriculum for the restructured courses as well as in articulation activities with high school faculty to make sure courses are properly aligned and sequenced. Involving all faculty in a continuous conversation on the need and reasons for change was an important strategy to establish this program-wide approach. In particular, teachers were encouraged not to feel resentful or fearful about abandoning the *integrity* of their discipline. It was made clear that integration of mathematics and technical subjects was not about watering down the material. It was about providing all students with common foundations so that, if a job changes or disappears, students still have the academic and technical skills foundations to enable them to learn on the job.

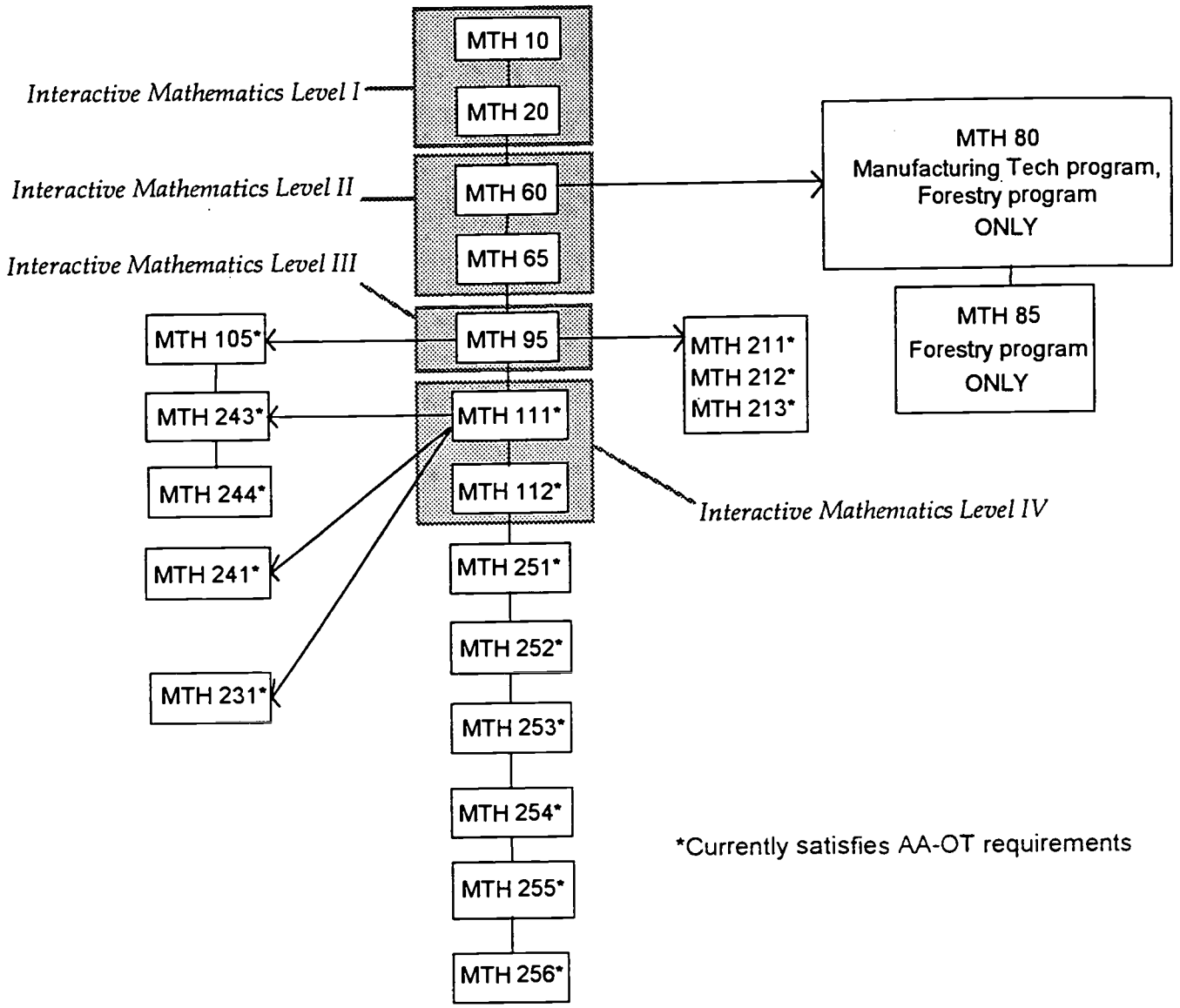
Professional Development

At MHCC, integration is tied to the notion of effective pedagogy that engages students and motivates them to demonstrate their learning to others. To develop a common understanding of how to improve mathematics teaching, full-time and part-time instructors participate in course teams, which meet regularly. When restructuring efforts began, Tech Prep conferences played a major role in administrators' professional development. These conferences were very effective in interesting instructors in education reform and integration issues.

The math division is active and has developed a collective understanding of the need for effective professional development. The entire mathematics division participates in faculty workshops during fall in-service time. These workshops include full- and part-time instructors and focus on issues of the ATO curriculum and pedagogy. Instructional teams facilitate ongoing discussions of these issues. These faculty training opportunities are funded in part by NSF. MHCC is currently working with Portland State University (PSU) to create a course/seminar for mathematics graduate students interested in teaching at the community college level. This seminar would be jointly taught by PSU and MHCC faculty. This seminar should help develop a pool of applicants who are more prepared to teach effectively in the reformed setting after grant funding ends. A related strategy has been to

provide release time for instructors, so their professional development can take the form of collaborative work to develop curriculum since available packages did not align well with the NCTM Standards. For example, a team of teachers wrote a math textbook, which is currently published in a preliminary edition. This work, in turn, creates opportunities for instructors to conduct workshops, present at conferences, develop reports and information brochures, and so on. In short, a combination of professional development activities, including conference participation, curriculum writing, and participation in demonstrations, provide ample opportunities for teachers to gain conceptual and practical understandings of integration issues as well as to network with peers in the field.

MHCC ATO MATHEMATICS CURRICULUM
BACCALAUREATE PREP/TECH PREP COURSE SEQUENCE



*Currently satisfies AA-OT requirements

★ • MTH 10	Interactive Mathematics IA
★ • MTH 20	Interactive Mathematics IB
✓ MTH 60	Interactive Mathematics IIA
✓ MTH 65	Interactive Mathematics IIB
✓ MTH 80, 85	Technical Mathematics I, II
✓ MTH 95	Interactive Mathematics III (formerly Intermediate Algebra)
♦• MTH 105	Introduction to Comtemporary Mathematics
✓ MTH 111	Pre-Calculus I: Elementary Functions
✓ MTH 112	Pre-Calculus II: Trigonometry & Analytical Geometry
♦★ • MTH 211, 212, 213	Fundamentals of Elementary Mathematics
♦ MTH 231	Discrete Mathematics
♦✓ MTH 241	Elementary Calculus
♦✓ MTH 243	Introduction to Probability & Statistics I
♦✓ MTH 244	Statistics II
♦ • MTH 251, 252, 253	Differential and Integral Calculus
♦ • MTH 254, 255	Vector Calculus I, II
♣ • MTH 256	Applied Differential Equations

KEY
- ★ Course requires at least a scientific calculator (TI-34 recommended)
- ♦ Computer lab included (fee required)
- ♣ Computer lab may be required
- ✓ Graphing calculator is required (TI-82 recommended)
- • Graphing calculator may be used (TI-82 recommended)

Institutional Climate and Support

The institutional climate and support for integration at MHCC is nurtured by educational changes mandated by the Oregon legislature, emphasizing real-world skills and contextual learning. However, much of MHCC's success is the result of the leadership provided by college officials, who have established a climate of effective collaboration internally and externally. The Consortium appears to be an exemplary partnership assisting in developing a vision for current and future work. All key Consortium stakeholders (e.g., feeder high schools, business/industry) are invited to participate in conversations and decisions about restructuring changes. For instance, business and industry (e.g., Boeing and Fujitsu) frequently send representatives to Consortium meetings to provide examples of real-world situations for contextual learning. Further, college faculty and leaders in mathematics and English curriculum reform conduct frequent hands-on training and assist in developing materials for high school and college faculty. This collaborative climate established by college administrators is perhaps the most important factor supporting restructuring efforts. The administrators provided constant conversation and feedback until all parties involved were convinced of change's necessity and that actions must follow. A mathematics teacher explained,

> The dean came in with a vision, but backed off for a while to see if we would come to that vision. She wanted a cohesive program, but it wasn't forced. It wasn't 'here's a philosophy, do you guys buy into it?' It really was brain-stormed one year and put together as a document the next year. A lot of people contributed to the vision and [we] tried to get other people on board. [The dean] really facilitated our work and elicited our ideas. She knew when to ask us the right questions, and she had a vision for working with the administration, because you have to have the administration buy in when you make such a radical change.

By 1991, everyone in the mathematics division decided to participate in restructuring efforts. The strength of the mathematics division, according to another math instruction, is that "once somebody tries something and it works, then we get together and talk about it and decide whether that's good for all our students and whether it's a direction that we all need to go."

Mathematics Integration: Implementing the NCTM Standards

To fully align restructuring and integration efforts with the principles of education reform, the Consortium reviewed the SCANS report and NCTM Standards. This effort was led by the dean of mathematics division, who, at the time, was highly influenced by

the book *Everybody Counts*, a report articulating NCTM and SCANS ideas. She was invited to review the SCANS report and saw how it correlated with the vision of the NCTM Standards. Thus, she arranged to meet with the associate dean of engineering and industrial technology to secure his interest in curriculum redesign proposals. At the same time, she was also communicating her ideas to high schools in the area and trying to influence the manner in which they were preparing students. The results of her efforts are reflected in the ATO model, an integrated, single-track, problem-solving mathematics program available at MHCC and participating district high schools. The ATO model's principles reflect the vision of the NCTM Standards and emphasize discovery learning. The following components are characteristic of the interactive mathematics classes taught in the ATO model: problem solving as the context for applying a variety of strategies for possible solutions; communicating (written and oral) to help students reflect and clarify their thinking; connecting mathematics to the real world, to underscore the value of mathematics in the workplace and society in general; using technology to model complex realistic problems; encouraging team activities and projects to promote interpersonal skills; relying upon guided discovery learning activities to promote critical thinking; and presenting mathematics as an integrated whole, to help students understand the connections among mathematics concepts.

Initially, discovery learning was "terribly uncomfortable" for many of the instructors because the methods are time-consuming and require active student participation as opposed to traditional modes where teachers do all the talking. Thus, initial professional development activities focused on developing a common philosophical understanding of teaching. The NCTM Standards were particularly useful in shaping the conversation on pedagogical matters and were embraced even when they were still in draft version. "[The NCTM Standards] were really the backbone and the guidelines we used all the way through," recalled one math instructor. Newer teachers were already familiar with the standards, upon which many of their college methods classes were based. Eventually, everybody was thinking at the same level. Further, instructors have discovered many benefits from using contextual learning. Students who traditionally felt incapable of doing mathematics have appeared now more comfortable with applied concepts and more confident solving problems because they could understand the context and interpret the information in ways relevant to them.

Regarding assessment, students receive constant feedback through in-class assessment worksheets, in-class and take-home tests, and observation of group work. Students' work is documented using journal writings and ensuring that different concepts and skills are assessed (e.g., use of technology, knowledge of concepts, and communication skills). Exams are sometimes written collaboratively and shared among members of the department. In general, faculty members are willing to try new things, evidenced by their early use of graphing calculators and discovery-based calculus. An instructor reported that there is a willingness to "leap in there and try something new and then come back and assess whether this is good for all of our students."

Swansea High School

Swansea High School is a public school located in Swansea, South Carolina, a rural setting near Columbia. Approximately 627 students are enrolled in the school, with the following ethnic breakdown: 73% Caucasian, 27% African-American, and less than 1% Hispanic. The mathematics department consists of 5 math instructors while the vocational-technical education department has 6. Swansea High School is an Advanced Integration Model site with the Southern Regional Education Board's High Schools that Work program (SREB) and features career paths in business, engineering, arts, and health services.

In 1988, the picture at Swansea High School (SHS) was not encouraging. High dropout rates, low rates of transfer to postsecondary institutions, high pregnancy rates, and low test scores characterized the times. Further, there was a wall between vocational and academic teachers. Academic teachers believed that "vocational education was for those students who couldn't do anything else." Needless to say, teacher morale was very poor. Drastic measures were needed to address this situation. With a new superintendent, the Board of Trustees mandated significant changes and in 1989 asked the Director of Vocational Education at the State Department of Education to study and evaluate the school programs. The results indicated that the equipment in the vocational department was obsolete and that teachers lacked appropriate pedagogical training. Seeking new direction, the school became aware of the High Schools that Work program supported by the Southern Regional Education Board (SREB). In 1989, the school volunteered to participate in a SREB pilot study to implement various changes under a five-year plan. During a six-month period beginning in January of 1990, the school and a steering committee developed this plan. Five groups were created to work on public relations, curriculum and instruction, staff development, acceleration and remediation programs, and evaluation. Further, these groups and the steering committee worked on six major areas of schoolwide interest: (1) changing attitudes toward change; (2) improving staff development; (3) revising curriculum to meet NCTM, SCANS, and business and industry skills standards; (4) reviewing instructional strategies; (5) reviewing assessment practices in the classroom; and (6) eliminating academic and vocational tracks. Initially, only four academic teachers believed in these restructuring efforts. To gain the support of instructors, the school's strategy focused on involving everybody in the conversation about school changes. The Associate Superintendent made sure to invite both believers and nonbelievers to meetings, send them to conferences on school reform, and ensure that all teachers were aware of even the smallest successes. This strategy paid off, and many nonbelievers began to support

restructuring efforts. In particular, teachers appreciated being taken to conferences and meetings, especially when they had the opportunity to share their success stories with their peers. Interacting with motivated peers has been an effective way to bring new instructors into the integration discussion and to reward those who are already participating.

Following the five-year plan, all general and remedial courses were eliminated; and beginning in 1990, the school planned to emphasize instructional strategies under Tech Prep principles, focusing on preparing students for further education and work while maintaining the rigor of the coursework. Many teachers were still reluctant, especially mathematics teachers who were still defending the value of the math tracking system. The turning point came when the president of a local tool and die company sat in on a curriculum meeting and said he did not want to employ Swansea High School students because they lacked employability and appropriate math and science skills. From that meeting, it became clear that all students needed an opportunity to participate in rigorous coursework preparing them for further education and work.

Under the old system, there were six levels of mathematics: advanced placement (AP), college preparation, general, basic, remedial and basic remedial. By 1990, all general math classes were eliminated, and applied mathematics classes were implemented that same year. The next step was to provide consistent professional development opportunities focusing on integration. The district began requiring new applicants to have at least one year of experience in applied instructional practices or to agree to be trained in an applied institute to learn how to use applied materials in any subject. Another critical juncture came during the academic year 1992-1993 when the school began serving as an Advanced Integration Site with the SREB's High Schools that Work program. The school was selected because of the restructuring efforts and integration activities already taking place as well as the school's continuous contributions to SREB conferences and workshops. Through this participation and exposure to nationally noted educators, teachers furthered their understanding and working knowledge of integration issues. Finally, the support of area administrators, specifically the school superintendent at the time, was vital to initial efforts. The superintendent's commitment to promoting restructuring efforts was especially important when the board of trustees came under tremendous pressure from some teachers reluctant to adopt proposed changes. Anticipating this situation before curriculum integration efforts began, the superintendent had arranged presentations to educate the board members about how and why certain things were happening. As a result, board

members were aware of the issues, convinced of the need to implement radical changes, and confident in responding to teachers reluctant to change. This early administrative support was crucial to the implementation and maintenance of the goals of the five-year plan.

Strategies for Integration

Fostering the integration process at this site is a constant and varied process. Creating an environment where integration is supported and creating the space and time for teachers to meet and share ideas appear to be key ingredients for success and above all, willing and eager participants. While at present there is state and federal support, the commitment and reinforcement provided by the district office has guided and maintained the continuous improvement of the integration efforts.

Integration Formats

Integrating mathematics across the curriculum occurs primarily under the applied mathematics series available to all students. These courses include Applied Mathematics for the Technologies I & II and Applied Geometry. Three of the five mathematics teachers are involved in integration efforts, focusing on integrating mathematics with occupational content using hands-on, real-world problems relevant to mathematics skills used in the workplace. According to the Associate Superintendent, "initially, mathematics was the least integrated discipline at SHS." Even though the focus was on contextualizing mathematics, integration efforts consisted of individual teachers integrating content, using systematic sequences of real-world examples for problem-solving. One of the teachers, for instance, collected examples of real-world problem situations involving mathematics from local business/industry and used them in her class.

Team teaching is another form of integration that is slowly taking place. A math instructor, for example, is collaborating with a technology instructor. Through co-op learning, they integrate mathematics and automotive technology to improve students' understanding of electronics and connections with science and mathematics. Occasionally, larger projects require various disciplines to collaborate. One project, "The Trail of Champions," involved planning and constructing a walking trail on campus, involving teachers from various disciplines (e.g., mathematics, English, and automotive/ engineering). Students participated in planning and designing of the trail, surveyed the site,

drew blueprints using CAD programs, budgeted costs, produced reports, and constructed the trail. Basic mathematics, geometry, trigonometry, English, engineering, and social studies were integrated into this project.

Professional Development

The "Linked" staff development model is particularly useful in promoting and maintaining a climate conducive for teacher collaboration. In this model, the five days of state required in-service time was converted to 44 hours, and the link between staff development and evaluation was emphasized. To properly focus professional development activities, fewer areas of improvement were targeted. Staff members were able to focus on areas for improvement they believed were feasible, manageable, and realistic in regard to personal or program goals. They can log 44 hours of inservice in various ways: collaborating with other teachers on integration projects, attending conferences, studying videos provided by the school, shadowing industry mentors, visiting workplaces, and so on. If a teacher logs hours for an activity such as working on developing an integration project, it is expected that the project will eventually be implemented in the classroom, rather than becoming a mere mental exercise. This model has allowed newer teachers, as well as those teachers who were "slower to come on board," to attend conferences, to work with peers who are more involved with integration efforts, and to learn about integration from a comfortable standpoint. The Associate Superintendent believes this inservice format to be particularly important because "when you have a school that's working on integration, every teacher may be at a different level of understanding about what integration is. You may still have that teacher who is struggling just to talk occasionally with the vocational teacher and integrate that content in some kind of a lesson, or you may have this teacher over here that's working with multiple teams." For those teachers further along in the process of collaborating on integration efforts, the flexibility and autonomy afforded by this model is ideal.

Scheduling

In addition to flexible and focused professional development activities, the school has implemented block scheduling to facilitate teacher collaboration. Under this scheduling strategy, teachers from different content areas can have common planning time during certain days of the week. For instance, the days of the week are marked as days A or B for scheduling purposes. On A days teachers from the same discipline meet while on B days

planning periods are scattered throughout the day so that, for example, there is a math teacher available as a resource for at least one person from every other area during the day. Because they may be working at different levels with integration, teachers need a flexible schedule to work together more confidently and to learn from each other. In addition to shared planning periods, teachers have access to an "idea board" in a common area. Instead of the customary weekly lesson plans reported to the principal, all teachers write general topical outlines of their weekly lesson plans on the idea board. All teachers are then aware of what content is being taught in other areas and can identify content that might coincide with and complement what they will be teaching at the same time. Lesson plans are often revised and/or adjusted to reinforce content across areas or to work together to formulate lessons and activities.

Institutional Climate and Support

Participating teachers attribute integration's success to two factors: (1) administrators' support and (2) the school's participation in initiatives such as SREB's High Schools that Work program, allowing them to meet other teachers and keep abreast of innovative practices. For instance, after an initial integration framework was conceived on the heels of the five-year plan and after participation in some of the initial SREB projects, some teachers became accustomed to working together. A couple of teachers reported how their collaboration got started: "We see each other a good bit, and we started doing a lot of modules with SREB and that was probably the big kick off. Then it just took off from there. We started working on some ideas during and after school: I would develop an idea and he would develop another one on the same topic and we would come together to compare and contrast until we came up with a project [or unit]."

Concurrently, the administration's support for experimenting with integration ideas has been integral to teachers' efforts. "We tell the faculty all the time, we want you to go out on a limb and if you fail, its OK," the principal stated. "If [the limb] happens to break, two things are going to happen: we're going to be on the limb with you or we're going to be under the limb to catch you, one or the other." Teachers working with integration echoed the sentiment, stating that the administration provides freedom to implement new ideas which were not available before restructuring efforts started. This type of institutional climate has invited teachers to create collaborative work such as "The Trail of Champions" project.

Further, being a part of initiatives such as High Schools that Work has afforded teachers the opportunity to find out what kinds of things are going on at other schools and to present to others what is occurring at SHS. When deciding which instructors will go to conferences, the Associate Superintendent believes that at least two-thirds of the instructors should be believers of integration and one-third should be reluctant people because "if you have two positives for every negative you can usually bring those folks along." This kind of institutional environment is reflected in the students' attitudes toward applied learning, which in turn reinforces teachers' motivation. Teachers at SHS reported that the student's involvement and enthusiasm are very influential in bringing other teachers onboard. As a result of teachers' different levels of interest and involvement regarding integration efforts, teachers integrating at any level are applauded for their efforts. They are taken to conferences to learn more about possibilities, and they are often held up as an example of what others should strive towards.

Mathematics Integration: Implementing the NCTM Standards

Although the mathematics program has been restructured and instructional practices have changed, full integration and use of the NCTM Standards has not yet been attained. Instructors reported that prior to restructuring efforts, there were general and college preparation mathematics courses and "the two could never cross." As one mathematics instructor recalled:

> I would go over homework problems for half an hour. Then you might have 10 or 15 minutes to go over new material. And then you would lecture and ask direct questions to see if they knew what they were doing. Textbook problems always came out with these nice neat little answers. And it wasn't right. Students were bored.

Students were not interested in mathematics, so instructors were charged with finding ways to hook students into an occupational context and "let them see why math was so important." As another teacher put it: "Math should have some focus on meaning. The theoretical concepts are useful and students need to understand that, but they also need to see where math is applied outside of the classroom and not just for math's sake." Presently, teachers are provided with related professional development opportunities, instructed to use the NCTM framework, and asked to focus on hands-on instructional practices. Teachers report that the NCTM Standards are embedded in their curriculum, instruction, and assessment. The primary emphasis is in using real-world contextual

applications, drawing on examples provided by local business and industry or based on ideas generated by teams of math/vocational instructors. Concurrently, problem-solving and the uses of technology are also emphasized. Finally, the school still uses traditional assessment measures such as multiple choice and true/false questions, but a trend toward portfolios and rubrics is gaining momentum. Teachers are becoming more open to using open-ended questions, discussion questions, and observation of how students work. Students are given credit for defining concepts, for showing their thinking process in seeking solutions, and for coming up with additional applications for mathematics concepts.

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