SCIENCE PROGRAM REVIEW AND EVALUATION

Internal Team Report

In preparation for a WW-P K-12 science program review, the internal team of teachers and supervisors met to discuss our role in this evaluation. We revisited our mission statements, compared our visions, brainstormed, and identified areas of strength. We also agreed on where to focus our efforts in the future. To support this district endeavor, the K-12 team has selected a graphic created by the National Research Council. We have borrowed the six elements of systemic reform from NRCO's publication*, Designing Mathematics or Science Curriculum Programs*. They roughly matched those from WW-P Board of Education's *Identified Components for Science Program Evaluation.* The elements of each are listed below.

WW- P Philosophy and Goals
Description of Instructional Content
Review of Research, Best Practices, and Current Standards
Analysis of Instructional Program
Assessment Data
Findings and Recommendations
Budget Implications and Guidelines
NRC/NSES
Goals
Standards
Instructional Materials
Teaching Practices
Professional Development Opportunities
Assessment Practices
NRC's graphic organizer shows the relationship between these components of systemic science reform.

Philosophy and Goals

District Mission Statement

The mission of the West Windsor-Plainsboro Regional School District is to ensure that all students acquire knowledge, skills, and attitudes necessary to realize their potential and become productive and responsible citizens of a changing world; this is accomplished by providing dynamic educational programs in partnership with parents and our entire diverse community within our unique academic, business, cultural and scientific environment.

Definition of a Science Program

Science, among other endeavors of human intellect, distinguishes itself because it operates under a set of universally accepted standards and rules. These standards and

rules allow us to understand how the natural world works. The art of questioning is of paramount importance. Consequently, an effective science education program must be inquiry-based.
Because people learn science best by doing science, science must be practiced. Students of all ages must engage in activities that mimic those practiced by scientists. These include but are not limited to: observing natural phenomena; recognizing patterns; predicting events; inferring relationships; asking insightful questions; testing predictions by designing experiments; collecting and evaluating data and communicating (both oral and written) data.

Science Mission Statement

The mission of Science Education in the West Windsor-Plainsboro Regional Schools is to develop scientific literacy and an understanding of scientific ways of thinking in all students, and to provide a strong foundation for students who may wish to pursue education and careers in science and technology.

Philosophy

Every student should have the opportunity for a quality science education, one that helps to develop scientific literacy and an ability to think critically. According to Science for all Americans, (Project 2061, p. xvii) this includes ". .being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes."
Benchmarks for Science Literacy (Project 2061, p. 322) states that a scientifically literate person is one "who uses the habits of mind, knowledge of science, mathematics and technology he/she has acquired to think about and make sense of many of the ideas, claims, and events encountered in everyday life.≤

In a world increasingly influenced by science and technology, it is essential that our program produce individuals that are capable of making well-informed decisions.

Description of Instructional Content

Elementary School

The West Windsor-Plainsboro K-5 Science Program shares the vision of the New Jersey Department of Education, the New Jersey Core Content Curriculum Standards, and the National Science Foundation. The goals of our science program are to provide all students with science experiences that develop their capacity to understand the natural world, cultivate habits of mind, and lead them to apply scientific reasoning and logical decision making to their daily lives.

To investigate interrelationships among disciplines, life, physical and earth science experiences spiral throughout the curriculum. Currently in the revision phase of our development, the curriculum will evolve to provide life, earth and physical science experiences each year.

In our K-5 life science strand, students interact with and observe the basic structure and function of plants and animals, noting their characteristics and adaptations. Observing student-created aquariums and terrariums helps students develop rudimentary systems of classification. In addition, students gain the knowledge needed to help in the identification of the needs of living organisms, as well as examples of interdependence found in sample ecosystems.

In physical science, students use a variety of materials to investigate the structure of matter. Through these investigations, they use physical properties to identify and separate materials. Students design experiments in which they observe changes in states of matter and record evidence of chemical reactions. Investigations in the physics of sound help to develop an understanding of the effect of vibration on volume and pitch. Working with electric circuits, students study the elements of a system, make changes to that system and develop their understanding of this form of energy.

In earth science, students observe weather, analyze changes and look for weather patterns. Working with rock and mineral samples, students continue to develop their ability to use physical properties in the identification of matter. In progressing experiences, students begin to understand the basic concepts of evaporation, condensation, and precipitation.

Infused through all science experiences are opportunities to develop scientific inquiry. Observation, data collection, and experimentation all develop an understanding that scientific investigations can take many forms. Investigations are framed in the form of a "testable" question. Students use tools such as calculators, thermometers, magnifiers, rulers, and balances to collect information. Students communicate science understandings through discussion, journals, and independent projects.

Middle School

The Middle School Science Program recognizes the need, in this highly technological and informational society, to provide students the scientific literacy necessary to reach their individual potentials in the field of science. To achieve this, we assist students in developing their ability to identify, understand, and use significant scientific laws, theories, and concepts and to develop problem solving and other life skills. The middle school science program reflects and supports the National Science Education Standards and the New Jersey Core Curriculum Standards.

Middle level science courses foster critical thinking, experimental design, and problem solving skills. This instructional approach is meant to actively engage students in investigating, discovering, and applying major science topics and concepts. Students are encouraged to work cooperatively, communicate their ideas through written, verbal, and graphic expression, and to utilize science to solve real-world problems. Instruction is varied to include a balance of discovery, group learning, and teacher-directed lessons in an attempt to address each student's individual learning style. The middle school program emphasizes basic scientific skills: observing and hypothesizing; collecting, illustrating, interpreting and reflecting on data; drawing conclusions. Middle school students use these elements of the scientific method to link together commonalities in earth, physical, and life science.

In keeping with the decision to connect life, earth, and physical science each year, the focus of the sixth grade science program is to use the properties of matter and characteristics of living things to see important themes, patterns, and connections in both the non-living and living world. For example, students conduct an in-depth study of density that they later use to explore such natural events as tornadoes and hurricanes. Their understanding of physical and chemical properties is further developed as they explore specimens from the different kingdoms in order to identify their characteristic properties.

In seventh grade, students follow the flow of energy through living and non-living systems. By studying interdependence within human bodies systems, various physiological processes are uncovered. Energy is revisited in the physical science unit where students investigate Newton's Laws and gravitational force and discover the relationship of energy, motion, and machines. Finally, the Grand Canyon provides the basis for the earth science strand where forces of nature and energy carved out one of the Seven Wonders of the World.

In the eighth grade, light serves as the important connecting element for all three science units. In physical science, students explore the behavior of light and apply their understanding to study vision and lenses. Later, they again use their knowledge of light to investigate our earth in space along with the other planets in our solar system. To complete the eighth grade year, we are considering such options as an independent problem-based unit.

In all three years, students are encouraged to pose questions, learn how to access information from a variety of sources, and gather data to draw justified conclusions. Close articulation between middle and high school science staff promotes attention to student needs.

High School

A comprehensive program focused on critical thinking, problem solving, and lab-based activities, the science program at WW-P high school engages students as active participants in learning science by doing.

The program includes a number of introductory courses, namely Biology, Oceanography/Meteorology, Chemistry, and Physics. These courses are offered on two levels, a college preparatory level and an honors level. Honors courses differ from regular college preparatory courses in terms of the level of expectations placed on students, the amount of independent work expected, the pace of coverage of content, the expected skill level, and the breadth and depth of the content covered.

At an advanced level, students may choose from Human Anatomy and Physiology, A.P. Biology, A.P. Chemistry and Modern Physics Honors. To enroll in these courses students need to fulfill prerequisites.

Four semester courses are currently pending curriculum development and Board of Education approval. These are Genetics, Descriptive Astronomy, Forensic Science, and Environmental Science. These courses will be open to any student who has completed 2 years of science at any level.

Course Description

Biology and Biology Honors

Grade 9-10: 5 credits

YR (meets 5 pds/wk)

Biology is a laboratory course designed to meet the needs of all students. The course of study stresses a qualitative analysis in three major concepts: The Environment, including studies of populations and interactions among organisms; Life Processes, including studies of cellular biology and systems of the body; and Species Continuation which includes studies of genetics, cell division, and evolution. Equally important to content is the development of critical thinking and analytical skills so important in doing and appreciating science. Such skills as problem solving, data analysis, inferring, communicating, observing, and summarizing are developed and evaluated. In addition to laboratory work, students will be engaged in using computer analysis techniques. Individualized support will be given to students as needed through a paired teaching model.

Oceanography / Meteorology

Grades 9-12: 5 credits

YR (meets 5 pds/wk)

Oceanography and Meteorology is a laboratory course designed to meet the needs of all students. Although this course is a study of the unique characteristics of the ocean and atmosphere, the curriculum develops essential concepts of chemistry and physics. In Oceanography, students complete laboratory activities that lead to an understanding of such topics as ocean profiles, cause of currents, current patterns, wave analysis, physical properties as a function of depth, tides, beach erosion, oceanic circulation and transport of sediment, chemistry of the ocean, ocean geology, and the effect of water masses on weather. In Meteorology, once again experiences with laboratory activities lead the students to an understanding of such topics as weather systems, climates, composition and dynamics of the atmosphere, water in the atmosphere, effect of land and water masses, life cycles of storms and tornadoes. Individualized support will be given to students as needed through a paired teaching model.

Chemistry and Chemistry Honors

Grades 10-12: 6 credits

YR (meets 6 pds/wk)

Chemistry is a laboratory course designed to introduce and explore inorganic, organic, and nuclear chemistry topics. Within these units, students will study matter, solutions, formulas, bonding, atomic structure, the mole concept, equations, and gases. General concepts are emphasized with real world examples, as the content is spiraled throughout the course. Laboratory experiments, problem solving and group activities are included.

Conceptual Physics

Grades 11-12: 6 credits

YR (meets 6 pds/wk)

Physics Honors

Grades 11-12: 6 credits

YR (meets 6 pds/wk)

Conceptual Physics is a laboratory course covering the topics of kinematics, dynamics, wave motion, and light. The course also introduces the student to electricity, electromagnetism, and modern physics concepts. The experimental method and problem solving techniques are utilized. In this course the major approach used in developing an understanding of the principles of the physical world is a thorough analysis of the conceptual themes of physics rather than the more mathematically rigorous Physics Honors course.

Modern Physics Honors

Grade 12: 7 credits

YR (meets 7 pds/wk)

This course is a study of physics of the 20th century. The course develops the content of the dual nature of light as students study such properties as thin film interference, diffraction, and the photoelectric effect.

Students then study the dual nature of matter that leads to the quantum idea, atomic structure, the Compton Effect, the electron, the Heisenberg Uncertainty Principle, and relativity. The next major unit of study includes condensed matter electronics and complex circuitry. The fourth major unit of study is nuclear physics including radioactivity, isotopes, nuclear structure, nuclear energy and forces, and applications. The final component of the course addresses elementary particles. Topics include classification, detection, analysis, and interaction forces.

Human Anatomy & Physiology

Grades 11-12: 6 credits

YR (meets 6 pds/wk)

This second year course is designed for students who may be interested in a career in health-related fields, and are interested in learning more about how the human body works. HA&P will review basic cellular biology, chemistry and the context of the overall levels of biological organization of the human body. HA&P will explore various body systems and investigate how they maintain homeostasis, as well as coordinate and control important physiological functions. In addition, students will have an opportunity to investigate human reproduction and developmental embryology. The course will include extensive laboratory work, library and electronic research, and guest speakers.

AP Biology

Grades 11-12: 7 credits

YR (meets 7 pds/wk)

AP Biology is a rigorous course meeting the same requirements found in a first year college biology course. This course is designed to give students an opportunity to study the biological and chemical aspects of cellular biology, Mendelian and molecular genetics, anatomy and physiology of plants and animals, evolution and environmental science.

Appropriate lab work as well as enrichment activities are included. Students are strongly encouraged to take the AP examination.

AP Chemistry

Grades 11-12: 7 credits

YR (meets 7 pds/wk)

AP Chemistry is a rigorous course meeting the same requirements found in a first year college chemistry course. Students will attain a depth of understanding of fundamentals and a reasonable competence in dealing with chemical problems. The course stresses the student's ability to think clearly and express their ideas, orally and in writing, with clarity and logic. This course differs qualitatively from the first year secondary course in chemistry with respect to the kind of textbook used, depth of topics covered, the emphasis on chemical calculations and the mathematical formulation of principles, and the kind of laboratory work done. Topics include: Atomic Theory and Structure, Periodicity, Chemical Bonding, Nuclear Chemistry, Gas Laws, Kinetic Molecular Theory, Solutions, Reactions, Equilibrium, Kinetics, Electrochemistry, Thermodynamics, and Organic Chemistry. Students are strongly encouraged to take the AP exam.

The following are semester courses pending Board of Education approval:

Forensic Science

Grades 11-12: 2.5 credits

SM

Forensic Science involves the application of scientific principles and analyses to criminal and other legal investigations. Students will utilize scientific concepts in genetics, chemical analysis, the laws of force and motion, and environmental relationships. Laboratory procedures from biology, chemistry, physics and earth science will be used to solve a variety of hypothetical crimes. Coursework will include group activities, problem solving, and laboratory work, outside readings, field trips, and guest speakers. After basic information and skills are learned, students will become involved with different activities or projects based on interest and ability. Individualized support will be given to students as needed through a paired teaching model.

Descriptive Astronomy

Grades 11-12: 2.5 credits

SM

In Descriptive Astronomy, students will investigate Earth's place in the universe by following the development of observations and ideas of the cosmos over past centuries leading to and including current thought. Topics to be studied include the Sun, Moon, Earth, planets, comets, stars, galaxies, black holes, and the relationship between science and technology. Attention will be given to the impact of astronomy on society. Some nighttime observing will be required. Individualized support will be given to students as needed through a paired teaching model.

Genetics

Grades 11-12: 2.5 credits

SM

This course will study the basic principles and concepts of genetics. Topics will include the structure and function of DNA, protein function, genes and chromosomes. Special attention will be paid to understanding modern genetics methods such as karyotyping, genetic testing, DNA electrophoresis, and the polymerase chain reaction and how each of these is used in modern genetic analysis. An additional segment of the course will be devoted to the techniques used in forensic science and paternity testing. A variety of laboratory procedures will be conducted that represent common methods used in genetic analysis. Labs will include DNA isolation and analysis, studies of cell division, and genetic crosses. Students will conduct genetic crosses using simple organisms such as bacteria, Drosophila, and the mustard plant to demonstrate simple patterns of inheritance. An independent research paper in genetics will be assigned to provide students the opportunity to purse their own individual interests. Suggested topics will include genetic engineering, cloning, gene therapy, genetic testing, and medical genetics. Individualized support will be given to students as needed through a paired teaching model.

Review of Teaching Practices and Current Standards

Teaching Practices

- West Windsor-Plainsboro teachers view science as an active process. Students are engaged in active exploration and investigation that make learning relevant and concept attainment more long lasting. *K-5, 6-8, 9-12*
- Teachers implement an inquiry-based science curriculum that promotes the use of critical thinking and scientific understanding. Students develop the abilities necessary to do scientific inquiry, including; forming and testing hypotheses, collecting, evaluating and communicating data, making predictions and drawing conclusions. *K-5, 6-8, 9-12*
- Teachers make science instruction real, relevant and motivating. Bringing real-life issues into the classroom, teachers take advantage of teachable moments and spark student interest. *K-5, 6-8, 9-12*
- Teachers observe and document students' interactions with peers and their ability to use materials effectively. In grades K-8, students work in heterogeneous cooperative learning groups to investigate and explore science concepts. Teachers modify and adapt the curriculum to meet individual learning styles and the varied needs present in any classroom. *K-5, 6-8, 9-12*

- Teachers reflect upon their instruction and look to improve their craft. Professional development opportunities include offerings through the district's Institute for Professional Development, $E=MC^2$ (elementary), Princeton's QUEST program and collegial shared activities such as individual building support meetings at the elementary level and department meetings at the middle and high school level. The coordination and sharing of equipment and expertise happens frequently as teachers visit their colleagues' classrooms. *K-5,6-8*

- Teachers strive to integrate the techniques of inquiry-based education into other areas of the academic curriculum. When possible, teachers look for opportunities to make connections between science and other content areas. In elementary classrooms, integration of reading, language arts, social studies, math and science occurs frequently. In middle school, an interdisciplinary approach, featuring a "team" philosophy and the use of curriculum mapping, encourages teachers to make cross-curricular connections. *K-5, 6-8*

- At the middle school level, professional collaboration within the science department and with members of the special services department has produced a cohesive team approach that ultimately benefits all students. Classified students are mainstreamed in heterogeneous classes where an inclusion teacher works with the content area specialist. *6-8*

- Assessment is varied and ongoing. Teachers use varied forms of pre-assessment to inform instruction. They take advantage of embedded opportunities to shape continuing experiences. Post-assessment tools, such as science journal entries, performance tasks, tests and quizzes, open-ended writing prompts and independent projects are also used extensively. *K-5, 6-8*

- Both teachers and students use technology (computer software, websites, Vernier hand held collectors, sensors and probes, calculators, thermometers, microscopes, electronic scales, DVDs, laser discs, CD-ROMS) for gathering, analyzing, and presenting data. *K-5, 6-8*

K-12 Standards

Science instruction at all three levels, K-5, 6-8 and 9-12 is carried out with attention to State and National standards. At the K-5 level, the development of the elementary science curriculum is an ongoing endeavor. To initiate science reform, a member of the American Association for the Advancement of Science trained the Elementary Science Curriculum Committee in the use of Benchmarks for Science Literacy (1993). The Science Curriculum Committee worked to align the NJ Core Curriculum Standards, the National Science Education Standards and the <u>Benchmarks for Science Literacy (1993) in order to select grade appropriate science modules. These modules are continually reviewed to ensure best teaching practices and alignment with state and national standards. As a result, the program has become more coherent and consistent. Also, science is taught more frequently and effectively.

When the New Jersey Standards were written and published, the middle school science department met during the course of the school year and over the summer months to align the curriculum, making sure that it addressed those standards. Later, when the sixth grade formally joined the middle school and after the elementary grades had received a significant grant for science reform from NSF, middle school science teachers again revisited the standards. This time, the staff examined the NSES as well as the <u>Benchmarks for Science Literacy</u> and again the NJ Core Curriculum Standards. A table was created comparing the three documents to determine omissions and possible gaps. In reviewing the K-5 program, teachers looked at patterns and themes, as suggested in the NSES. By identifying those units and standards already taught and found to be appropriate, relevant, and important, a more coherent sequence of major concepts, topics, and skills was created. Those documents are available as a separate addendum.

Teachers at WW-P high schools plan lessons and write curriculum aligned with the New Jersey Core Curriculum Standards as well as National Standards.

The high school science curriculum is rich in activities and experiences that correlate well with the NJ Core Curriculum Standards and accompanying "Cumulative Progress Indicators.≤ Whereas all courses offer these experiences, a few specific examples are offered below.

- In fulfillment of standard 5.1 Chemistry students alter conditions of chemical reactions to study the effect of these conditions on reaction rates.

- In fulfillment of standard 5.1.15 Biology students approach the study of photosynthesis by focusing on the structure and function of a leaf. Students test the affects of light intensity and CO_2 concentration on the rate of photosynthesis.

- In fulfillment of standard 5.6.13 Biology I Inclusion students supplement a comparison of living and nonliving things by using pictures of various animate and inanimate objects as a source of information to produce a list of qualities associated with the two groups respectively. Students group the statements and then classify them according to which corresponds with "living" and which with "non-living." Students rework lists into charts. The pictures are then moved into and out of the groups as a visual aid correlating the traits with the pictures.

- In fulfillment of standard 5.5.14 Physics students perform laboratory exercises relating force, mass and acceleration in which the students express these physical relationships in terms of mathematical equations derived from collected data. Students construct hypotheses as to how varying the mass and the force effects acceleration. They test these hypotheses experimentally and then derive Newton's Second Law from a graphical analysis of the relationships.

An assessment of how well the high school science curriculum aligns with the standards has also been accomplished. Through this evaluation teachers were able to see which standards are adequately met in the curriculum and which standards are not adequately addressed or missing. The High School Science Department will look to this assessment as it revises existing curriculum and writes the curriculum for new courses.

Instructional Materials

To comply with NSF recommendations, curricular materials were selected from the following sources, the National Science Resources Center (Science and Technology for Children, STC), the Lawrence Hall of Science at the University of California at Berkeley (Full Option Science for Students, FOSS), and the Educational Development Corporation (Insights). Other teacher-created materials are used to extend the modules at various times throughout the year, for example when the consumables are being refurbished. Other NSF-approved materials are also available and will be reviewed as elementary staff revisits earlier decisions to consider better alignment of the curriculum and the standards.

Middle School teachers followed similar guidelines in selecting new curricular materials. Such programs include Aries*: Astronomy-Based Physical Science* by the Harvard-Smithsonian Center for Astrophysics and the American Geologic Society's *It's About Time* series. Such materials will continue to be reviewed and considered for possible purchase and implementation in order to provide current and high-quality exploratory-based lessons.

At the high school level, teachers inventory laboratory materials yearly and supplement the existing equipment with new items as dictated by changes in the curriculum. These changes are driven by innovations and improvements in available science materials. In addition, teachers have accumulated a collection of quality models, laserdiscs and CD-ROMS for use in demonstrations, lectures and tutorials. Many teachers have incorporated PowerPoint presentations and Internet resources into their lessons.

Professional Development

Elementary School

Professional development in science has increased significantly in the last six years due primarily to a heightened awareness of and interest in science education. Having identified a strong need to improve the quality of the elementary science experience, early in the 1990s, a group of WW-P administrators and educators applied for and received a grant from the National Science Foundation. After collaborating with Ewing and Lawrence Townships, the three districts were awarded a $1.7 million grant to support professional growth in the area of inquiry-based science. Each district was responsible for the purchase and implementation of NSF approved curricular materials, maintenance of those materials, as well as community and BOE support. District committees piloted, examined, and selected appropriate materials.

In 1996, pre-implementation workshops began. Through the centralized services of the grants project coordinator, two-day trainings were held for teachers of all three districts. They came together to work through the lessons and to become knowledgeable about the science content. This successful protocol was followed for the duration of the grant. In addition, summer institutes were held for K-6 teachers. These workshops included the pedagogy related to best practices in education and specifically in science. Technology and assessment followed soon after in a second week of professional development. To date, there are three institutes, with the latest designed to strengthen content knowledge. Generic cross-grade topics were selected and presented along side appropriate instructional strategies. Participants focused on heat and electrical energy during the last two summers. By establishing these avenues for communication and collaboration, science education was most definitely enhanced.

In addition to these workshops, teachers participate in a variety of workshops led by lead teachers, mentors, and building coordinators. They also regularly attend professional conferences as presenters and participants.

To assure the continuation of professional development opportunities beyond the life of this grant, we have developed an elementary science offshoot to the WW-P Institute for Professional Development. For the past two summers, WW-P has led the way in promoting post-grant training. Although the grant has ended, funding from other sources has helped $E=MC^2$ to remain a viable provider of training. However, the district has established its own professional growth model. A core group of teacher-leaders, trained in effective professional development design will create and present kit-specific training for our novice teachers. For our more experienced teachers, sessions focusing on the development of meaningful enrichment activities and authentic assessment opportunities will be available. While content training is currently bolstered by the latest addition to the $E=MC^2$ institutes, WW-P has offered, and will continue to offer additional opportunities to expand the science understandings of our elementary staff. Additional opportunities to investigate inquiry strategies and propagate their use will also be available.

Middle School

In 1997, three seventh grade teachers were selected by the National Science Resources Center to participate in the field testing of new middle school curricular materials, STC/MS (a continuation of the elementary STC program). After one week of intensive pedagogical and content training, they returned to WW-P to implement the unit and provide feedback to the developers over the next three months. It was an important professional growth experience and provided the district with an excellent model, one to which we would return. In 2001, three teachers were again selected from hundreds of applicants to pilot a second round of modules. From the six pilot teachers, two were selected to serve on a national committee. The work at NSRC was an important milestone because it allowed us to take part in a science initiative taking place across the country. Our educators were recognized for their work and allowed them to chart WW-P's progress education. It also provided us with a model for designing our own professional development workshops.

In 1999, a second middle school, the Thomas R. Grover Middle School opened. This allowed WW-P to finally house students in grades six through eight under one roof. It was also an opportune moment to review the middle school science program. With our clients arriving having had a significantly different science experience and approach to learning, it behooved middle school educators to examine both instructional content and process. Therefore, professional development in science was once again spotlighted.

In October 1999, a team of middle school teachers and administrators attended the NEXT STEP Institute in Nashville, Tennessee. Over a five-day period, they met with other professionals from around the country to exchange and share experiences and visions for the future of middle school science. Teams met to plan strategically and design long-range plans to be implemented over a three to five year period.

Over the course of the next school year, members of the science department met to review the standards, and to identify their needs and preferences for the first summer of professional development workshops. In July 2000, staff and guests from neighboring districts, worked with a national science consultant to explore the practice of hands-on, minds-on science based on common themes in physical and earth science. Teachers requested it to be repeated the next summer.

Following each of those weeklong workshops, representatives from each grade level met to begin writing a draft curriculum document to reflect revisions. Simultaneously, several middle and high school teachers formed a committee to continue articulation that began in 1999. Members selected lab skills as an area to promote conversation and agreement. They identified standards and expectations. Articulation and collaboration were so successful that staff asked to work again during the summer to create a working, teacher-friendly document outlining important skill expectations for students in grades six through twelve. Over the next two summers during professional development, the group produced a document clearly outlining the results of their work including essential skills for each grade level and how to use a lab journal. Teachers report positive gains from using these guidelines and request additional opportunity to continue this work. Recently, a K-8 Articulation Committee was formed with the goal of aligning curriculum and building skills and content from year to year.

High School

High school science teachers regularly attend professional conferences both as presenters and as participants. For example, two of our teachers are attending the Science Specialty Conference hosted by the College Board. Many teachers participate in the NJ Science Convention and discipline-specific conferences throughout the year, mostly on their own time.

WW-P has an in-house Institute for Professional Development. Teachers are encouraged to present courses for their peers as well as participate as learners for professional development hours. These activities take place both during and after school.

Tenured staff may opt for alternative assessment measures in lieu of traditional classroom visitation reports. Teachers choosing this option must write a proposal for engaging in a specific professional development activity. For example, two of our chemistry teachers plan to do a comprehensive survey of Web Sites that will be helpful in the teaching and learning of Chemistry.

WW-P high school Science teachers hold memberships in numerous professional organizations such as the Biology Teachers Association of New Jersey, the National Association of Biology Teachers, the New Jersey Science Teachers Association, the National Science Teachers Association., the American Chemical Society, the American Association of Physics Teachers, and the Earth Science Teachers Association.

WW-P science teachers are heavily involved in after-school enrichment activities. A partial list follows: Science Club, Environmental Action Club, Academic Decathlon, New Jersey Science Olympiad, Merck Science Day, Delaware Valley Science and Math Competition, National Chemistry Olympiad, and National Physics Olympiad.

Assessing Our Own Needs

The members of the WW-P internal team consider the process of a program review to be an outstanding professional growth opportunity. The chance to come together with a group of highly qualified experts to share visions, document strengths, and identify needs is both valuable and appreciated. This part of the report concludes with a summary of short and long-range goals, most of which have been identified over the past two years.

In trying to keep up with the incredible pace of WW-P's growth, we omitted important first steps in program development. Therefore, our first priority is to design and write a coherent and rigorous curriculum for all grades. We know that in order to accomplish this we must continue to articulate and map the standards, comparing what we have addressed so far with what we are missing. We must also continue to refine units to better support the "less-is-more" philosophy. We feel that in some areas, at certain grades, we have "too much on our plates."

Following the alignment of units in grades five through eight, we must revisit the selection of materials to support the written curriculum and the proper management of those materials. We recognize that the "third party" procedures currently in place may not be the most effective way to refurbish science materials used in elementary classroom. We also hope to move "beyond the science kit" by promoting more open-ended investigations. We have talked about the value of problem-based learning. With the new Plainsboro Preserves and Audubon Society facility, we have an outstanding resource in our backyard that will enable our learners to identify local issues and explore alternate solutions through hands-on investigations. We must make these 500 acres an extension of the classroom.

Content background and training, as well as authentic assessment strategies for teachers should continue to be provided by way of workshops, seminars, visiting professors, and university-level courses. The integration of technology into our program is also of top priority.

Middle and high school staff members want to continue to work on competencies for science students. This successful connection allowed the committee to create a usable set of guidelines for which teachers are appreciative. To know what is expected of students as they enter high school and what they experienced in middle school has proved to be a valuable tool. Elementary level teachers would like the time to go through a similar process.

High school science teachers are keenly aware of the limitations that the lack of a double period for laboratory activities in Biology and Oceanography/Meteorology imposes on these programs. The high school Science Department is anticipating the day when a more creative schedule will allow for these courses to enjoy the same laboratory status as Chemistry and Physics.

Finally, we are most anxious to study assessment techniques that will allow students to demonstrate in meaningful ways how they have grown and benefited from the WW-P science program. We must identify ways for our pupils to communicate their knowledge and understanding. At the same time, we must find ways to internally assess and evaluate our successes and future needs. It is essential that we find out, as best we can, if we are coming as close as possible to truly meeting the needs of every child in our district.

External Team Report

The West-Windsor-Plainsboro School District is an exemplary school system. It is justifiably proud of its enthusiastic and well-trained teachers, dedicated supervisors, superb facilities, and eager, bright, and articulate students. Five years ago this district took a major step in the systemic reform of its science program by introducing hands-on instructional materials in every elementary classroom. Major changes followed at the middle school level, and these are leading high school teachers to consider the tension between their traditional curriculum and the challenge of providing "science for all≤. The administration’s goal is to create a world-class science program, and to that end, the external team was invited to the district to observe the program and report on its progress towards "world class≤ status. The district is to be commended for its pursuit of this ambitious goal and for initiating this review as part of that process.

WW-P made an impressive start towards a standards-based, world-class program. Elementary science students now engage in hands-on/minds-on investigations using developmentally appropriate instructional materials. The recent changes in the middle school curriculum appropriately build upon the concepts and skills students acquired in the lower grades and maintain an emphasis on learning science by doing science rather than reading about it. High school and middle school teachers are collaborating to articulate skills. The district's substantial investment in professional development has been an important factor in all of these recent advances.

It is tempting to dwell on these successes and describe the many outstanding classes that the external team observed during recent visits. There is substantial evidence of excellence within the district and of its capacity for further growth. However, the administration's charge to the external team is not to describe the current program but to compare its features to those of world-class programs and to frame recommendations that will guide the district's next steps toward its goal. This charge is the focus of the following.

Introduction

In January 2002, Mr. Gary Reece, assistant superintendent for Curriculum and Instruction, convened a team of consultants from outside the district (the external team) to observe and report on the K-12 science program. He asked the team to compare the programs essential features to those of a world-class science program and to examine specific areas of interest to the school board (Appendix 1). At the same time, an internal team of science teachers and supervisors was appointed to collaborate with the external team, sharing with them an overview of the recent history and current practices in the science program. The internal team contributed to the report by writing sections on the philosophy, goals and instructional content of the science program. The external team's portion of the report summarizes its impressions, lists specific findings and offers recommendations to guide the district in developing its own world class vision and implementing it.

Background

This review occurs at a time when the science program is in flux. Five years ago, with funding from a National Science Foundation, the district initiated a standards-based, inquiry-centered elementary science program. In many cases, this new program brought science into elementary classrooms for the first time. The keystone of this initiative was professional development of the K-6 faculty preparing them to use newly purchased science kits containing the instructional resources for hands-on lessons. As this report will describe, the elementary initiative produced many outstanding science teachers with the vision and passion to inspire young students. Some of these teachers are now teacher leaders in the district and around the state. One of the district's current challenges is to help new teachers and some of the veteran teachers still wedded to traditional pedagogy achieve the high standards established by the leaders. The district's first full time elementary science supervisor took the helm in September 2001. Coming from the faculty ranks, he has experienced the growing pains of this science reform, is committed to its goals, and is skillfully moving the program forward.

During this same five-year period, the district has grown rapidly in student enrollment and faculty size. A second middle school and a second high school opened to accommodate the increasing numbers. A new elementary building will open in September 2002, and other elementary buildings are being reconfigured to extend teaching space. Three years ago, as part of the district reorganization, the 6th grade moved from its elementary school affiliation to become part of the middle school. At the same time, a new middle school science supervisor was appointed. She, too, came from the teaching ranks and was committed to changes that would align the program with the New Jersey Core Content Standards and embrace the inquiry-centered approach of the elementary curriculum. Under her leadership, the program began a transformation from a traditional one-science-each-year approach to a spiraling curriculum. Newly released instructional materials, some of which were field-tested in WW-P middle school classrooms, form the core of this program. Like its elementary counterpart, it is experiencing growing pains. Teachers, not all of whom are committed to the changes, are in the process of adjusting to new materials, the inquiry pedagogy, and the need to develop content expertise in other areas of science. Judging by the elementary school experiences, this period of adjustment will last for quite a while.

The high school is experiencing change as well. Five years ago when the second building opened to accommodate the burgeoning student population the faculty was split between the two campuses, and many still talk longingly of the collegiality that characterized their former professional lives. The high school course offerings are traditional in design; there are yearlong courses at the introductory, honors, and advanced levels in biology, chemistry, and physics. The department also offers interdisciplinary courses such as physical oceanography. The high school science department has not restructured any of its offerings in response to the program changes in the lower divisions. The new secondary science supervisor assumed his post just days before the external team arrived. His efforts and spirit of cooperation on behalf of this review are therefore all the more praiseworthy and have been all the more appreciated.

The external team is viewing a science program in various stages of change. While this report reflects the range of stakeholder responses to these changes, its central purpose is to examine the existing program by world-class standards. We have observed several teachers who already function at world-class level, others that are struggling to understand that vision, and a few that are adamantly opposed to it. The supervisors, teachers, and many of the administrators are aware that change is a long-term often-painful process, and the district is only partway through it. The supervisors already have an agenda for addressing some next steps in the change process. Professional development is planned this summer to work on a middle school written curriculum and to reflect on the instructional materials that were introduced last year. Elementary teachers are examining new kits that will help them meet some of the NJ standards not currently addressed. Developing better assessments is a major focus at the elementary and middle schools. While individual high school teachers offered their views on program needs, they are waiting for their new supervisor to become more familiar with the current programs and assume a leadership role in the change process.

Methodology

The external team visited WW-P several times between late February and mid April 2002 to meet with the internal team and focus groups of faculty, parents, students, administrators, and school board members (Appendix 2). The students were particularly candid about their classes, their teachers, and the classroom experiences that had the greatest impact on their science learning. The external team visited each building in the district and observed ten to fifteen classes in each division. Often team members were able to talk to teachers before or after class about their goals and impressions of the science program. External team members interviewed several teachers, principals, supervisors, and other administrators to collect specific information about issues such as administrative support for the science program, course selection procedures for 8th grade students, grading policies, and scheduling issues at the high school. Team members also reviewed documents including the High School Program of Studies, the NJ School Report Card, the school board polices with respect to curriculum and technology, drafts of miscellaneous curriculum documents, and course descriptions provided by the supervisors. This report is based primarily on the information gathered during the classroom observations, focus group meetings, and individual conversations.

The focus group sessions were guided by a question protocol (Appendix 3), although discussions often went beyond these questions driven by the interests of the participants. When less than half of the team was present for an interview or focus group, detailed notes were written and shared with others. All team members used a standard observation protocol to document their classroom observations (Appendix 4). This format enabled the team to identify patterns in instructional style and content. During each visit to the district, the external team reserved time to meet, share their findings, and identify the additional information and potential sources needed to clarify their impressions.

The external team identified characteristics considered essential to a world-class science program:

- a coherent, standards-based curriculum
- instructional practices aligned with the curriculum
- an on-going professional development program
- an assessment plan aligned with the curriculum and used to monitor both student learning and the program
- policies that support the district’s vision, providing structure and a commitment to the program, and establishing accountability guidelines
- a technology plan that supports the program
- evidence of equity in the resources and learning opportunities provided to all students
- stakeholder support of policies and practices and involvement in decision making

These characteristics are drawn from the National Science Education Standards and other publications that elaborate on the vision of the standards. (1-6) The report will address the first six characteristics in separate sections, each consisting of an overview, findings, and recommendations. Where there are substantial differences in practices between the three divisions, the relevant section addresses each division separately. Equity and stakeholder involvement issues appear in each section. The areas of special concern to the school board have been woven into this format. Effectiveness of organizational support is addressed within the policy section, and to some extent under curriculum, instruction, and professional development. The issue of coherence of the K-12 program is discussed in sections on curriculum and instruction.

Curriculum

Overview

The call for reform in science education can be traced back to the early 1990πs when the recognition of a growing need for a scientifically literate society along with a technologically literate workforce led to a flurry of reports addressing and documenting this concern. Foremost among the initiatives that followed was the drafting of curriculum and program standards by two prestigious organizations, the National Research Council (1) and the American Association for the Advancement of Science. (2) The efforts of these organizations helped to define quality science education and have had a profound effect on what and how science is taught in schools across the nation.

Closer to home New Jersey's attempt to develop content standards coincided with reform activity at the national level. In May of 1996, New Jersey adopted Science Content Standards that addressed its unique needs while clearly reflecting the national movement. Since their adoption New Jersey's Science Standards have been recognized as among the finest in the nation. They are lauded for, among other features, the balance they present between science content (what students should know) and science process (what students should be able to do) -- a balance that must be retained at all grade levels in any quality science program.

Having already established a tradition of excellence as one of New Jersey's premier school districts, WW-P should offer a comprehensive K-12 science program aligned with, if not exceeding, state and national standards and delivered to all students at a consistently challenging level commensurate with their abilities. The external team met with teachers, students, parents, and administrators and visited classrooms to collect information about the district’s success in delivering quality science instruction to all students and providing the resources and facilities that allow all students to "learn science by doing science.≤

As of this writing, while energetic attempts to articulate the science program and move it to new heights of excellence are underway, the defined program at all levels - elementary, middle grades, and high school - remains unsettled. While several documents that collectively address components of the K-12 science program were made available to the external team, there is an overriding need for a cohesive, written, standards-based curriculum as required by policies of the district Board of Education.

Elementary Grades

The K-5 science curriculum is centered on a collection of science kits, procured by the district after receiving a grant from the National Science Foundation or, in one case, developed by teachers within the district. The kits were selected from among several programs endorsed by the National Science Foundation. While the kit materials can encourage critical thinking and help students develop content knowledge and investigative skills, these outcomes depend upon teachers who are well trained in content and pedagogy. The inclusion of the kits in the WWP science program presents an opportunity for high quality science instruction. But the kits are instructional materials; they are not a curriculum. It is doubtful whether the present reliance on selected kits is providing comprehensive coverage of the standards.

The arrival of the kits marked a renewed emphasis on science instruction at the elementary level. By naming an elementary science supervisor, the district reinforced its commitment to elementary science and assured its continuing priority status. However, many teachers, particularly at the primary level, reported that science time is not blocked into their daily schedule. Some juggle other subjects to create enough time for a hands-on lesson; others skip science or alternate it with social studies. The district, as part of its commitment to science, must address this scheduling pressure, rather than leave it to the resourcefulness of committed teachers.

Three kits have been assigned to each grade from 1st to 5th and serve as the primary resource for the teaching of three science units each year. In most cases, the units adhere to a pattern of three "strands', life, physical, and earth/space science in each grade. The kits are collected, replenished, and rotated among teachers on a regular basis.

The kindergarten science program is less well defined. With the support of the administration, the teachers have rejected kits, believing that these materials are inferior to those the schools purchase on their own and time is too limited in kindergarten to include a formal science program. In conversations with kindergarten teachers, it was clear that they are committed to teaching science. Teachers follow an informal curriculum but do teach the same topics in every classroom.

For the most part elementary teachers now see the kits as the whole of the prescribed elementary science curriculum in grades. Teachers accept the importance of teaching science as inquiry, but many believe that an over reliance on the kits has led to an imbalance between the teaching of science content and science process skills. Many upper elementary teachers expressed the need to supplement the prescribed units with content oriented resources. The main topic at the focus groups of upper elementary teachers was the need for a written curriculum to help them understand what is important in each kit and how the kits fit together.

In a companion document to the National Science Education Standards entitled Selecting Instructional Materials (9), the following statements appear:

"Importantly, although the Standards stress inquiry-based teaching, they do not assume that all science can be learned through an inquiry process, given the amount and diversity of science concepts that should be learned."(p. 6)

"In addition, instructional materials affect the science program indirectly by influencing stakeholders in the greater community. For instance, parents use the content of the student's materials or textbooks to examine what their children are learning. Often the sole link to the classroom, these materials can determine whether parents support or object to the school science programs." (p. 8)

Many teachers reported that the kit topics are often rushed or interrupted to meet the kit rotation deadlines. Teachers and principals stated that replenishing the kits exhausts whatever monies are available for the purchase of science supplies. As a result, there are few standard science teaching materials, such as balances and hand lenses, available in elementary classrooms. Teachers expressed their desire for supplies that would allow them to take advantage of "teachable moments'. What science is taught during the 2-3 week intervals between kits is ill defined and left to the discretion, interest, and resources of the individual teacher. At least one teacher admitted that she had chosen not to use a kit at all.

Most of those attending the parent focus groups were parents of elementary students. Their resounding message is that a child's science experience depends on the child's teacher. There is wide variation from classroom to classroom, and some children have very little exposure to science. Many parents showered praise on individual science teachers, and others who came to express complaints listened with envy. While parents voiced enthusiasm for the kits and for hand-on science, they seemed to have little awareness of the content addressed at each grade.

Middle School

Two years ago the middle school science curriculum began a transition toward spiraling program with units in life, physical, and earth/space science in each year. The program was to be centered on recently developed middle school kits and emphasize the inquiry approach. These changes were initiated, in part, to introduce more hands-on/minds-on investigations into middle school classrooms, to assure that all students received comparable standards-based learning experiences, to achieve consistency across science classes at the same grade level, and to develop coherence from grade to grade[8]. The program is clearly a "work in progress".

The 6th grade teachers came to the middle school from a kit-based elementary program; they are embracing the changes and are enthusiastic about the three kits selected for their grade. The 7th grade has always had an overstocked curriculum, a situation that is not relieved by the three kits selected for their grade but should be addressed when a curriculum is drafted. Some 7th grade teachers told the external team that they are concerned about the rigor and appropriateness of their kits. Not all of the 8th grade kits are selected at this time, but the ultimate choices will be governed by the vision of a coherent, spiraling, standards-based curriculum. At a focus group of 8th grade teachers, several expressed the opinion that the new program has compromised the rigor of the former middle school earth science offering. Their concerns should be addressed in meetings of the entire middle school faculty and weighed against the opinions of teachers in other grades. When a written curriculum is completed and approved by the school board, its delivery will be the responsibility of all teachers.

The external team met in several focus groups with middle school students. They communicated their strong preference for hands-on science. They grumbled about 8th grade classes devoted largely to lectures and note taking. 7th and 8th graders described the grade-wide solar car investigation as the highlight of middle school science. The kits received mixed ratings from the students. As they talked with one another, they decided that their likes and dislikes are not governed by the science topic but by particular teachers who are able to make science topics interesting and relevant.

There is currently no middle school science curriculum document. Essential concepts to be taught at each grade level have yet to be finalized, and, as of this writing, topics to be taught in eighth grade science for the last quarter of this school year had not yet been determined. A starting point for the curriculum document could be the skills array developed by the grades 6-12 articulation committee. It provides a meaningful, standards-based framework for curriculum development and suggests a foundation for articulation between high school and middle school offerings.

The middle school is now facing some of the same kit-related issues seen in the elementary school. These include impact of tight schedules for sharing the kits on the science program, the need to mold the kit investigations into a coherent curriculum, and the need for additional content-rich instructional materials. Middle school teachers expressed a greater concern than elementary teachers did about the need for strong content in their courses. Some teachers are already working on kit modifications that will improve their alignment with standards-based content. In focus groups, 8th grade teachers expressed dissatisfaction with the kit materials, finding some supplies inferior and/or inappropriate for use at their grade level.

High School

The science program at both high schools offers an impressive array of full year courses in life, earth, and physical sciences taught in spacious classroom/laboratories for 5, 6, or 7 forty minute periods each week. Additionally, as of this writing, four new semester-long courses have been proposed for school year 2002/03 - Environmental Science, Forensic Sciences, Descriptive Astronomy, and Genetics.

Ability grouping at the high school results in courses being offered in three "tiers," First

Tier Survey Courses, Honors Courses, and Second Tier Science Courses which include AP Biology, Modern Physics, and AP Chemistry. The honors and advanced placement courses are "weighted" for purposes of calculating student's Grade Point Averages (GPAs). Admission to some courses ostensibly requires teacher recommendation, although parents invoking a readily available "override≤ option can set that recommendation aside. The override option was a major topic in focus groups with high school teachers and students. Students described the override as a way to maneuver into a class with a preferred teacher or to be with close friends. They also talked about the importance of the weighted grades in honors courses on their GPAs. Teachers have a different perspective. They are concerned about students who enroll in courses for which they lack the essential skills, prior knowledge or discipline and then struggle to succeed or complain about the difficulty of the course. From the perspective of one administrator, the override is an invitation to students to challenge themselves to the maximum.

Although a wide array of courses is available, students are not always directed to a sequence of courses designed to complete a standards based science program. Such a standards-based sequence is particularly critical for a small percentage of students that could be considered at risk of failing the science component of the HSPA. Current practices allow students to enroll in selected science courses at the expense of a comprehensive science education. For example, Human Anatomy & Physiology, AP Biology, and AP Chemistry are all available to students who may never enroll in a physics course.

Samples of course guides were available for review along with other documents that suggest an alignment between courses of study, state and national standards, and test specifications for New Jersey's High School Proficiency Assessment (HSPA). Most classroom observations indicated that the taught curriculum varies significantly from that described in the course guides. As with the other divisions, the high school lacks an updated written curriculum that is aligned with the standards and guides day to day instructional practices. But for a few exceptions, in which small groups of teachers find a common meeting time, there is little coordination between what is taught from section to section of the same course. Based on the external team's classroom observations there is substantial variation in the rigor of high school science courses. Students spoke about this candidly when comparing biology (too demanding) to physical oceanography/meteorology (not very demanding).

Based on the samples available for inspection, high school science course guides are in need of revision. The biology guide, for example, was last revised in 1995 the year before the state adopted core content standards. Another curriculum document entitled "Biology and the Standards - 1997"appears to be an attempt to align the course with state and national standards but its format would not be understood by anyone who was not intimately familiar with the standards and benchmarks. Likewise the articulation matrix completed in the summer of 1999 keying course content to HSPA specifications exists as a separate document presenting meaningful information that should be incorporated into an updated, revised curriculum guide.

The ninth grade biology course was a major discussion topic in focus groups with high school teachers, students, and parents. From the teacher's perspectives, there isn't enough time for labs and laboratory supplies are not consistently available in all classrooms. Students described the transition from the 8th grade earth science into high school biology, particularly honors biology, as culture shock due to the abrupt shift in topic and increase in the amount and intensity of the work. Some students attributed their problem, in part, to the biology course's emphasis on lectures, and others reflected that studying life science more recently than 7th grade would have helped them. Parents acknowledge that the biology courses are very demanding and lecture-dependent, and yet they encourage their children to take honors biology realizing that it is a gateway to other advanced course offerings in the science program

The science faculty includes a large number of newly hired teachers, some just entering the profession. As a group they spoke of seeking more guidance and structure and needing more time to meet with colleagues who teach the same course.

Findings

- The existing curriculum documents do not adequately describe what is taught in many classrooms.
- At the elementary level, the teacher's guides that accompany the kits have become the de facto curriculum. The middle school is in danger of following that path.
- The current system for replenishing and rotating the elementary kits has a disruptive effect on the continuity of science instruction. This system also creates problems with respect to logistics and budget.
- There are large inconsistencies in the delivery of science program. At all levels, instruction (content and pedagogy) varies significantly from one teacher to another at the same grade and within the same course.
- Some teachers with concerns about their kits do not feel there is an appropriate forum for reviewing and revising kit selections.
- There is no prescribed sequence of required coursework in the high school to insure that all students acquire a comprehensive standards-based science background.
- There is substantial variation in the rigor of high school science courses.
- 9th grade biology classes have few hands-on experiences because scheduling difficulties limit their laboratory time.

Recommendations

- Prepare comprehensive, coherent, standards-based written curriculum documents for each level of the science program. The science standards, rather than the kits, should be used to identify the central concepts taught at each grade. As stipulated in district policies, the curriculum documents should include objectives and suggested activities (not just those associated with the kits) and be keyed to New Jersey's Science Content Standards. The curriculum documents are essential to insure consistency of implementation and teacher accountability.

- Plan more articulation meetings to insure that the curriculum is coherent in content and skills across the divisions of the district.

- Provide additional instructional material the current upper elementary kits or replace them with kits that offer a stronger content base.

- Review the middle school kits to determine whether they provide adequate content. If not, investigate additional content-based instructional

- Provide sufficient financial support to improve the current kit refurbishment system, which is both costly and inefficient. Providing the kits to teachers on a more flexible schedule will allow teachers to make adjustments when necessary to accommodate schedule variations and to take advantage of "teachable moments".

- Provide a forum for soliciting widespread teacher support when selecting units of study.

- Examine course offerings at the high school and revise those that do not offer the rigor appropriate to a secondary level course.

- Investigate more flexible scheduling patterns at both the middle and high school that will allow extended blocks of time for experimental work. It is important that the district pursue more innovative solutions to its current scheduling problems.

- Revise and update high school course guides to assure alignment with the standards.

- Insure that all students at all ability levels enroll in courses that will expose them to all sciences. An exceptionally talented student population, prestigious college acceptance rates, or 100 percent pass rates on statewide assessments does not relieve the district of its responsibility to pursue this objective.

- Develop sequences of high school course offerings that will insure all students a comprehensive science background in satisfaction of the standards.

- Examine the admission requirements and pre-requisites for high school courses looking at both the practice of and the causes for overrides. This review should be part of an overall study of placement procedures and policies. Admittedly this is a politically sensitive issue. It calls for parent and student aspirations to be weighed and course content to be reviewed. The district must also examine its responsibility to place students in courses commensurate with their ability. Policies should be clarified and shared with stakeholders.

- Convene groups of students to provide feedback about the science program and be aware of this important perspective in writing the curriculum and making decisions about instructional materials.

Instruction

Overview

Inquiry is an approach to learning that involves a process of exploring the natural or material world that leads to asking questions and to making discoveries in the search for new understanding. Inquiry, as it relates to science education, should mirror as closely as possible the enterprise of doing scientific research11. In inquiry-based instruction, the teacher creates a learning environment that emphasizes student-centered, hands-on/minds-on activities. (10)

Elementary Grades

In the elementary grades, teachers use science kits that are intended to promote inquiry-based instruction. However, each teacher's own management style and implementation strategies determine the degree to which a true inquiry approach is achieved. According to the external team's observations the elementary classes were, for the most part, developmentally appropriate and engaging to students. In a few cases, teachers introduced concepts or vocabulary that were beyond the comprehension of young students. Most elementary students appeared comfortable with the hands-on nature of the activities, the role of the teacher as a guide, and the procedures and dynamics involved in working in cooperative groups.

Elementary teachers used several strategies to engage students in their lessons. In many cases, the teacher began the lesson by referring back to a previous related lesson, and activating the students' prior knowledge. For example, in a first grade lesson on measuring the temperature of a mixture of hot and cold water, the teacher began by asking the students what had happened to the liquid in their thermometers during a prior lesson measuring hot or cold water separately. Teachers also engaged students by relating the lesson to a familiar real world situation. For example, in a primary lesson about weather, the teacher and students examined their weather chart, and discussed what to wear on a rainy day. The discussion proceeded from clouds to rain, to umbrellas, and then to materials from which umbrellas and children’s clothes are made. In the lesson, students tested various fabrics and rated which would make the best umbrella. In a fourth grade lesson on series and parallel circuits, the teacher engaged students by discussing previous wiring experiments, and relating circuits to traffic jams in the school corridors. A third strategy used for engaging students involved challenging students with a problem to solve, often involving an unknown.

Elementary students were encouraged to explore the topic under study by working in pairs or small groups, making and testing predictions, and discussing their observations with their peers. In many cases, the teacher provided minimal direct instruction during the activities, and circulated through the classroom asking the students questions about what was happening. Teachers implemented various degrees of structure in the activities. Most classes simply followed specific procedures in conducting their investigations, while others had some latitude in determining procedures. For example, in a first grade lesson on measuring water temperature, the student groups determined their own proportions of hot and cold water to mix and measure the temperature. The teacher displayed their proportions and resulting temperatures on a class data chart on the board, and students made predictions about the temperature of their mixtures (e.g., "I think it will be between hot and cold.").

Students explained what they were learning by discussing results with their peers, reporting to the class, or making entries in journals. Additionally, teachers commonly circulated through the classroom and asked students to explain their observations and outcomes.

In several classes, the external team observed teachers extending the lesson beyond the kits. The fourth grade lesson on electric circuits went beyond the kit by introducing a motor and challenging students to construct a circuit that would make it work. The familiar single battery circuits were not adequate, and students gradually discovered that they had to use two batteries in series to be successful. Other examples of extensions involved teachers asking thoughtful and probing questions to specific groups of students. However, few teachers are moving beyond the structure of the teachers guide and introducing relevant, developmentally appropriate standards-based investigations that will emphasize the important concepts, make a kit more relevant to students, and create opportunities for students to design their own experiments.

Reflection and evaluation of the lesson by students was the weakest area in elementary classrooms. When time allowed, elementary students reflected on what they were learning while sharing their observations with the whole class during a wrap-up of the lesson. However, there was not always ample time for adequate reflection and evaluation. One teacher remarked that her 40-minute class time limited the effective implementation of investigations, because the tasks take longer than the allotted time period. During focus group discussions, primary teachers frequently mentioned lack of time to teach science. Some talked about creating extra time by incorporating science topics in reading and writing activities. Others responded to the time issue by teaching just a few lessons from the kit or by teaching no science at all.

Classroom observations revealed little differentiation of instruction. Informal differentiation did occur when teachers worked with specific students or groups who were struggling with the activities. In some classrooms, a support teacher was present to assist some children with special needs. In most cases, all students engaged in the same basic activities, and produced the same outputs (e.g., data tables, lab sheets, written questions).

Middle Grades

The external team observed middle school teachers using the inquiry method with varying consistency. For the most part, activities were engaging to students, and the content and processes were developmentally appropriate. However, as in the elementary grades, middle school teachers were more adept at the engage and explore components of the learning cycle than the extend and evaluate components.

Middle school teachers engaged students with a variety of strategies. In a 6th grade lesson on continental drift and catastrophic events, the teacher engaged students in thinking about mental models. The cars and incline planes they were using to collect data engaged a class of 7th grade students. Another 7th grade teacher "hooked" students with key questions about the material they would be learning in the lesson.

The external team observed several examples of effective exploration by middle school students. Two seventh grade teachers teaching about incline plane encouraged students to try different approaches to the experiment, which deviated from the original lesson. In their small groups, the students discussed their approaches and resulting outcomes. In some cases, students were encouraged to explore a topic or phenomenon without guidance from the teacher. Although it appeared that the teacher was attempting to be the "guide on the side" rather than the "sage on the stage," some more interaction and guidance from the teacher would have been appropriate and beneficial. This behavior was an indicator of some teachers misunderstanding of the inquiry method.

In focus group meetings, middle school students talked about the value of hands-on activities. Students stated that their interest and applicability vary by teacher. Students felt that they would prefer more hands-on work and that less time should be spent listening to lectures and copying notes. An eighth grade student remarked, "We do lots of whole group experiments. We sit at our desks and the teacher does the experiment. We skim lots of things quickly, and then we forget. We used to do more hands-on.≤ Another eighth-grader responded, "We want more projects and more hands-on. There’s no point in doing an environmental science project where we stay in the class and do research and never go outside into the environment.≤ Seventh grade students felt that their geology unit was too long and too repetitive. In contrast, the human body unit, they felt, was confusing because there was not enough time to cover all the material.

High School

In both high schools, the external team observed classes that were traditional teacher-directed lessons, with very little significant student participation. There was an overall lack of rigor and low expectations, especially in classes that were not a part of the Biology/Chemistry/Physics honors track. In a few classrooms, students "did" labs following specified procedures with little or no discussion of content or outcomes and minimum interactions between teachers and students. These classes were characterized by a lack of open-ended or higher order questions. Questions on the lab worksheets or posed by the teacher were factual, and elicited short answers from students. In most classes where labs were not observed, the typical format was a lecture by the teacher, with students copying the prescribed notes from the board or overhead. Although these teachers appeared knowledgeable about their content and collegial with their students, there was little to no active student engagement.

The external team did observe a few classes in which teachers skillfully posed questions that engaged students in scientific discussions leading to deeper understanding. These included a demonstration by the teacher followed by students sharing their observations and trying to interpret them. As in other divisions, there is no consistency in a student's learning experience from one teacher to another, even in sections of the same course.

In focus group conversations, secondary students stated that science classes depend mostly on lectures and note taking. A few courses receive high praise from students due to the passion and excitement generated by the teacher. In general, students talked more about grading practices than course content, and those coming through the honors sequence reported feeling over-prepared for college science classes. Students from non-honors classes were less than enthusiastic about their classroom experiences. Some felt unchallenged and had little homework. By contrast those in the honors classes, particularly honors biology, felt overwhelmed by the amount of content and the homework burden.

Findings

- At the elementary and middle school level, teachers equate the kits with the curriculum, because they have no written curriculum to follow. The teacher's guide accompanying the kit dictates instruction. Teachers are not using the kit materials to their fullest potential or reaching all of the standards.

- Science instruction at the elementary level varies from building to building based on the principal's priorities and from classroom to classroom based on the teacher's interests and satisfaction with their kits. Science instruction is implemented more consistently at the middle school level, but wide variation still exists from classroom to classroom.

- Science teachers and administrators talk about a program based on inquiry. However, the district lacks a formal commitment to inquiry as the district's approach to teaching science and administrative support for inquiry-based instruction is inconsistent.

- Inquiry in science instruction is implemented unevenly across and within grade levels. Some elements of inquiry (i.e., engagement and exploration) and used more strongly and consistently. Other elements (i.e., extension and evaluation) are weak or non-existent. There is little evidence that teachers exploit the potential of kit materials to support to inquiry-centered lessons.

- Elements of inquiry-based science instruction are virtually non-existent in the high schools.

- Technology use in science instruction is rarely evident at any grade level.

- Some teachers and administrators equate the use of kits with having an inquiry centered science program. The kit materials are inquiry-neutral (i.e., they neither promote nor inhibit inquiry). Using them does not guarantee that teachers are committed to or students are engaged in inquiry.

- Students and parents have mixed responses to science instruction. These appear to be based on the wide variations in instructional practices from one teacher to the next, on experiences with a specific teacher and how well these experiences matched a student's needs and interests, and on some stakeholders' misconceptions about the goals of the science program.

Recommendations

- Develop a coherent curriculum document that will provide clear guidelines about district-wide instructional practices in science.

- Provide professional development time for teachers to digest the document and reflect on how to apply it to their classroom practice.

- Provide professional development for elementary and middle school teachers (including special education teachers) on inquiry-based pedagogy and on teaching beyond the kits. Utilize the expertise of consultants to demonstrate how to extend activities and differentiate instruction to meet the needs of diverse learners.

- Provide professional development that models the use of technology in instruction.

- Provide professional development to high school teachers on implementing inquiry-based instruction in their classrooms.

Professional Development

Overview

The WW-P school district has a liberal budget for professional development. The district funds a Professional Development Institute that provides courses promoting teachers professional growth. The district also contributes to the tuition of faculty members wishing to study in one of the many surrounding colleges and universities. The teacher, as an individual, plans professional growth experiences that may or may not be related to current teaching responsibilities. In addition, the district funds professional development that is organized by supervisors and addresses content and pedagogy directly related to the instructional program. Funds are also provided for teachers and supervisors to meet for the purposes of curriculum writing and program articulation across divisions. While these sessions are specifically oriented toward a product, teachers who have participated state that curriculum work is a powerful form of professional development. The high school structures its professional development activities differently than the elementary and middle schools where the emphasis is on use of the kits to teach science. Professional development at the high school will be discussed separately.

Considering the district's urgent need for a written curriculum to guide instruction at all levels, a larger portion of the professional development budget should be directed toward this purpose. While curriculum development is a distinct activity, it does provide unique professional development experiences to all that participate. Furthermore, as the comments below suggest, all future professional development should map back to the curriculum and prepare teachers to use it effectively. At the current stage of the program, curriculum development should take priority over further kit training, assessment design, and other professional activities that consume the limited time teachers have available.

Elementary and Middle School

In focus group discussions, teachers reported that they enjoyed participating in the professional development and found the initial professional development activities appropriate introductions to the kits. Elementary teachers in WW-P participated in professional development programs provided by $E=MC^2$, the NSF-funded consortium that played a key role in establishing an elementary science program. $E=MC^2$ offered workshops in inquiry-based science instruction, assessment, technology, and, more recently, science content. As each kit was adopted, training was provided by either consultants, lead teachers, local scientists, or representatives of the kit developers or distributors.

The middle school science curriculum is also kit-based. As each new kit was added, general and inclusion teachers received one to two days training that included both content and pedagogy. For the past three summers (1999-2001), most 6^{th} 7^{th}, and 8^{th} grade teachers attended weeklong content-based workshops. These addressed central concepts, such as energy transfer and conservation laws that are broadly applicable across the middle school curriculum. The workshops emphasized modeling and promoting inquiry. Seventh grade teachers received training for FOSS Earth History (at Princeton University) and STC/MSs Energy, Machines, and Motion. Training for 8^{th} grade teachers included a two-day workshop on their light unit. 6th grade professional development focused on the STC/MSs Properties of Matter and Catastrophic Events kits. Additionally, three 6^{th} and three 7^{th} grade teachers received a week of professional development preparing them to field-test new middle school modules for the National Science Resource Center (NSRC). Middle school teachers have received some training in the use of probes, devices that interface with a computer or hand-held calculator to measure temperature, force, motion, or light intensity. Teachers also mentioned the need for assistance in weaving science topics into the interdisciplinary thematic units that are widely used at the middle school

Teachers also spoke at length about their desire for opportunities to reflect on the effectiveness of the kits and to discuss modifications. The need for further professional development was reinforced during classroom observations and subsequent conversations with teachers who were aware of lessons that "didn't work" or were needlessly repetitive.

Although the elementary science professional development needs are still great, the district's NSF grant is drawing to a close. Teachers, supervisors, and principals agree that much more professional development is needed, but the external committee did not learn anything about the district's plan to fund future professional development.

All teachers have access to professional development in technology through the Professional Development Institute. The Educational Technology Teaching Collaborative (located at Princeton University) also provided a facilitator to help teachers work with Excel for collecting data and creating spreadsheets and graphs.

Findings

- The majority of the professional development at the elementary and middle school focuses on an introduction to the kits. Little attention is spent establishing a context for the objectives in each kit. That is, teachers receive no training about how the content and process skills spiral through the grades or what prior knowledge to expect of students at each grade level.

- There has been little professional development addressing the New Jersey Core Content standards or the alignment of the WW-P science program with the standards.

- Professional development has not addressed integrating science into other content areas.

- Professional development has not adequately addressed differentiating the kit activities to accommodate students with special needs and those who seek enrichment experiences

- Teachers report not having the time or knowledge to integrate technology into their science instruction.

- There is little professional development time available for teachers to evaluate and modify their kits.

- There is no formal professional development in the use of science kits for teachers new to the district. They currently rely upon veteran teachers who volunteer to offer guidance and support.

- The NSF grant that supported elementary science professional development is drawing to a close, and it is not clear whether the district is prepared to maintain this level of funding.

Recommendations

- Create a multifaceted professional development plan that will prepare all teachers to meet the instructional goals of the science curriculum. (12)

- Incorporate in all kit-based professional development an overview of alignment between the kit's objectives and the curriculum, state standards addressed by the kit, and prior knowledge required for students to succeed with the kit. This overview should also be included in each kit's teachers' guide.

- Engage supervisors of science and other disciplines in collaborating with teachers to create the thematic interdisciplinary units used in the middle school.

- Enhancing teachers' science content knowledge in topics they currently teach should be the priority of elementary and middle school professional development. This content should be integrated with instructional strategies that model inquiry.

- Provide professional development on differentiating instruction for students with special needs and those who have an exceptional interest in science.

- Explore the professional development potential of the district's rich technology resources and encourage greater use of electronic communication in professional development.

- Encourage science supervisors and the technology staff to collaborate in offering professional development on science applications of the district's technology and, specifically, on the use of probes in middle school science teaching.

- Allocate professional development time for teachers experienced with the kits to list teaching suggestions, assessments, and literature resources that will help colleagues use the kits more effectively.

- Create a professional development plan for supporting teachers who switch grades and those who are new to the district.

- Allocate professional development time

High School

High school teachers report that they initiate their own content-specific professional development experiences. These include participation in offerings at nearby universities, such as Princeton's Teachers as Scholars program. Many enroll in graduate courses, taking advantage of the tuition stipends provided by the district. Others have taken advantage of the Woodrow Wilson Institutes and similar national programs designed for high school science teachers. The WW-P Professional Development Institute offers courses on pedagogy but not specifically related to science. Examples include: Effective Lesson Design, Differentiating Instruction, Using Rubrics to Differentiate Instruction, Writing for Teaching and Publishing, Writing Strategies that Work, Action Research, and Exploring Web Sites. A small group of chemistry teachers have schedules that permit meetings with colleagues to collaborate on lesson plans, performance assessment matrices, and test specifications. Recent articulation meetings with middle school teachers were regarded as valuable professional development experiences. Unlike the elementary and middle school, the high school rarely offers summer professional development that bring many teachers together to work with a consultant on topics essential to the program.

Findings

- Professional development at the high school level is at the discretion of individual teachers and not necessarily coordinated with program needs.
- Limited professional development time is available for teachers of the same subject to meet and explore content and strategies that will enrich their courses.
- While some professional development in effective instructional strategies is available, there are no offerings on inquiry or its application in high school science teaching.

Recommendations

Consider offering school-based professional development that will bring high school teachers together to explore innovative instructional strategies and build consensus about course content.

- Identify areas of the science program that can be served by teachers bringing new ideas from workshops (i.e., innovative laboratory activities, better use of technology), encourage teacher participation in relevant workshops, and create a process for sharing the information teachers bring back with colleagues.
- Provide professional development to help teachers integrate inquiry into both instruction and lab investigations.

Assessment

Overview

An assessment plan aligned with the learning goals of the curriculum is an essential component of a world-class science program. The roles of assessment go far beyond assigning grades on student report cards. Classroom-based assessments inform day-to-day instructional practices, long-term policy decisions, and provide students with the feedback essential to learning[13]. Assessment results monitored over time help a district demonstrate accountability to its stakeholders, assure that all of its students are mastering the state and national standards, and evaluate its curriculum and policies. This last role is critical during a period when a science program is undergoing major changes.

The assessment plan should employ multiple components including performance tasks, science journals, written tests, projects, teacher observations, and external standardized assessments[14]. The plan should be consistent across the district and respected by students and their parents as fair and equitable measures of student learning. The district should collect and analyze assessment data and use the results to refine the science program, set priorities for professional development, and devise strategies to support students who are not reaching their fullest potential.

The external team gathered information about assessment practices and policies through conversations with teachers, administrators, students, and parents and from classroom observations, many of which included assessments. Practices vary significantly from teacher to teacher at all levels of the school. In the primary grades, assessment consists largely of teacher observations and focuses on science attitudes and skills. In the upper elementary and middle school grades, content receives greater attention, although teachers continue to assess students work habits and experimental skills. A combination of traditional tests, performance tasks, and journals are used to monitor students learning and generate report card grades. At the secondary level, assessment focuses on generating grades. In many conversations with students and teachers, the topics of grading practices and GPAs received greater attention than course content or objectives. Many of the secondary classes observed by the external team were, in fact, devoted to reviewing for a test. Considering the importance of grades in this high school culture, it is noteworthy that both students and teachers commented on inconsistencies in the grading policies, particularly between sections of the same course.

The only standardized test data available to the external team were scores on recent state science tests administered at 4^{th} grade (ESPA) and 8^{th} grade(GEPA). According to *New Jersey School Report Card 1999-2000*, a district publication, the general education student population performed far above the state average on science portion of the ESPA (58.7 % advanced proficient vs. a state average of 32.4%). Middle school students also perform well (45% advanced proficient vs. a state average of 22%) although somewhat lower than elementary students do. Fewer than 2% of the student population scores at the lowest level of the three-point rubric used to report performance on the state test. Elementary teachers made no mention of the ESPA, but preparing students for the GEPA was a concern identified by 8^{th} grade teachers. According to administrators these tests are not rigorous enough to aid the district in program evaluation. No other standardized science tests are administered.

Elementary Grades

The nature and purpose of science assessment varies from teacher to teacher reflecting each persons understanding of the goals of the science program. Primary teachers describe these goals as helping children become good observers and sustaining their enthusiasm for science. Assessment is based largely on teacher observations, specifically students’ ability to work collaboratively, follow instructions, manipulate materials, and complete student sheets from the kits. Several teachers stated that once they have a written curriculum they will know what is important and develop assessments of content knowledge. At the upper elementary level, grades generally are based on a combination of written work (journal entries, report sheets, etc.), classwork (participation, experiments, etc.) tests, and projects. Most students earn As or Bs. One upper elementary teacher said, "The grade is based mostly on participation and teamwork. I grade on process skills.≤ There is no consistency in the assessments used by those teaching the same kit, nor do teachers receive feedback on the assessments they use. While many teachers use student journals for assessment, there was no agreement journal writing expectations.

Assessment was one of the topics included in the K-6 professional development provided by the NSF grant. However, none of the teachers indicated this training significantly influenced their assessment practices. Some lessons that were observed by the external team afforded outstanding examples of performance assessments. They were imaginative, challenging, and well matched to the students' prior classroom experience. However, these were primarily a function of one teacher's creativity and not used across a grade to standardize assessment practices or student learning objectives.

A recent publication of the National Science Resources Center[7] proposes a 5-level rubric for describing progress toward standards-based assessment practices in elementary science.

Table 1. Stages in a District-wide Assessment Plan

Level 0

Indicator: No change; no plan for change.

Level 1

Indicator: Studying the issue, planning, changes driven by outside forces (new state mandates).

Level 2

Indicator: Some use of alternative assessment strategies in individual schools or by teachers using inquiry-centered curriculum materials.

Policy of acquiring curriculum materials that incorporate active assessment strategies.

Level 3

Indicator: Systematic professional development on assessment and/or teachers developing active assessments.

Level 4

Indicator: Initiating system-wide implementation of active assessment tied to grading practices and substituting for traditional, test-based grades.

Level 5

Indicator: Complete implementation of district-wide active science assessment, and/or new science assessment is part of a large district-wide assessment plan.

The external team observed many teachers at level 2 in their assessment practices and heard about a small group of teachers at level 3--participating in a long-term study of assessment and developing performance assessment to accompany their science kits. Higher levels require a systemic approach to assessment. There was no evidence that the district is moving in this direction. Elementary classroom visits provided some outstanding examples of embedded performance assessments. A 4th grade lesson on electric circuits included an embedded assessment in which students had to construct a working circuit that would operate a motor and explain the function of each component. Ongoing student learning during the assessment was apparent from the questions within experimental groups and exchanges with the teacher. As part of a 5th grade performance assessment students were asked to develop a strategy for comparing the concentration of three look-alike solutions and order them by increasing concentration. The students had no difficulty developing a plan and the group's discussion of their results provided rich evidence of their understanding. Each of these teacher-designed performance assessments was based on an engaging problem that examined students' understanding of a key concept and required them to plan their own procedures.

Middle School

The topic of assessment came up frequently during focus groups with middle school teachers and students. There is no consistency in assessment practices across grades at the middle school. Sixth and seventh grade teachers spoke of working collaboratively to develop assessments aligned with their new science modules and beginning to depend more heavily on journals for assessment purposes as a result of recent articulation efforts with their high school colleagues. The eighth grade teachers emphasized the GEPA and their concern that students be adequately prepared for the content and format of that test.

Assessment generally includes some traditional tests involving vocabulary, multiple choice, and short answer questions, observations of student work, performance tasks, journals, and, in some cases, research projects, to determine grades. Rubrics are used to evaluate lab reports and students' experiments.

From the students' perspectives, attitudes toward assessment vary by grade and by teacher. Sixth grade students spoke of teachers helping them review for a test through games and other tension-free activities that focus on essential vocabulary and details of recent experiments. Seventh and eighth grade students were less cheerful about assessment. Many complained about what they perceived as busy work test preparation, including making note cards and memorizing vocabulary. Eighth grade students complained that too much class time was spent on test preparation which, as their teachers told them, was intended to prepare them for high school. Ninth grade students, however, felt that their eight grade tests addressed trivial content and didn't require anything like the serious preparation that high school biology tests required.

High School

Assessment and grades are high stakes topics at the secondary level. According to teachers and administrators, students and their parents are very concerned about grades and whether their child is developing a transcript that will be attractive to a competitive college. The external team observed several classes devoted to reviewing for a test in which students copied information from overheads and recalled vocabulary. Judging from these reviews, the tests focus on definitions and facts and include few higher order operations. During focus group meetings, several teachers spoke of other assessment strategies, particularly in the honors science classes, including power point presentations and research reports using multiple information sources. Teachers reported that while a common final examination is developed for most multi-section courses, individual teachers modify parts of the exam to align with the curriculum they teach.

Program Assessment

The external committee heard a range of opinions on the science curriculum from parents, board members, teachers and principals concerning the effectiveness of the science curriculum. Some elementary school parents feel the curriculum tried to cover too much and others describe it as trivial. Elementary teachers voiced similar concerns. Middle and high school teachers are more divided on their perceptions of whether the current curriculum is meeting the needs of all students. Most parents and teachers acknowledged the role of inquiry, but many voiced concerns about the tension between inquiry and content coverage and fears that inquiry may result in a lack of rigor. The district needs objective evidence to respond to these concerns. The effectiveness of the kits, the de facto curriculum at the elementary and middle school grades, must be evaluated. "How well do diverse students achieve the intended results (standards) using the new instructional materials?≤ The same question applies to the multi-tiered program at the high school.

Findings

- The district lacks a comprehensive assessment plan for documenting student's science learning and determining whether all students are achieving the national and state science standards.

- Current student assessment practices vary from teacher to teacher, often depending primarily on traditional paper and pencil tests, and rarely examine higher order thinking or students' mastery of the skills of inquiry.

- The district does not have a procedure for program assessment that uses objective data to review and evaluate whether the science curriculum and instructional materials are producing the desired outcomes in student learning.

The district does not collect and analyze longitudinal student assessment data for the purpose of monitoring achievement, assuring stakeholders that all students are meeting standard-based learning goals for their grade, guiding long-term planning.

Recommendations

- Establish fair and consistent assessment practices across all sections of the same course.

- Focus on articulation of assessment practices from grade to grade, particularly across division boundaries. The discrepancy between assessment practices at 8^{th} and 9^{th} grade was of particular concern to the students interviewed.

- Provide professional development that will lead to uniform criteria for evaluating student work and help teachers devise instructional interventions for students who have difficulty meeting the learning goals.

- Develop prototypes of formative and summative assessments to accompany each component of the curriculum. Incorporate these prototypes into the written curriculum documents.

- Provide professional development to enhance teachers' ability to create and evaluate standards-based assessments. Review features of the prototypes during professional development sessions and begin to build teacher awareness of and support for the district's assessment plan.

- Communicate the assessment plan to parents helping them understand the need for a variety of assessment strategies and the relation between assessment practices and students' report card grades.

- Incorporate in the assessment plan a standardized instrument to supplement the district-developed assessments.

- Employ multiple forms of assessment, including paper and pencil items, performance tasks, portfolios, teachers' observations of students at work, etc.

- Develop a protocol for assessing the effectiveness of the science curriculum and instructional materials, including the elementary and middle school science kits. Apply the evaluation protocol to all new instructional materials under consideration. Involve teachers and students in evaluating instructional materials and plan to replace those that are not effectively meeting the district's learning goals.

- Develop a plan for annually collecting and analyzing student work samples at selected grades to determine whether key learning objectives of the curriculum are being met. Engage teachers and supervisors in this analysis. Evaluate areas of the curriculum in which all students do meet learning objectives.

- Communicate results of the districts' data driven review of student achievement and the curriculum to all stakeholders.

Policy

Overview

National, state, and district policies govern public education systems. In the majority of districts across the nation, it is the district policies that have the greatest impact on the parameters of its programs. As stated in the National Science Education Standards, "policies that influence the practice of science education must be congruent with the program, instruction, professional development, assessment, and content standards while allowing for adaptation to local circumstances.≤ A district that aspires to world-class status must have policies consistent with the standards and accountability measures to insure that these policies guide the program and guarantee all students equal access to it.

Policymakers often have a variety of views and interests. In a world-class science program, all stakeholders' views must be taken into consideration when establishing policies and analyzing their impact upon the budget, the instructional resources, and, above all, the learning experiences of all students. Financial and professional development resources must be available to support the district's policies; administrators must be committed to translating the policies into practice.

The external team reviewed current WW-P school board policies regarding the curriculum development process and curriculum documents. While the policies are explicit, the team did not find much evidence of them in practice. Some science curriculum documents exist, but they are either out of date or differ from what the committee observed in classrooms. These documents are not necessarily familiar to or supported by administrators.

In conversations, most principals did not communicate a clear understanding of the science standards or why particular kits were selected. They are aware of unevenness in science instruction from one classroom to the next but have no plan to correct this problem. Elementary principals did praise the hands-on science teaching in their buildings and voiced their commitment to inquiry. However, to principals, as to teachers, the science curriculum is a list of kits. Primary teachers report that they are rarely observed teaching science and are left on their own to find the time for science lessons. Principals are aware that some elementary teachers do not like or use the kits; these teachers are not held accountable for teaching science.

The most consistent concern expressed by parents relates to classrooms where science isn't taught, isn't taught well, or isn't taught in the way that parents prefer. In other words, a child's science experience is not determined by district policies, but by the preferences of individual teachers. Some parents and school board members expressed skepticism about the emphasis on inquiry in the science program. A survey of the currently available district documents revealed no policy statement with regard to inquiry science and only one document that endorses incorporating the skills of inquiry into the science program

The Science program is designed to encourage curiosity and exploration by asking questions, making observations, collecting and analyzing data, and drawing conclusions. In all grades, students continue to build their knowledge and enhance their skills through discovery and problem-solving activities. WW-P Middle Schools Program of Studies 2001-2002

Many of the concerns expressed by principals, teachers, and parents in focus group meetings are related to ambiguities in these stakeholders' understandings of school policies. It is difficult to respond to their concerns without district policies that are supported by the administration and honored by all teachers. The district has lavishly supported a standards based science program in the elementary and middle schools. While there are many successes, progress is uneven and will become more difficult without the support of clear policies and better communication of these policies with stakeholders.

As an example, some teachers at each level expressed dissatisfaction with decisions recently made about a particular kit or a program change or a course design. It was not clear the extent to which these teachers were involved in the original decision making process, their attitudes suggest feelings of powerlessness about the changes around them. Clearly few changes of the magnitude that the science department is undergoing will be met with universal applause. However, when policies with respect to program change are clear and have been followed, teachers have a professional responsibility to support them.

Findings

- This district has indicated its willingness to provide substantial financial resources to support the policies it puts in place.

- The district's current policies lack clarity about the roles and responsibilities of the administrative and the instructional personnel.

- While the district's policies are sensitive to local concerns, they do not adequately reflect some features of standards-based, world-class science program

  Not all stakeholders feel involved in the development of district policies, especially those with respect to curriculum and course selection.

Recommendations

- Review and refine policies to insure that they are consistent with a world-class vision.

- Establish policies that mandate a curriculum offering rigorous standards-based courses with high expectations for all students.

- Develop a K-12 policy statement expressing the district's commitment to an inquiry-centered science program.

- Establish policies related to professional development stipulating that a substantial portion of the available funding be allocated to offerings specifically aligned with instructional needs.

- Develop policies that mandate and support the inclusion of technology in the science program.

Technology

Overview

Classroom observations and information gathered from teachers and the technology department suggests that technology-related practices and issues in WW-P cut across all disciplines. Accordingly, most of the observations, findings, and recommendations in this section are broadly applicable. To provide student and staff access to the technology and effective technology-based teaching and learning, five essential components of a program must simultaneously be in place: hardware/infrastructure; software/instructional materials; professional development; long-term support; and maintenance.

The external team met with Mr. John Peraino, director of Technology, and the elementary, middle, and high school technology facilitators to gather information about their program and responsibilities. There is one technology facilitator at each level; they divide their time between the buildings at their level providing support and training. Mr. Peraino has responsibility for voice, video, and data transmission throughout the district. His staff includes eight technicians, two programmer analysts, and one AV engineer who service the district's hardware, phones and other technology resources.

WW-P has liberally provided computer hardware and other technology resources for its schools and is aware of the need to regularly upgrade equipment. The school board and community are technologically aware and understand the need for students and staff to use technology as an integral part of teaching and learning. The school board has consistently supported technology funding and, with guidance from its technology department, the district now has a substantial investment in educational technology. However, the external team did not find evidence that this investment is guided by district vision for the seamless integration of technology into the instructional program.

Elementary schools have Macintosh equipment with a client/server configuration, and 6-12 schools operate on a PC platform with NT-4/ 98 or XP. Each school has a LAN with a WAN connecting all schools and the central office. Plans for the schools to be opened in 2002-2003 include wireless access, which will allow creative use of technology throughout each new building. WW-P provides all K-12 teachers with a desktop computer connected to a large screen monitor. There are from one to three additional student computer stations in all classrooms along with Internet access. A filter system blocks access to inappropriate sites. While the current system is slower than teachers would like, the technology department is working on improved access speed. The high schools, middle schools, and some elementary schools have computer labs with 23 to 26 stations. Media Centers have computers for student use during non-class hours. In addition, the district has sets of Alpha-Smarts, graphing calculators, digital cameras, videodisc players, probeware, and laptops, although this technology is not distributed evenly across the schools. Some existing equipment is four to five years old creating differences in access and capability in each building.

With the exception of basic software such as word processing, presentation software, databases, and spreadsheets, software availability varies from school to school. Software purchases and installations are handled by the technology department in response to requests from teachers, administrators, or computer facilitators. At the present time, there is no standard process for selecting and evaluating software purchases or for tracking their instructional effectiveness.

WW-P does not have specific expectations for its teachers with respect to technology awareness or expertise. While some teachers spoke of cutting edge instructional applications and student projects, others expressed their ambivalence about communicating via email. WW-Ps Institute for Professional Development provides optional classes in PowerPoint, Web design, and Microsoft Office in the faculty computer lab at the Grover Middle School. Individual schools also use their own computer labs to train teachers in specific applications. A recent survey on teachers' technology interests is being analyzed to establish an agenda for future professional development. Although none of the training sponsored by the technology department incorporates applications in science, science supervisors have organized professional development addressing technology needs specific to their programs.

The science listings in the "Programs of Studies" do not mention technology-related activities. Science teachers independently decide which technology applications, if any, they will use. When asked about Internet use, teachers report that they search for teaching resources and content information. No examples were offered of students communicating with their counterparts in other regions or countries. Many teachers who discussed technology with the external team lack a vision for technology as an integral part of instruction and offer many reasons not using technology. Elementary teachers believe that the limited amount of classroom hardware makes it difficult for them to integrate any technology into their programs. They perceive that technology will take time away from already too-brief science periods. Upper elementary science teachers mentioned that the tight schedule in their building's computer lab prohibits class visits to process data or to explore other computer applications. High school teachers explained that they use technology more often when they are acquainted with relevant software or Internet sites.

The new middle school science kits include computer-based investigations and student resources, and these offer teachers good models of technology as a component of instruction rather than as an optional add-on. The middle school teachers who are using probes are finding them effective in instruction and pleased with students' enthusiastic response to them. The external team observed some good examples of technology use in middle school classrooms, such as a 7th grade class working with a CD-ROM that modeled plate tectonics. Most WW-P students have access to technology at home and are comfortable using the available technology. No students were observed using computers to play games or engaging in non-classroom applications.

Findings

- The WW-P infrastructure and installed technology base are planned well.
- WW-P parents are supportive of the technology program and eager to extend their children's access to technology resources.
- Technology use in science is in its infancy. Where emphasis has been placed on technology training, teachers are using the resources more. In some cases, technology use is limited because the resources are not available in sufficient quantity to accommodate science needs.
- Integration of electronic resources into the high school science courses is at the discretion of individual teachers.
- Individual teachers initiate software purchases but have no evaluation protocol to guide their selections.
- The high quality WW-P technology infrastructure is not used to its fullest potential in professional development, and there are there are few curriculum-specific professional development offerings.
- Distance learning and online courses are not currently used in WW-P

Recommendations

- Shorten the real replacement time of technology to 3-5 years. Outdated equipment can be used for probeware stations, word processors, and special projects. Consider purchasing several replacement units to substitute for computers that need long-term repair.
- Extend the availability of wireless technology as rapidly as funding levels permit.

- Develop a process for reviewing and selecting software that is aligned with the curriculum.

- Incorporate relevant technology applications in all science professional development sessions.

- Consider wider use of the video studio in professional development and instruction, i.e. broadcast programs of exemplary science teaching, share special activities with teachers in different schools.

- Explore the rich technology base in the WW-P community and identify community members who can advise teachers on science related technology applications.

- Establish high expectations for student and teacher use of technology. Use existing guidelines (Milken, U.S. Dept. Education) as a framework.

- Incorporate activities using standards-based electronic resources in all science curriculum documents. Include at least one Internet-available application, such as Journey North, Jason, or NASA, for each grade level.

- Develop probeware stations on AV carts that can be wheeled into classrooms and shared among several science classes.

- Provide teachers with a current list of Internet sites that contain quality instructional materials; resources such as the electronic database developed by the NJSSI (http://njssi.rutgers.edu) list many such sites.

Conclusions

The West Windsor-Plainsboro school district has begun an ambitious science initiative with the goal of providing all of its students with a standards-based world-class science program. Due to many changes over the past five years the district is making substantial progress toward this goal. The most significant change is that science is now taught at the elementary level and engaging, developmentally appropriate instructional materials are available in each classroom. Professional development has been liberally funded and a cadre of well-trained teacher leaders is providing support to their colleagues. Comparable changes are taking place at the middle school, and the high school faculty is aware that its curriculum documents are mostly out of date and need revision.

The district is prepared to examine more closely the attributes of world-class status to which it aspires and to frame an action plan that will raise the science program to the next level of implementation. The district's three highly qualified, dedicated supervisors are well aware of the next steps needed to advance the program: updated curriculum documents; curriculum articulation; technology integration; assessment design; and professional development to enhance teacher's content knowledge and ability to facilitate inquiry-centered instruction.

In addition, the external team would like to call attention to: the importance of assuring that ALL students are experiencing a rigorous, standards-based science program that will allow them to maximize their potential; the need to carefully examine the district's policies with respect to curriculum development and accountability and to assure stakeholders that the adopted curriculum will, in fact, be taught throughout the district; and the importance of better communication with parents about the vision and goals of the science program, and particularly about the nature and role of inquiry in science teaching.

The following concerns emerged in the focus group discussions and should be addressed to advance the science program:

- Parent concerns about the extent to which a student's science experience is dependent upon a particular teacher rather than a district-wide program

- Teachers need for time to meet and reflect upon the science program, share successful strategies, and revise the ineffective portions

- Supervisors awareness that curriculum writing is the most urgent next step and must become a funding priority

- Students difficulty in adjusting to the abrupt transition from middle to high school science classes

Finally, the external team wishes to express its admiration for the WW-P science faculty and the vibrant science program they envision for their students. We are particularly grateful to the internal team for candidly sharing their impressions with us. Our joint meeting was the starting point for our visit and helped us by establishing a landscape for our observations. We hope that this report will help them advance the WW-P science program.

Appendix 1: Science Program Evaluation Components

This Table lists evaluation components of particular interest to the administration and school board and identifies the section(s) of the report in which each is addressed. The external team lacked adequate information to address some components.

Components for Science Program Evaluation:

Program philosophy and goals: Definition of science program; mission statement (K-12): philosophy and goals Common and unique areas of responsibility/expectations in the science program at the various levels.

Addressed in Section: Internal Team Report.

Components for Science Program Evaluation:

Description of instructional content.

Addressed in Section: Internal Team Report.

Components for Science Program Evaluation:

Review of recent research, best practices, and current standards.

Addressed in Sections: Included in relevant section of the report; references listed in bibliography.

Components for Science Program Evaluation:

Analysis of instructional program in light of program philosophy, goals, standards, research, and best practice: Alignment of taught curriculum to written curriculum and state framework; Coherence of K-12 program; Instructional effectiveness (delivery); Effectiveness of organizational support (structure and resource allocation); Client satisfaction; Professional development; Professional organizations; Percent of science teachers who majored in discipline; best district practices.

Addressed in Section: Curriculum, Instruction; Instruction; Professional Development; Policy; relevant sections.

Components for Science Program Evaluation:

Analysis of results based on student work samples, nor/criterion referenced tests, local performance tasks, and other unobtrusive measures.

Addressed in Section: Assessment

Components for Science Program Evaluation:

Findings and recommendations.

Addressed in Section: Included in relevant sections.

Components for Science Program Evaluation:

Budget implications and timelines.

Addressed in Section: Not explicitly addressed.

Appendix 2: Focus Group Meetings

Focus Groups

- High School Principal
- Middle School Principals
- Elementary School Principals
- Science Supervisors (2 sessions)
- Primary Teachers

- Kindergarten Teacher
- School Board Members (2 sessions
- Parents (2 sessions
- Middle School Teachers (Gr. 6 & 7)
- 6th Grade Students (Community and Grover)
- High School South Teachers (3 sessions
- Upper Elementary Teachers (3 sessions
- Technology Department
- Middle School Teachers (Gr. 8)
- 8th Grade Students (Grover and Community)
- High School North Teachers (2 sessions)
- High School North Student
- Internal Team (2 sessions
- 7th Grade Students (Grover and Community)

Appendix 3: Focus Group Questions

Appropriate questions from the following list were used to frame the focus group discussions.

- It what ways has professional development changed the way teachers in West Windsor/Plainsboro teach science?
- How can the science curriculum be improved to ensure that it meets world-class standards?
- To what extent is technology available and integrated into the science curriculum?
- To what extent are the following available across all schools: a) science resources, and b) equitable access to science classes?
- What types of assessments are used in science classes?
- To what extent are you involved in designing or revising the science curriculum?

Appendix 4: Classroom Observation Protocol

Teacher:

Grade Level:

Observer:

School:

Date:

Number of Students:

- Provide a brief description of the objectives and activities you observed in this lesson. Include your assessment of the accuracy, relevance, and developmental appropriateness of the science content.
- Describe and provide examples of the ways in which the teacher engaged the students in the activity, e.g. activation of prior knowledge, "hook" activity, linking to real world context.
- Describe and provide examples of the ways in which the students explored the topic, e.g. hands-on/ minds-on activities, working collaboratively, asking/answering higher-order open-ended questions.
- Describe and provide examples of the ways in which students explained what they were learning in the lesson, e.g. journal entries, reporting out to the entire class, sharing data among groups.
- Describe and provide examples of the ways in which the teacher extended student learning beyond the original lesson, e.g. enrichment activities.
- Describe and provide examples of the ways in which the teacher allowed students to evaluate and reflect upon what they did in the lesson, e.g. wrap-up discussion, time for sense-making, follow-up activities.
- Describe and provide examples of the ways in which technology was integrated into this lesson.
- Describe and provide examples of the ways in which the teacher differentiated the activities to accommodate diverse learning needs.
- Describe and provide examples of any other teacher characteristics or instructional strategies that impacted the implementation of the lesson or the learning environment (positively or negatively).

Appendix 5: Inquiry

Description of Inquiry

One’s own curiosity, wonder, interest, or passion to understand an observation or solve a problem drives the inquiry process. The process begins when the learner notices something that intrigues, surprises, or stimulates a question ≠ something that is new, or something that may not make sense in relationship to the learner’s previous experience or current understanding. As the process unfolds, more observations and questions emerge, giving occasion for deeper interaction and relationship with the phenomena ≠ and greater potential for further development of understanding.

The next step is to take action ≠ through continued observing, raising questions, making predictions, testing hypotheses, and creating theories and conceptual models. The learner must find his or her own pathway through this process. It is rarely a linear progression, but rather more of a back and forth, or cyclical series of events. Along the way, the inquirer collects and records data, and makes representations of results and explanations, and draws upon other resources such as books, videos, and the expertise or insights of others.

Making meaning from the experience requires reflection, comparison of findings with others, interpretation of data and observations, and application of new conceptions to other contexts. These help the learner construct new mental frameworks of the world. Teaching science using the inquiry process requires a fundamental reexamination of the relationship between the teacher and the learner whereby the teacher becomes a facilitator or guide for the learner's process of discovery and creation of a deeper understanding of the world. (11)

Three Levels of Inquiry

Inquiry may vary in the degree of structure and guidance provided by the teacher and the amount of responsibility assumed by the student. It is convenient to describe three levels of inquiry, structured, guided, and open. Each method is appropriate at certain stages of concept development, and may or may not be linear in sequence. The method selected depends on the desired learning outcomes.

Students should have opportunities to participate in all three types of inquiries in the course of their science learning10.
Structured Inquiry. The teacher identifies a problem to investigate and provides the procedures and materials but does not inform students of the expected outcomes. Students are to discover relationships between variables or otherwise generalize from data collected. Structured inquiry is used to teach a specific concept, fact, or skill, and provides the groundwork for subsequent open inquiry. Example: Students are given a step-by-step procedure, including diagrams for constructing several electrical circuits. Questions prompt students to remove individual bulbs from each circuit and record their observations. (15)

Guided Inquiry. The teacher provides the materials and problem to investigate. Students devise their own procedure to solve the problem. The teacher facilitates the investigation and encourages students' generated questions that may lead to further investigations. Example: Students are given batteries, bulbs, wires, and other materials. Procedures instruct them to make a bulb light as many ways as they can, using the supplies provided. Later, they are instructed to make two bulbs light, again using different combinations of materials. Finally, students are asked to note what happens when they remove individual bulbs from their circuits. (15)

Open Inquiry. This differs from guided inquiry in that students formulate their own problem to investigate. Open inquiry allows students to develop their understanding of a concept and use scientific reasoning. Conducting an open inquiry independently is an important goal for all students. Example**:** Students have a question about how bulbs behave in an electric circuit. They are given batteries, bulbs, wires, and other materials and they design and perform an investigation seeking answers to their question. (15)

The Learning Cycle

In observing science classes, the External Team utilized a protocol called the learning cycle. It based upon research findings that suggest students learn best when they can make discoveries and actively construct their own understanding of new science concepts. A learning cycle approach is the basis for the FOSS and STC instructional materials used throughout the elementary and middle school. The stages of the learning cycle are engage, explore, explain, elaborate, and evaluate, referred to the "5 Es" of an inquiry-based lesson. A variation called FERA, focus, explore, reflect, apply, is employed with the STC materials. Table 2 provides examples of teacher and student behaviors associated with each of the 5 Es.

Table 2: Examples of 5 E Behaviors in an Inquiry Lesson

Engage

Teacher: Creates interest. Generates curiosity. Raises questions. Elicits responses that uncover what the students know or think about the concept/topic.

Student: Asks questions such as, "Why did this happen?" "What can I find out about this?" Shows interest in the topic

Explore

Teacher: Encourages students to work together without direct instruction from the teacher. Observes and listens to the students as they interact. Asks probing questions to redirect the students' investigations when necessary. Provides time for students to puzzle through problems.

Student: Thinks freely, but within the limits of the activity. Tests predictions and hypotheses. Forms new predictions and hypotheses. Tries alternatives and discusses them with others. Records observations and ideas. Suspends judgment.

Explain

Teacher: Encourages students to explain concepts and definitions in their own words. Asks for justification (evidence) and clarification from students. Formally provides definitions, explanations, and new labels. Uses students' previous experiences as basis for explaining concepts

Student: Explains possible solutions or answers to others. Listens to others' explanations. Questions others' explanations. Listens to and tries to comprehend . Explanations the teacher offers. Refers to previous activities. Uses recorded observations in explanations.

Elaborate

Teacher: Expects students to use formal labels, definitions, and explanations provided previously. Encourages students to apply or extend the concepts and skills in new situations. Reminds the students of alternative explanations. Refers students to existing data and evidence and asks: "What do you already know? What do you think?"

Student: Applies new labels, definitions, explanations, and skills in new, but similar situations. Uses previous information to ask questions, propose solutions, make decisions, and design experiments. Draws reasonable conclusions from evidence. Records observations and explanations.

Checks for understanding among peers.

Evaluate

Teacher: Observes students as they apply new concepts and skills

Assesses students' knowledge and skills. Looks for evidence that the students have changed their thinking or behaviors. Allows students to assess their own learning and group-process skills. Asks open-ended questions, such as: "Why do you think? What evidence do you have? What do you know about ..? How would you explain.?"

Student: Answers open-ended questions by using observations, evidence, and previously accepted explanations. Demonstrates and understanding or knowledge of the concept or skill. Evaluates his or her own progress and knowledge. Asks related questions that would encourage future investigations.

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11 Exploratorium Institute for Inquiry, Workshop Notebook, A Description of Inquiry, (1998), Exploratorium, San Francisco, CA

13 Black, P. & Wiliam, D. Inside the Black Box; Raising the Standards Through Classroom Assessment, (1998) Phi Delta Kappan 80 (2): 139-148

14 Hein, G.E. and Price, S., Active Assessment for Active Science (1994) Heinemann, Portsmouth, NH