Fermilab

FERMILAB-Pub-02/088 May 2002

ARISE: American Renaissance in Science Education

Implementation Resource Book
Suggestions from the Field

Convened by
Leon M. Lederman

Report Edited by
Marjorie G. Bardeen

Sponsored by
Fermi National Accelerator Laboratory and Friends of Fermilab
P.O. Box 500, Batavia, Illinois 60510

Funded by
The Marmon Group
The David and Lucile Packard Foundation
The U.S. Department of Energy

March 2002

Fermi National Accelerator Laboratory
Batavia, Illinois

A Department of Energy National Laboratory
Managed by Universities Research Association, Inc.

WORKSHOP PARTICIPANT LIST

Participants

Karen Bardeen*
Oak Park and River Forest High School
Oak Park, IL

Miguel Brito
St. Philip's Academy
Newark, NJ

John Chamberlain*
Glenbard North High School
Carol Stream, IL

Beth Christopherson
Piedmont High School
Berkeley, CA

Bryce Cordes
Loretto High School
Sacramento, CA

Gary Curts
Dublin Coffman High School
Dublin, OH

Margaret Dufeny
Berkeley Prep
Tampa, FL

Samuel Dyson
Walter Payton College Prep
Chicago, IL

John Fenoli
Forest Ridge School
Bellevue, WA

Frederick Fisher
Casa Grande High School
Casa Grande, AZ

John Ford
Choate Rosemary Hall School
Wallingford, CT

Michael Fowler
Farmington High School
Farmington, CT

Eric Goldstone*
Pinnacle High School
Phoenix, AZ

Diana Gordon
St. Mary's Academy & Vernier Software
Portland, OR

Scott Greenhalgh*
Tempe High School
Tempe, AZ

Karen Hinkley
Forest Ridge School
Bellevue, WA

Susan Hooker
Junipero Serra High School
San Diego, CA

Tom Knutson*
Glenbard North High School
Carol Stream, IL

Ruth Leonard
Edison Schools
Kingsport, TN

Pete Lohstreter
The Hockaday School
Dallas, TX

Patricia MacEgan
Loretto High School
Sacramento, CA

Pam McConnell*
Girls Preparatory School
Chattanooga, TN

Don McNeil*
Dwight-Englewood School
Englewood, NJ

Colleen Megowan*
Jess Schwartz Jewish Community H.S.
Phoenix, AZ

Sue Ann Moore
Clinton Middle School
Clinton, OK

J. C. Morris
Mission Bay High School
San Diego, CA

Fred Myers*
Farmington High School
Farmington, CT

Kristin Newton*
Cambridge Rindge and Latin H.S.
Cambridge, MA

Dave Noodell
Millard North High School
Omaha, NE

Leslie Nyckel
Glenbard North High School
Carol Stream, IL

Marco Pagnotta
Dwight-Englewood High School
Englewood, NJ

Dean Papadakis*
South Pasadena High School
South Pasadena, CA

Andrea Prybylski*
The Westminster Schools
Atlanta, GA

Tomas Ramirez
Providence School District
Providence, RI

John Samp
Cambridge Rindge and Latin H.S.
Cambridge, MA

Carol Savin*
Pinnacle High School
Phoenix, AZ

Cece Schwennsen
Millard South High School
Omaha, NE

Emma Smith*
Box Elder High School
Brigham City, UT

Elizabeth Sorrell*
Belmont Public Schools
Belmont, MA

Janet Spencer
Piedmont High School
Piedmont, CA

Emma Stellman*
Cambridge Rindge and Latin H.S.
Cambridge, MA

Mark Vanacore*
Albion High School
Albion, NY

Susan Weinshanker
Mission Bay High School
San Diego, CA

Daniel Wood
Tombstone High School
Tombstone, AZ

Randy Wortman
Casa Grande High School
Casa Grande, AZ

*Group facilitators at March meetings

Fermilab Education Office

Moderators
Marjorie Bardeen
Susan Dahl
Spencer Pasero

Workshop Staff
LaMargo Gill
Gayle Stephens
Yvonne Twomey

TABLE OF CONTENTS

"We are quite aware of the enormity of the task of creating a new curriculum and gaining the national consensus which would lead to the desired result: high school graduates who can be informed voters, prepared employees of the new work force, American students of the liberal arts who are science savvy and students who are meaningfully prepared to enter and thrive in all fields of science and engineering."

Leon M. Lederman

Anyone wishing to be on a mailing list to remain informed about or participate in the initiative should contact:

Denise Koehnke
Illinois Mathematics and Science Academy
1500 West Sullivan Road
Aurora, IL 60506
630-907-5911 • Fax: 630-907-5913

ARISE information online: www-ed.fnal.gov/arise

INTRODUCTION

> The sequence of high school study in science—biology, chemistry and physics—was set out in 1894 on the basis of a prestigious national commission (The Committee of Ten). Today's high school science courses, largely textbook-driven, are treated as independent and unrelated. This, in spite of eloquent voices in the educational literature who have, in vain, called attention to the absurdity of the sequence. The sequence is inappropriate and does not respect developments in the disciplines over the past century, nor does it respect changes in mathematics teaching, with algebra now introduced as early as eighth grade.[1]

Pioneer schools and districts are replacing their old science sequence with a new secondary school science curriculum based on a hierarchy of science concepts that follows national science standards and which begins in ninth grade with a focus on physics, moves to a focus on chemistry and finally on biology. Leon M. Lederman is leading a national effort to encourage this type of science education reform and remains in touch with these pioneer schools to track their progress.

Change of this magnitude is not undertaken lightly nor does it always proceed smoothly. This report, which summarizes discussions from three workshops held in December 2001 and March 2002, contains reflections and suggestions on experiences, successes, concerns, and needs that teachers have encountered as they introduce and sustain a new science curriculum. Teachers have taken one of two approaches, "physics first" or integrated science. They work in different school settings—public and private; large and small. The story at each school is different; in some cases the new curriculum was mandated from above; in others the suggestion for change came from the teachers themselves. As the teachers say, "the more teachers we meet, the more we realize that our issues are the same. It is good to know we are not alone."

[1]From the report, *ARISE: American Renaissance in Science Education Three-Year High School Science Core Curriculum - a Framework*, Fermilab, July 1998.

A Message from Leon M. Lederman

These workshops are an incident, a skirmish in the War on Ignorance, which we can call science education reform, to be in tune with the times. I increasingly look at our education problems, the failure of US students—seniors—to measure up to the needs of 21st century citizenship. I worry about future scientists and our need to decrease our dependency on foreign scientists (as well as on foreign oil). We want to welcome them as colleagues, as collaborators in the advance of our societies—not as essential components of our industrial might. But I worry much more about our future citizens, the product of the average students in our schools.

What can we do to enable them to thrive in this 21st century, which opened with such promise and such peril? The average citizens are employed, manage their families, vote, pay taxes, send children to school, and write letters to the editor. Are we preparing them for the complexities of 21st century life? I don't think so. We do need to improve our schools, pay our teachers, elevate them socially, create continuous professional development, mostly collegial, and look very critically at our curricula. But we can't do everything at once.

ARISE is a focused program that concentrates on one glaring defect—on how we teach science. Our commitment to this very specific problem has been greatly encouraged by our learning of many of your efforts and innovations. Until recently, you were a small group of innovators, perhaps 200 or so out of 25,000 high schools (?). But with the "conquest" of San Diego and Cambridge, we now have a golden opportunity to use these school systems as dominos. Thus, we are obligated to help them succeed as best we can. That's why we are here! But as I said, we should from time to time, look up and way ahead.

If we succeed here, we can create a new ethic of teacher-to-teacher, scientist (and other professionals)-to-teacher cliques. The process: How does it work? How did we learn? What are the qualities (i.e., democracy, honesty, openness, lack of commitment to dogma . . .) that define the scientific culture? We can expand our successful connection of physics-to-chemistry-to-biology-to-science-to-history-to-literature. We can study the latest results in neurosciences as they relate to how children learn. We can incorporate the most useful educational technologies. We can invest time and creativity on affecting the students' way of thinking so that it penetrates deeply and influences their tastes, their ethics, their appreciation of truth and understanding, and the liberating quality of finding meaning in a jumble of experiences. They may even relate scientific truth and adventure to the human striving for a just and meaningful world.

We are living in a time of great tension and foreboding. There is a discouraging similarity of our present crisis to early episodes of crisis. We desperately need a recommitment to rationality, to environmental sanity. Of all the social obligations we may assume in order to make a better world, education is by far the most powerful. So as we go about making our schools better, let's keep some energy for the achievement of universal basic education.

From a recent New York Times Op Ed: *"A major American commitment to achieving universal education would give millions of poor children more hope and greater opportunities for choosing constructive futures."*

SUMMARY REPORTS

Assessment and Student Achievement

General Description:

We can do assessment for different reasons and in different ways. Among them are:

- Assessment as it relates to grades.
- Assessment for program success.
- Authentic assessment.

From among these, we identified our primary task as assessing program success.

Recommendations:

The following areas of assessment and registration statistics could be used as evidence to show that the physics-first course sequence is beneficial for student understanding of science.

Areas of Assessments:

- Content (SAT II, Force Concept Inventory)
- Student attitude/Enjoyment, VASS (values about science survey)
- Modes of learning (Bloom's Taxonomy)
- Habits of mind
- Science literacy

At this time tests do not exist for all of these areas, but such tests would be sources of valuable feedback. Monitoring increases in test scores of populations underrepresented in science-related fields (women and minorities) would provide additional valuable feedback.

Registration Statistics:

Student enrollment in upper-level and advanced placement courses

Student enrollment in science courses beyond science requirement

Number of students attending college and the number of science majors

Student enrollment in college science classes

Grades of students taking college science classes

Enrollment increases in student populations underrepresented in science-related fields (women and minorities)

Curriculum Comparison:

It would be useful to know how the curriculum of individual courses changed because of the change in the order of teaching those courses. For example, which concepts were added or deleted from a biology course when it followed physics and chemistry courses?

Related Issues:

Identifying elements or criteria that represent evidence of success.

High-Stakes Testing

General Description:

- What is the importance of standardized tests for physics-first or integrated science curricula?
- How will curriculum change affect test scores and test content?
- How do tests (like the examples listed) influence curriculum decisions? Should they have influence? For example, some state exams assume a particular order for science courses.

  <u>Examples of 'High-Stakes Tests'</u>

Texas	TASS: a state test required for graduation
Illinois	ISAT: partial ACT and state content, not required for graduation
Mass.	MCAS: science portion, recently changed, not required for graduation
California	SAT9: science portion, plus a standards section taken by grades 9-11

Recommendations:

- Establish a long-range evaluation plan that may include some standardized testing as well as other evaluative methodologies.
- Educate appropriate constituencies (parents, administrators, guidance counselors, college admission officers) about program benefits and assessment beyond test scores.
- Collect and analyze data to see how changes in curriculum affect test scores.
- Judge the program after three or four years, not after each year.
- Call the College Board or ETS for advice or explanations.
- Ask colleges for feedback about how they use standardized tests.
- Give standardized tests by course and not by grade.
- Look at standardized physics tests to see if they are testing conceptual or math-based physics.
- Base testing programs on national standards as a foundation but extend beyond these standards to meet the needs of the testing group.
- Push for changes in tests to match the new program, in content, methodology and

timing.

- High-stakes exams should include "hands-on" science problems in standardized tests (Golden State Exam Model).
- Students need to spend less time on testing and more time learning.

Related Issues:

- What are the essential goals of the course sequence? Should it be to increase science competency?
- How much does teaching to or preparing for an exam control curricular content?
- Does teaching physics first improve math scores (by giving students meaning behind the math!)?
- Are exams going to be used as a graduation requirement?
- Where will change happen? At the teachers' level? Administrators?
- How well will students be prepared for advanced placement courses? Tests?
- Will these curricular changes affect math test scores?

Middle School Articulation

General Description:

Schools must build support among parents, students and community members. *Mostly Physics First* requires that students experience a K-12 articulated mathematics and science curriculum. K-12 teachers need frequent, ongoing communication with each other. Articulation topics include:

- A sixth-eighth grade articulated curriculum plan creating a bridge from eighth to ninth grade and a preK-5 curricula that provides a seamless K-12 pathway.
- Communication skills and knowledge necessary for curriculum.
- The need to "sell science."
- Math preparation.

There is no continuity in middle school preparation for high school in the following areas:

- Teacher training
- Administrative support
- Funding
- Scope and sequence

Recommendations:

- Training and Leadership: Development and implementation of both a physics-first and meaningful middle school curricula require training and staff development that includes team building so there is collaboration and communication throughout the process and the district.
- Start where middle school teachers are: Build on knowledge established prior to ninth grade.
- Content Experts: The school will need teachers with strong science content backgrounds to develop and teach an integrated course.
    - Articulation: Establish partnerships between elementary and middle school and middle and high school teachers and their students
    - Implementation: Allow teachers autonomy in daily implementation.

- Curricular Objectives: Have clearly defined objectives. The curriculum should suggest how to reach objectives but not be a required curriculum.
    - National Curriculum Standards: A "set" middle school curriculum would allow districts with a high mobility rate to better serve student achievement.
- Funding: Provide adequate money for instructional materials and supplies and staff development.

Related Issues:

- Disparate or lack of funding
- Time and resources for teachers to communicate with one other
- Administrator background, support and attitude
- Lack of science-certified teachers
- Student background and skills
- Curricular content (both mathematics and science), including the entire K-12 curriculum
- Community involvement—articulating and communicating
- Providing physics/mathematics early to women and minorities

Parental Concerns

General Description:

Parents' concerns about implementing and maintaining a physics-first science sequence focus on the rationale for making this sequence change and the preparedness of students and their teachers for change.

Recommendations:

Many parent concerns are essentially unfounded and can be handled proactively with a well-thought-out public relations campaign**.**

- View parents as customers who can be persuaded to support the program, rather than as adversaries.
- Use parent-teacher nights to talk about the broad, long-term goals and rationale of the entire three-year sequence. The long-term goal is to create science-literate citizens. In today's world where technology is changing at an ever-increasing rate, average citizens will be called upon to vote on issues relating to the ethics and morality in scientific research. It is more imperative than ever that the average citizens be educated in the sciences.
- Use non-English newspapers, radio programs, focus groups and other communication channels to reach ESL parents. Ideally, science teachers proficient in a specific language should provide this information to those parents.
- Educate the parents of incoming freshman parents about the merits of teaching physics first. For example, hold an open house where prospective parents may be given literature and are invited to discuss the program.
- Show parents what their students do in physics classes.
- Explain to parents how the exposure to physics in the freshman year benefits girls and other traditionally underrepresented minority groups. Only 7% of the girls enroll in traditional physics courses. The percentage is low for Hispanics and African American students as well. By introducing physics to both groups early on, they may take more science and opt for careers in fields such as engineering.
- Arm college counselors with current data about college admissions and how

colleges perceive freshman science to help parents with concerns about college admissions.

- Promote physics as an investment in chemistry and biology.
- Clarify to the parents that ample learning support will be provided to their children.
- Develop a formal plan for struggling students.
- Allow time at the beginning of the course to give students a common toolkit of skills and vocabulary.
- Inform parents about the amount of professional development received by teachers moving to the inverted sequence, particularly in physics instruction.
- Redesign courses with the state or national standards in mind and make national and state standards available to parents. If this is done, no questions can be raised regarding the merit or rigor of the new curriculum.

Related Issues:

- Meeting state standards and assessments
- Mathematics skills
- Placing transfer students (mixing upper classmen with freshmen)
- College acceptance of freshmen physics as high school physics (i.e., will colleges consider it as "rigorous"?)
- Meeting physics requirements for college-bound, future science majors
- Level of the sophomore chemistry course (Will chemistry course become water downed as a result of physics first in the ninth grade?)
- Teaching physics to ESL/bilingual ninth-grade students (Where there are significantly large number of immigrant students, parents might be concerned that their children will not be as successful with physics as with other science courses (i.e., earth science, physical science, etc.)
- Availability of technology (digital divide)
- Empowering students (If they could see technology jobs for themselves linked vitally to this new curriculum, they would be more apt to buy in to the work they are being asked to do.)

Planning and Development

General Description:

Issues of planning time, retraining and resource needs are quite different depending on whether a school is implementing an integrated or a physics-first sequence. Implementing a physics-first sequence is a matter, at least superficially, of reordering the courses, whereas an integrated sequence involves creating connections between the science subjects and designing a curriculum that currently does not exist.

It is important to develop a comprehensive public relations plan that reaches every constituent group in the school community. The broader the support for the idea, the greater are chances for success. Clearly, it is important to include the school administration, all curricular leaders, faculty, the guidance staff, students and parents. Just as important, testimonials from colleges and universities, the College Board, the Educational Testing Service, and the National Association of College Admissions Counselors should promote the curriculum. Printed materials, workshops and systematic correspondence with all constituents are imperative and should be ongoing if the curriculum has a chance to be imbedded in school culture. Tracking and presenting both the quantitative and anecdotal information after the curriculum is launched remains a critical ingredient.

Recommendations:

The planning and development process has three distinct areas of focus: planning, implementation and continuous growth and development. The issues that connect all parts of the process are ongoing support from all stakeholders, communication with stakeholders, and evaluation and revision to meet current needs.

<u>Planning</u>

- Develop teacher buy-in. Teachers cannot teach junior chemistry to sophomores, nor senior physics to freshmen. The curriculum must be redesigned to be age appropriate.

- Start the planning process from scratch with philosophy and pedagogy, not just remodeling the old program.
- Provide teachers:
  - Common planning time and a location to do this work.
  - Release time before, during and after implementation.
  - Summer planning time.
- Address state/national standards and assessments in the new courses.
- Include stakeholders in the planning process.

<u>Implementation</u>

- Plan on a four-year process where basically both programs are taught as the school moves through a cycle beginning with a freshman class. This requires flexibility in teacher schedules and assignments and could cost more in FTE'S DURING THE TRANSITION.
- Team teachers with diverse backgrounds.
- Involve teachers who have broad backgrounds in science or a willingness to learn.
- Give teachers teaching new courses a reasonable prep load.
- Continue a program of staff development (curriculum planning and teacher training in content and pedagogy) as you implement the new sequence.
- Articulate with K-12 science and mathematics program.
- Network with other schools.
- Share resources with other schools (outlines/curriculum documents, etc.).
- Identify books and curriculum resources.
- Include the program in the school budget. Also, look for support from other sources such as businesses and universities.

<u>Continuous Growth and Development</u>

- Recognize and empower teachers.
- Plan for and support (time and resources) continuous staff development in content and pedagogy.
- Recruit teachers for the new sequence.
- Conduct ongoing programmatic evaluation and revision.
- Look at student performance and adjusting content and pedagogy to current needs.

- Reach out to university teacher training programs through student teaching and other contacts.
- Provide ongoing parent and community education.

Special Recommendation:

Use available resources to build a <u>comprehensive public relations program</u>.

- Make the goal to imbed curriculum into the school culture (Have others talking your walk).
- Continue to have a "vision" that will attract constituents.
- Include every constituent group possible (alignment, alignment, alignment).
- Monitor the "temperature" of all constituents continually.
- Continue to "feed" all constituents (educate, educate, educate).

Related Issues:

- Continuing K-12 science articulation
- Planning and revising in light of assessment results
- Monitoring changes in college requirements
- Managing teacher attrition and requirements
- Recruiting students
- Monitoring the impact of standardized testing
- Integrating of math and science
- Dealing with student mobility (transfers in and out of program)

Special Related Issues: Public Relations

- Keeping the administration excited and supportive
- Keeping teachers fresh and excited (Especially acknowledging that after the program is established that it will be more difficult to get the funding for planning and professional development that were available when the program was the "new baby.")
- Keeping the guidance office informed and supportive for the program

- Answering parents' questions
- Tracking college trends—How do they impact the program? What are good answers?
- Tracking evidence of success (be friends with those people in guidance)
- Talking the same language when we talk about the program

Professional Development

General Description:

Professional development is essential to planning, implementing and sustaining any curriculum initiative. We define professional development opportunities to include the following approaches:

- System-wide staff development in content and pedagogy that contributes to a support structure for ongoing improvement in professional practice.
- Departmental collaboration using discipline and course-based teams to provide rigorous, long-term staff development frameworks.
- Content workshops and institutes offered by districts, universities, collaboratives and others.
- Television and Web-based courses such as those offered by the University of Montana and the Annenberg Foundation.

Recommendations:

<u>Recognize the difference in needs for integrated science courses and physics-first courses</u>. Moving to integrated science courses requires a focus on content-based professional development, whereas moving to physics first requires a focus on pedagogy. For example, a physics teacher who traditionally teaches twelfth-grade physics will need professional development to be able to effectively teach ninth graders physics.

<u>Facilitate department-based, homegrown professional development</u>. Teachers will benefit greatly from weekly collaboration in which they create and share curriculum, support new teachers, do labs together and discuss pedagogical strategies. Incentives for weekly meetings can include pay, movement on salary scale and the professional benefit of collaboration. When these meetings are well organized and productive, teachers grow to depend on them as the culture of teaching shifts from a closed-door to interdependence and collaboration.

Devote district and school-wide professional development time to science department needs. Hire specialists or join local education collaboratives to bring fresh ideas to the district.

Take advantage of regional and national professional development opportunities such as:

- Distance learning (Annenberg courses)
- Online courses (University of Montana and NSTA)
- Statewide DoEd summer institutes
- Educational research collaboratives (BSCS, WestEd, TERC, EDC)
- National NSF teacher education projects (Kitt Peak)
- Advanced placement workshops (typically regional)
- University/community college partnerships
- Museum and science center partnerships
- Conferences at professional organizations (AAPT, NSTA, ACS)

Related Issues:

- Teacher fears precipitated by a lack of content knowledge as well as a lack of professional support throughout the transition the first year and beyond
- Time for professional development and how and when this will be accomplished
- Need to reflect both current and future needs/trends in science education in teacher training programs in college and graduate schools
- Articulation with the K-8 curriculum

Students’ Mathematics Skills

General Description:

There will be concerns about the nature and extent of students’ mathematics preparation for success in ninth-grade physics.

Recommendations:

- Build a relationship with the mathematics department based on common goals and a spirit of cooperation in order to coordinate the sequencing of mathematics to support science effectively.
- Make sure students are grounded in basic mathematics procedures.
- Develop a common vocabulary that is used to teach students in both mathematics and science courses.
- Encourage the development of science and mathematics projects based on shared, real lab data.
- Model application skills in physics and mathematics classes.
- Find a developmental assessment tool to determine students’ capacity for abstraction.

Related Issues:

Consider merging the science and mathematics departments.

Student Placement

General Description:

One important and potentially controversial topic for a school adopting a new science program, especially a non-traditional physics-first program, is that of student placement. There are three facets to this issue—the underlying philosophy for the program, factors affecting students prior to entering the program and factors affecting students leaving the program.

The phrase "student placement" itself can evoke debate about what it encompasses. We address five specific areas related to the placement of students in a physics-first science program: mathematics skills, sequence, special education, middle to high school transition and public relations.

Recommendations:

The school needs to:

- Determine a philosophy that will guide all other decisions.
- Establish a consistent set of policies to deal with students entering and leaving the program. These should foster appropriate student placement and be consistent with the guiding philosophy.
- Provide sufficient time for teacher collaboration to make accommodations for transfer students.
- Maintain opportunities for advanced courses (honors and second year).

<u>Mathematics Skills</u>

The decision that must be made before placing students in physics courses is how the physics course(s) will be taught. Physics can be taught with varying degrees of mathematics, ranging from purely conceptual (little to no mathematics), to algebra/trigonometry-based and calculus-based (often advanced placement physics). Once this decision is made, teachers can identify the mathematics skills students need which seems to be a major concern in student placement.

Low mathematics ability need not be the determining factor in physics placement. Students are capable of acquiring the necessary mathematics skills through the physics class. If a conceptual physics course is chosen, then mathematics skills are not a significant issue; students with any level of mathematics skills can enroll in this class. For the algebra/trigonometry based-courses, there are three options. First, physics teachers can address the mathematics skills as they come up. The second option is to integrate and coordinate curriculum with the mathematics department. The third option is to create an additional support/enrichment section in which students of different skill levels can participate.

Sequence

There are two recommended three-year sequences. One is physics, chemistry and biology, taken in this order.

The second is a spiraled, integrated course. In their fourth year, students can take an elective course such as astronomy, anatomy and physiology, marine biology, robotics, or any other course the school offers.

Special Education

A natural consequence of an increased enrollment in physics is a larger number of students with learning disabilities and special needs taking physics. The traditional sequencing does not see a large number of LD students in physics classes. Most high schools across the country participate in mainstream/inclusion settings rather than pulling LD students out of the regular education class as is often seen in elementary settings. Consequently, these recommendations are based on the assumption that the physics course is heterogeneous.

Whenever possible, it is highly recommended that physics teachers team-teach with full-time special educators. The following recommendations come from such a collaboration. If teaming is not feasible, then physics instructors should seek professional development opportunities in the needs of students with different learning styles. When implementing a course that takes into account individual learning styles, the following have been found critical for student success:

- Mechanisms in place for immediate feedback (online quizzes and tutorials, self-guided modules which facilitate remediation)

- Emphasis placed on visual components (appropriate use of color such as coding information to assist learning, concept mapping)
- Kinesthetic activities that allow freedom of movement and ensure students employ all their senses in acquiring concepts
- Varied instruction and student activities (lecture mixed with demonstration, hands-on laboratory work, review games, etc.); this includes use of different instructional audiovisual media.

<u>Middle to High School Transition Issues</u>

1. Skills in rising ninth graders.
   - Some schools or school districts track mathematics skills as early as fifth grade. This results in a multi-tiered system where only some rising ninth graders have algebra skills. Algebra skills are instrumental in determining the level of physics offered to ninth graders.
   - In some school districts there are many feeder schools leading to one high school. This can mean that there are differing levels of both mathematics and laboratory skills for rising ninth graders.
2. Instructors should be aware that some rising ninth-grade students and their parent(s) might suffer from *physics phobia*. Some anecdotal evidence has suggested that freshmen who have taken physics first have done well on SAT II in physics. Other evidence suggests that the physics-first sequence has led to a dramatic increase in the number of seniors taking AP science courses and science electives.
3. Whether the district or school is just starting with physics first or has already committed to this program, the issues in regard to placement surrounding transitions from middle school remain the same.
   - Rising ninth graders who have already had algebra in middle school would be more prepared for a more advanced or honors physics track.
   - Rising ninth graders who have not had algebra should be enrolled in an algebra course in grade 9.
   - Grade 9 classes with students having a broad range of laboratory skills and science reasoning abilities will need to be assessed by the instructor and any deficiencies addressed on an individual basis.

- Instructors need to reassure students and parents that conceptual physics has proven to be age appropriate and that students can be successful in this course.

4. Administrators and counselors should tell perspective ninth grade students and parents that the physics-first option has created more opportunities for taking advanced science courses in their senior year.

<u>Public Relations</u>

When a school or district moves to a physics-first science program, a thoughtful, proactive approach to public relations will help lead to desirable results and alleviate some of the misconceptions and concerns about the program. A first approach is to consider the stakeholders involved and explain the rationale for the program change to each of the stakeholder groups. An understanding of the rationale helps eliminate misconceptions and phobias. Open discussion sessions encourage the airing of concerns help resolve concerns and get stakeholders on board. Important stakeholder groups include the parents, community members, the board of education, administrators, guidance counselors, teachers and students.

The placement of students into the best science courses flows from having the stakeholders well informed regarding the initiative. If the adults who give the students advice understand the underpinnings of the science sequence, it is more likely that the students will receive good advice. The key players in this arena are the parents, the guidance counselors and the teachers.

Related Issues:

- Transfer students
- Remedial education
- Advising students beyond the sequence

Teachers' Fears/Resistance

General Description:

One of the barriers to implementation of the physics, chemistry and biology sequence is the fears that stakeholders in the process bring to the table. These are summarized as follows:

- Physics without higher math not as valid a course as physics with higher math
- Physics concepts missing in the conceptual curriculum
- Reduced enrollment in upper-end physics courses
- Freshmen not ready developmentally for physics capacity
- Teacher credentialing issues, for example, teaching out area of expertise and temporary assignments during transition period (and beyond if it results in increased physics enrollment)
- Too much teacher inertia to change

There are additional implications of these barriers relevant to integrated science courses.

Recommendations:

Missing Concepts: Less is more**.** Relevant information presented in context taught in an engaging manner leads to more learning. Building a contextual framework is more important than the volume of content. Data is available to show that "less is more." Brain research supports this concept (depth vs. breadth).

Mathematics Concerns: Do not let mathematics ability concerns overshadow other issues in the decision to go to physics first. Older students may have higher mathematics skills, but they still have difficulty applying what they know to physics applications. Spend time teaching the freshmen the application as you would older students; just spend a little more time checking for understanding.

Fears/Resistance: Right now there is no integrated curriculum available. Can teachers get enough time to develop the course properly? Administrative support is essential.

See the staff development component in this report. Released time and/or paid summer time is necessary for developing pedagogical skill and curriculum. Time available in the school day during implementation years is essential for proper curriculum development.

<u>Addressing Fears/Resistance</u>:

1. Students will receive inadequate physics preparation for college physics due to reduced mathematics component and to time lapse from frosh year to college.
   - All students have difficulty in transferring mathematics concepts to physics (and other courses) applications; don't let this red herring stop the process: spend time teaching/showing the necessary mathematics concepts.
   - Physics is what you make it in terms of rigor, whether it is conceptual or mathematics-based.
2. Teachers will have to teach outside areas of expertise in an integrated course and during a period of temporary adjustment for sequence realignment to physics first:
   - This should be viewed as an opportunity for professional development for all teachers (should be encouraged through incentives such as salary advancement, release time).
   - Additional benefit comes to the physics course with the fresh approach from a non-physics perspective.
   - Additional benefit comes to subsequent courses taught by the non-physics teachers with the additional understanding that comes from learning/teaching physics.
3. There will be reduced enrollment in "real" physics (second year):
   - Perhaps, but overall the second-year courses should flourish.
   - Alternatively, if the mathematics concepts are taught in the frosh-level course, this point is not true.
   - Alternatively, more students may take some physics because it is a frosh course without the higher mathematics.
4. Teachers will have to spend more time talking/teaching mathematics resulting in less physics content:
   - Teaching fewer concepts doesn't necessarily mean less physics concepts are learned. Building a conceptual framework is more important than the amount of

content. This is borne out in numerous research articles.
    - On the New York Regents' tests, scores on mathematics exams were 10% higher if students had taken freshman physics.
5. Are freshmen mentally capable to handle conceptual physics or mathematics-rich physics?
    - Physics is the easiest science to understand on the concrete level. There are numerous examples that are in each student's daily experience.
6. Additional problems arise from implementing an integrated science program: lost physics and other content, teaching out of comfort zone, additional planning time:
    - The first two items have been previously dealt with.
    - Additional planning time needs to be offered to teachers implementing integrated programs.

<u>Teacher Inertia</u>: These personal issues are natural and common amongst teachers (especially those with greater years of experience). Although the issues need to be acknowledged, they should not be elevated as valid reasons for preventing the transition. With time and experience in the alternative sequence these usually go away. Examples include the idea that going from homogeneous (tracked) to heterogeneous classrooms means a "lower" standard of students in that teacher's classes or that teachers are committing academic fraud because the conceptual physics isn't the same thing as "real" physics.

Related Issues:

- Staff development
- Planning and development
- Mathematics skills

SMALL GROUP REPORTS

Assessment and Student Achievement
Group A

Fermilab, Saturday, December 1, 2001

General Description:
- Assessment as it relates to grades
- Assessment for program success
- Authentic assessment

From among these we identified our primary task as assessing program success.

Recommendations:
Our recommendations consist of the types of assessments that would provide evidence that the "Physics First" course sequence is beneficial for student understanding of science.

<u>Types of tests that could be used as evidence</u>:

Content tests (SAT II, Force Concept Inventory)
Attitude/Enjoyment of students, VASS (values about science survey)
Modes of learning (Bloom's Taxonomy)
Habits of mind
Science literacy
These are the areas identified as useful to be tested. Not all of these are tests that currently exist, but are sources of valuable feedback. Increases in test scores of those populations who are less represented in science-related fields (women and minorities) should be monitored.

<u>Registration statistics that could be used as evidence</u>:

Student enrollment in upper-level and AP courses
Student enrollment in science courses beyond science requirement
Numbers of students attending college and the number of science majors
Student enrollment in college science classes
Grades of students taking college science classes
Enrollment increases in those populations who are less represented in science-related fields (women and minorities) should be monitored.

<u>Comparison of curriculum before and after changing course sequence</u>:
It would be useful to know how the curriculum of individual courses changed because of the change in the order of teaching courses. For example, which concepts were able to be added or deleted from a biology course if it was preceded by a physics and chemistry course?

Comments:
<u>Cambridge Rindge and Latin High School</u>
At Cambridge Rindge and Latin School, we are in our first year of implementing "Physics First." We are teaching a conceptual physics course to all incoming freshmen. Our major assessment focus so far has been on how to assess the success of the

individual course. We are beginning to write pre- and post-tests for each of the four major units of our course. It is also useful for us to collect ideas about assessing the entire new course sequence. Since we are at the beginning of our implementation, we are still able to collect information about students who were in the original sequence to be able to compare to those students who experience the new sequence.

Pinnacle High School

Seeking evidence for the success of the physics-first program presupposes successful implementation of the program. Yes, we teach physics to the ninth graders in our school. Does the tenth-grade chemistry teacher effectively build on the physics learned the previous year? Is the biology course in eleventh grade a cellular and molecular biology curriculum, and is it effectively building on the chemistry and physics taught prior? These questions must be addressed before evidence of the success of the physics-first program can be assessed. It was brought up that the program should not be named physics first, but rather biology last, since the program is much more than just a change in the sequence of physics instruction.

It was also brought up that in order to "sell" the program to schools and parents, it would be helpful to begin by explaining the long-term goal of the science curriculum in producing science-literate citizens especially in the changing climate in science and technology where citizens will be voting on numerous issues on the morality and ethics in scientific research and technology today. With agreement on that issue, it can then be proposed and supported that the physics-first program will best address and achieve this goal.

Tempe High School

Prior to the 1995-96 school year, the Tempe High School Science Department decided to rearrange the honors-level science courses to align with the AAAS suggestion of physics, chemistry and biology for the core science sequence. This would also move the honors-level curriculum into closer alignment with the standard level sequence of chemistry/physics, biology, chemistry, physics. (The chemistry/physics course consists of a semester of physics and a semester in chemistry, with the sequence varying according to individual teacher preference and lab availability. Only one-half of the biology enrollment takes chemistry, and only one-fourth to one-third of those students enroll in physics.) The realignment of the honors level lasted for four years before the political climate of the department changed again, and the department voted to return to a traditional sequence (biology, chemistry, physics), while keeping the regular level science sequence the same.

The reasons given for reverting to the traditional sequence were these:

- Enrollment in the Honors Physics 3/4 (second year) and physics courses went down due to the change to the alternative sequence.
- The integrity of the physics course was severely compromised by moving it to a conceptual basis to make it appropriate for freshmen.
- Students were not adequately prepared for college-level physics after taking just a freshman-level physics course.

I was unsuccessful in persuading enough department members to maintain the alternative sequence, though I used the following arguments:

Although the physics course was not the same, having less math-based curriculum, it was also true that the biology course was different, having stronger molecular and bioenergetics components.

More of our students would enter the workforce in biology-related fields (health and medicine, food production, etc.) than in physics-related fields (engineering, etc); therefore, it is more important to prepare students for success in the life science fields.

Preparing students to be scientifically literate citizens meant putting more emphasis on topics that were biology related (health, environment, biotechnology, bioethics, etc.) than physics related (nuclear energy, government funding, etc.).

While enrollment in the second-year physics course was down, the overall enrollment in physics courses was not down.

What I didn't have available for the discussion was research showing how students on the alternative sequence did on standardized tests to compare against those on a traditional sequence. I don't know if it would have carried enough weight—the discussion obviously was political, but it would be nice (and appropriate) to have data to support (or refute) the hypothesized value of the alternative sequence.

I hope to gather that kind of information to present to my department in an attempt to revisit the issue in the near future.

<u>South Pasadena High School</u>

At my school in South Pasadena, California, we offer physics to our sophomore students. We have two levels of physics, regular (conceptual) physics and honors physics. In my view, there are two main issues at our school. The first issue is the problem that many of our students have varying math skills and abilities. Some students simply haven't learned certain math skills yet because of the level of math they have already taken. If trigonometry and/or the law of sines and cosines are being used to teach vectors, then these math skills must be understood well in order for success to follow. Either you teach vectors without these math skills or you ensure the students understand these skills first.

A second issue is how much time is placed on certain topics. If too much time is devoted for certain topics, then not enough time will be available for later topics which may be just as interesting and just as important. The problem is compounded if the topics that are missed are topics included in the state standards. The question is: "Depth or breadth? "

<u>The Westminster Schools</u>

As a member of the science department at The Westminster Schools I have taught high school students in their first year, taking biology as ninth graders, and in their third year in either honors biology or advanced placement biology. There is a very noticeable difference in teaching students who have had chemistry and physics prior to taking a first-year biology course. I begin the year discussing what I refer to as biological chemistry building on what students learned previously in chemistry and quickly move into cell physiology. When we begin our discussion on energy conversions, bioenergetics, again a background in physics and chemistry is very useful and enables students to understand the processes with greater appreciation.

The issue in successfully changing over to teaching physics to all ninth-grade students was having qualified science teachers in the physics classrooms. Essentially, we had to accommodate the new sequence and the old at the same time, therefore having a large number of physics sections to cover. Fortunately, three members of our department, who normally taught chemistry or biology, were able to teach a regular, physics-first course for high school students.

Group Members:
M. Fowler, E. Goldstone, S. Greenhalgh, C. Megowan, K. Newton, D. Papadakis, A. Prybylski, G. Wheeler

(High-Stakes Testing)
Impact of Standardized Testing on Curriculum
Group A

Fermilab, December 1, 2001

General Description:
To assess the importance of standardized tests on physics-first or integrated science curricula

Recommendations:
- Judge the program after 3 or 4 years, not after each year.
- Do not hesitate to call the College Board or ETS for advice or explanations.
- Ask colleges for feedback about usages of standardized tests.
- Establish a long-range evaluation plan that may include some standardized testing as well as other evaluative methodologies.
- Educate appropriate constituencies (parents, administrators, college guidance, college admission officers) about benefits of the program that go beyond standardized tests scores.

Related Issues:
What are the essential goals of the program? Should it be to increase science competency? How much does teaching to or preparing for an exam control curricular content?

Schools should carefully examine their educational philosophy before committing to using standardized tests as a measure of success.

Comments:
<u>Two major categories of tests were delineated</u>.
These include subject-specific tests that measure content and/or competence, and district or statewide assessments. These include:
Subject-specific exams.
AP, SAT II, ACT and some state assessments that include the New York State Regents Examination.
School district-wide assessments.
State tests in general science such as the Golden State Exams in California.

<u>What evidence can be used to show improvement</u>?
It was difficult to agree on a definitive "*measure of success*" for the program, however, other indicators can be used as evidence for success. These include:

- Increased enrollments in AP science courses.
- Increased variety and enrollment in science electives.
- Increased exposure to science of traditionally underserved students such as females and minorities when physics is required in grade 9.
- Programs that stress problem solving, positive feedback from college professors and other professionals about the importance of having better science skills.
- Feedback from college professors and prospective employers about the need for programs that stress problem solving and integration among the sciences.

- Feedback from students who have gone through the program and are currently enrolled in college science programs.
- General improvement in science skills.
- General increase in interest in science.
- Improved AP and SAT II scores.
- Improved college performance.

CAUTION: The data, especially from SAT II, may be misleading.

Group Members:
M. Brito, B. Khoury, D. McNeil, F. Myers, M. Pagnotta, D. Papadakis

High-Stakes Testing
Group B

San Diego, Tuesday, March 26, 2002

General Description:
Some state exams assume a particular order of science courses.

Recommendations:
1. Give standardized tests by course and not by grade.
2. Look at standardized physics tests to see if they are testing "conceptual physics" or traditional math-based physics.
3. High-stakes exams should include "hands-on" science problems in standardized tests (Golden State Exam Model).

Related Issues:
1. Does teaching physics first improve math scores (by giving students meaning behind the math!)?
2. Are exams going to be used as a graduation requirement?
3. Where will change happen? At the level of the teachers? Administrators?

Comments:
High Stakes – For whom? Student? School? Administration?

CASE Exam in Chicago—a yearly exam with physics on the 11/12-grade version. Physics First did not jive with this. Funding may be dependent on this test.

Also in Illinois, the Prairie State Exam. ACT EXAM has been rewritten as the Prairie State Exam for Illinois. Students in integrated program score about 1 point higher on this exam than other students in the state.

New York Regents Exam is the same. Given as after physics course is completed.

California Standards are made for physics first. Golden State Exams are hands-on and multiple choice.

Exams that assume a specific content has been learned are problematic.

How do graduation requirements fit in with order of science courses?

Earth Science is in the national science standards and has been added to many state standards.

State tests are often focused on biology rather than physics.

Making physics accessible to some students means hands-on, reduced importance of math.

Physics may need the scaffolding of math to help students understand certain concepts.

"By this grade they must have had these courses . . ." approach in some schools is problematic.

In addition to looking at high-stakes scores, do pre- and post-concept inventories so you can track your students' gains (i.e., FCI, Chem Concept Inventory, etc.).

Group Members:
J. Chamberlain, M. Dufeny, F. Fisher, D. Gordon, B. Layton, R. Leonard, M. Vanacore

High-Stakes Testing
Group C
San Diego, Thursday, March 28, 2002

General Description:
How do tests (like the examples listed) influence curriculum decisions? Should they have influence?
How will curriculum change affect test scores and test content?

List of 'High-Stakes Tests'

Texas	TASS: a state test required for graduation
Illinois	ISAT: partial ACT and state content, not required for grad
Mass.	MCAS: science portion, recently changed, not required for grad
California	SAT9: science portion, plus a standards section taken by grades 9-11

Recommendations:
We need to educate the community (colleges and parents) on how to assess the new program beyond the test scores.

Testing programs need to be based the national standards as a foundation, but extended beyond these standards to meet the needs of the testing group.

We need more collection and analysis of the testing data, to see how changes in curriculum affect test scores.

We need to push for change in tests to match the new programs, in content, methodology and timing.

Students need to spend less time on testing and more time learning.

Related Issues:
- How well will students be prepared for advanced placement courses? Tests?
- Is there a possibility that these curricular changes would affect math test scores?

Concerns:
- Are the tests testing what kids really need to know? Content vs. essay/lab/process
- What is the purpose of testing?
- Testing is driving curriculum.
- What are the consequences of making curriculum changes which do not necessarily match tests?
- How can we test how well kids make connections?
- What about the timing of tests?
- Too much testing and loss of instructional time
- Will improvements in programs be reflected in test scores?
- Community response to test results
- Will college admissions be impacted?

Group Members:
T. Knutson, P. Lohstreter, D. McNeil, K. Newton, J. Spencer

Middle School Articulation
Group B
San Diego, Tuesday, March 26, 2002

General Description:
No continuity in middle school preparation for high school in the following areas:
1. Teacher training
2. Administrative support
3. Funding
4. Scope and sequence

Recommendations:
1. National Curriculum Standards. Having a "set" middle school curriculum would allow districts with a high mobility rate to better serve student achievement.

2. Content Experts. Teachers with limited science content backgrounds may not be as willing or able to develop and teach an integrated course.

3. Training and Leadership. Development and implementation of both a physics-first and meaningful middle school curriculum requires training and staff development that will include team building so that there is collaboration and communication throughout the process and the district.

4. Adequate Funding. A universal problem with adopting a new program is having adequate money for materials and supplies as well as staff development.

Related Issues:
- Disparate or lack of funding
- Administrator background, support, and attitude
- Lack of science certified teachers
- Divergent student background and skills

Comments:
Mission Bay High School
Very diverse student body, large number of ESL students, high mobility of students (military), physics first using active physics curriculum, lack of physics teachers (non-science teachers), lack of reading and English skills (large Mexican population).

Millard Public Schools
Teacher training is leading toward generalists rather than content specialists. The implementation of a meaningful integrated program is then compromised because teachers are not comfortable with the curriculum and instruction.

Very little open communication between levels — "Independent Contractor" mentality of teachers rather than team player approach. Teachers do not want to give up their "favorite lessons." There is no accountability for "failing students" at the middle level. They move on regardless.

Tombstone High School

Being a small district allows us to address many of the articulation concerns. We teach an integrated course that includes math, science and English. At the present time I am leading a group of junior high teachers to help them look for a pilot program that will be used by elementary and middle school teachers within our district. The curriculum will hopefully articulate with the high school math, English and science courses. Presently there seems to be a common commitment by all the teachers seeking to establish a quality curriculum that can be taught and assessed on a continuing basis.

Group Members:

K. Bardeen, P. McConnell, D. Noodell, C. Schwennsen, S. Weinshanker, D. Wood

Middle School Articulation: A K-12 Pathway, Not an 8-9 Bridge
Group C
San Diego, Thursday, March 28, 2002

General Description:
Mostly Physics First requires that students experience a K-12 articulated math and science curriculum. K-12 teachers need frequent and ongoing communication with each other. Build support through communication with parents and community members.

Preparation

6-8 needs an articulated plan that connects to curriculum plan in high school and preK-5 articulation.

Need to "sell science"

Creating a bridge or a path? Bridging from 8 to 9 or a K-12 pathway?

Math preparation

Communicate skills and knowledge necessary for curriculum.

Communicate to all constituents (parents, students, community).

Recommendations:
1. Have clearly defined objectives; curriculum should suggest how to reach objectives, not a required curriculum.
   - Allow for teacher autonomy in daily implementation.

2. Start where middle school teachers are: Build on knowledge established prior to ninth grade.

3. Establish partnerships between elementary and middle, middle and high school teachers and their students.

<u>Related Issues</u>:
1. Determine curricular content.
2. Involves entire curriculum K-12
3. Involves entire community, articulating and communicating
4. High school teachers must communicate with each other—need time and resources provisions.
5. Math curriculum K-12
6. Providing physics/math early to women and minorities empowers their future academic endeavors and wage-earning potential

Comments:
1. In-service with middle school teachers and high school science teachers:
   Address: Why mostly physics? . . . The necessary skills for mostly physics . . . .
2. Meeting with school board/committee/administration to support curriculum change
3. Math application collaboration

4. Are the physical sciences (physics, chemistry, earth-space sciences) equally weighted with life sciences?
5. Is freshman physics for every freshman a good thing? A student's interest can be as defining as their skills..
6. For some students, are other sequences appropriate? Freshman course, then physics, chemistry, and then biology.
7. We need to seize the opportunity to collect data on physics first before we recommend mostly physics first.
8. Need to collaborate with chemistry and biology teachers because these courses will need to change as more students have mostly physics first.

Cambridge Rindge and Latin High School
John Samp
All freshmen take physics.

Clinton Public Schools
Sue A. Moore
Integrated Science is taught 6-8 and students take Honors Chemistry or Physical Science.

Concord Consortium
Hilton Abbot (resource to Springfield, MA Public Schools)
Currently taking Physical Science in grade 9, Biology in 10, Chemistry in 11, Physics in 12

Forest Ridge School
John Fenoli
All freshmen take physics.

Pinnacle High School
Carol Savin
All freshmen take physics except for one earth science for special needs.

Walter Payton College Prep High School
Samuel Dyson
One-third of all students take physics as freshman; the remaining students take biology.

<u>Group Members</u>:
Leader: C. Savin
Members: H. Abbot, S. Dyson, J. Fenoli, S. Moore, J. Samp

Parental Concerns
Group B

San Diego, Tuesday, March 26, 2002

General Description:
This discussion is about parental concerns relative to implementing and maintaining a physics-first science curriculum sequence.

Parents have expressed a variety of concerns revolving around preparedness of students and their teachers and around the rationale for making this sequence change.

Recommendations:
<u>Many of parents' concerns are essentially unfounded and this can be handled proactively with a well-thought-out public relations campaign</u>.

- Use parent-teacher nights to educate and demonstrate what occurs in physics classes.
- Clarify to the parents that ample learning support will be provided to their children.
- Develop a formal plan for struggling students.
- Allow time at the beginning of the course to give students a common tool kit of skills and vocabulary.
- Promote physics as an investment in chemistry and biology.
- Inform parents about the amount of professional development received by teachers transitioning to the inverted sequence, particularly in physics instruction.
- Make national and state standards available to parents.
- Encourage teachers to view parents as a customer that can be persuaded to support the program, rather than as an adversary.

Related Issues:
Technology is not uniformly available to all schools. This problem needs to be addressed. Our students need to be empowered. If they could see technology jobs for themselves linked vitally to this curricular change, they would be more apt to buy in to the work they are being asked to do.

Comments:
The group identified the following collection of parental concerns:

- Children are "forced" to take physics, which limits their science options in later years. (There is a concern that they could miss out on AP or advanced science courses.)
- Fear of Physics – When the parents were in high school, physics was reserved for the intellectually elite.
- Students may not have the necessary math skills to succeed in physics.
- Physics may jeopardize their GPA and their college admissions.
- The short-term solution of allowing biology teachers to teach physics puts their children in a class with an unqualified teacher.
- Many parents feel unable to help their children with their homework.
- Parents recognize the value of the breadth of content and are concerned when depth is emphasized at the expense of breadth.
- When enrollment includes all freshmen, large class size becomes an issue.
- Parents prefer a traditional content-laden text. (*Active Physics* is problematic for

many parents.)

- Some teaching strategies commonly used in physics involving group evaluation are objectionable to parents. (i.e., collaborative groups)
- Insufficient data is available to warrant inversion of sequence.
- Parents perceive that physics may favor high achievement for boys over girls.
- Physics contains concrete and abstract ideas and parents want to be sure that it is developmentally appropriate for their children.
- Can students used to structured coursework succeed in an inquiry-based physics program?
- Learning disabled students' problems may be exacerbated.
- When and where do high school students study earth science?
- Are ample, appropriate materials and equipment available to do the job right?

Group Members:
B. Cordes, G. Curts, P. MacEgan, C. Megowan, F. Myers, J. C. Morris, E. Smith, R. Wortman

Parental Concerns
Group C
San Diego, Thursday, March 28, 2002

General Description:
The issue at hand is parent concerns regarding the sequence of science instruction taught in high school.

Recommendations:
Pinnacle High School
Teachers need to make sure that they speak to the broad, long-term goals of the new sequence. The focus should not be on "Why physics first?" but rather on the rationale behind the entire three-year sequence. The long-term goal is to create science-literate citizens. In today's world where technology is changing at an ever-increasing rate, average citizens will be called upon to vote on issues relating to the ethics and morality in scientific research. It is more imperative than ever that the average citizens be educated in the sciences.

Providence Public Schools
The change to physics first is significant in itself. Parents of all language backgrounds must be informed to this change. Focus groups, newspapers that print in different languages, radio programs, and other communication channels must be utilized to fully inform parents of the change to physics first. Ideally, science teachers who are proficient in different languages should be asked to provide this information to language diverse parents.

Incoming freshman parents need to be educated about the merits of teaching physics first.

It was also noted that by having physics in the freshman year, the exposure of girls and other traditionally underrepresented minority groups is increased. Traditional curriculums have only a 7% female student number; Hispanics and African American numbers are also fairly low. By introducing physics to both groups early on, they may not opt out of the hard sciences and hopefully this will encourage more into fields such as engineering.

Other Recommendations:
When transitioning from a traditional program to biology on top, it is vital to have the buy-in of the teachers. Teacher training is critical. Teachers cannot teach junior chemistry to sophomores, nor senior physics to freshmen. The curriculum must be redesigned and age appropriate. Transitioning is a four-year process where basically both programs are taught, a cycle beginning with a freshman class and moving on through. This requires flexibility in teacher schedules and assignments. It could cost a district more in FTE'S DURING THE TRANSITION.

Courses should be redesigned with the state or national standards in mind. If this is done, then no questions can be raised regarding the merit or rigor of the new curriculum. It is a change of mindset for the teachers. Time must be scheduled for collaboration between disciplines so as to build a coherent curriculum that actually builds on the skills previously learned. Communication is critical.

Arming college counselors with current data about college admissions and how freshman science is perceived might help parents with concerns about college admissions.

Teaching sophomore chemistry is not a watered-down junior class. Teaching physics first should have a positive impact on the skill level of entering chemistry students. The chemistry teacher can build on atomic theory, energy transformations, etc., giving more depth to the concepts previously taught. Because these concepts are introduced at an earlier time, less time is spent in the chemistry classroom; therefore, additions like organic chemistry can find time in the schedule. This deepens the knowledge base of chemistry students entering biology.

Related Issues:
Students' math skills:
Q1: Transfer student placement implies upper classmen mixed with freshmen.
Q2: Is sophomore chemistry a "watered-down" course? Secondly, will chemistry course become water downed as a result of physics first in the ninth grade?
Q3: Will colleges acknowledge freshmen physics as high school physics? (i.e., will colleges consider it as "rigorous"?)
Q4: Will curriculum address state standards and assessment?
Q5: Will college-bound, future science majors meet the physics requirements in ninth-grade physics?
Q6: Teaching physics to ESL/Bilingual ninth-grade students (This question is more of an issue in urban schools with a significantly large number of immigrant students who are new to the country. There could be the concern from parents that their youngsters will not be as successful with physics as with other science courses (i.e., earth science, physical science, etc.).

Comments:
Pinnacle High School
The school where I teach is a new school in its second year. We opened the school teaching physics first. As such there was no transitional process to the new sequence. Consequently, the only parent concern was whether the math requirements for ninth-grade physics matched the ninth-grade math curriculum.

Providence Public Schools
There is always a concern in urban districts in providing information to parents. There is a danger that the English-speaking parents will receive the information in changing to physics first, but non-English speaking parents are often the last group to be informed (if at all).

Incoming freshman parents need to be educated about the merits of teaching physics first. This is usually handled by Forest Ridge School with an open house where prospective parents may be given literature and are invited to discuss the program. In a private school setting where parents select the school, those who don't approve or have faith in our system will opt not to register their students with us. Response from most parents has been very supportive. Most warm to the idea after the rationale has been explained. Many comment that they never understood why biology was first in the first place. Teaching physics first has improved the biology program greatly, giving students a better literacy on issues they will vote on in the future and better preparing them for college biology. The chemistry program has changed in that we can now build on the concepts taught in physics and delve into areas such as organic chemistry, not traditionally taught to high school students.

Group Members:
E. Goldstone, K. Hinkley, D. Papadakis, T. Ramirez

Planning and Development
Group A
Fermilab, Saturday, December 1, 2001

General Description:
Issues of planning time, retraining and resource needs are quite different for schools attempting to implement an integrated sequence as opposed to physics first. Implementing a physics-first sequence is a matter of, at least superficially, reordering the courses, whereas an integrated sequence involves creating connections between the science subjects and designing a curriculum that currently does not exist.

Public Relations
It is important to consider a comprehensive public relations plan that reaches every constituent group in the school community. The broader the support for the idea, the greater are chances for success. Our group clearly saw the importance of including the school administration, all curricular leaders, faculty, the guidance staff, students and parents. Just as important, testimonials from colleges and universities, the College Board, the Educational Testing Service, and the National Association of College Admissions Counselors should promote the curriculum. Printed materials, workshops, and systematic correspondence with all constituents are imperative and should be ongoing if the curriculum has a chance to be imbedded in school culture. Tracking and presenting both the quantitative and anecdotal information after the curriculum is launched remains a critical ingredient.

Recommendations:
<u>Planning</u>
- Planning process should start from scratch with philosophy and pedagogy, not just remodel old program.
- Common planning teacher time and location
- Release time before, during, and after implementation
- Summer planning time
- Address state/national standards and assessments.
- Include stakeholders in the planning process.

<u>Implementation</u>
- Reasonable prep load
- Public relations for parents, teachers, administrators, guidance
- Teachers should have broad backgrounds in science or a willingness to learn.
- Staff development (curriculum planning and teacher training in content and pedagogy)
- Networking with other schools
- Support through budget and other sources such as business and university partnerships, grants
- Resource sharing with other schools (outlines/curriculum documents, etc.)
- Teaming of teachers with diverse backgrounds
- Books and curriculum resources must be identified.
- Articulation with K-12 science and math programs

Continuous Growth and Development

- Ongoing staff development in content and pedagogy
- Looking at student performance and adjusting content and pedagogy to current needs
- Support in time and resources for continuous staff development
- Teacher recruitment
- Outreach to university teacher training programs through student teaching and other contacts
- Ongoing parent and community education
- Teacher recognition and empowerment
- Ongoing programmatic evaluation and revision

The planning and development process has three distinct areas of focus: planning, implementation, and continuous growth and development. The issues that connect all parts of the process are ongoing support from all stakeholders, communication with stakeholders, and evaluation and revision to meet current needs.

Special Recommendations:
Public Relations

Use available resources to build a comprehensive public relations program.
Include every constituent group possible (alignment, alignment, alignment).
Continually monitor the "temperature" of all constituents.
Continue to "feed" all constituents (educate, educate, educate).
Goal must be to imbed curriculum into the school culture. (Have others talking your walk.)
Continue to have a "vision" that will attract constituents.

Comments:
Dwight-Englewood High School
I was given the opportunity at the Dwight-Englewood School to help design a public relations program that would support the introduction of a three-year integrated Math/Science/Technology curriculum, based on the ARISE program. Unlike some of the reported experiences, the genesis of the idea came from the Head of School and, though supported by key administrators, found a partially reluctant faculty.

Any stubbornness on the part of the faculty was overcome by giving the faculty legitimate empowerment and ownership in creating and continuing to evolve the curriculum. While it was clear the administration had made a decision to go in a different direction, the faculty was charged to design the specifics of that direction. We were able to secure funds to have the faculty complete exhaustive research. Visits to the Illinois Mathematics and Science Academy, the Thomas Jefferson School in Alexandria, Virginia, and the opportunity to visit five schools in England proved invaluable in securing full faculty support, if not enthusiasm for the evolving curriculum.

In the meantime, the school systematically presented an outline of the new plans to fifty colleges and universities (which we visited personally), the College Board, and the Educational Testing Service. We apprised each participant of program development updates and continued, at appropriate times, to ask participants for written and oral testimonials. Such information was conveyed to appropriate school constituents (faculty and administration, students, and parents) through a series of workshops. As we grew nearer to "launch time," workshops, presentations and seminars became more specific and frequent. We featured outside speakers when appropriate (directors of admissions at various colleges, ETS test developers, college professors).

When the program was finally launched, we continued to expand the public relations program, emphasizing the "track record" of the curriculum (SAT II scores, the number of AP science courses taken) versus previous years. We also made sure that people in strategic corners of the school (principal, college guidance, admissions, department chairs) were continuing to talk about and emphasize the program. In addition, it was important that those people were saying the same things, using the same language.

<u>Glenbard North High School</u>

Glenbard North was involved in an Illinois Scientific Literacy Grant through the ARISE program directed through Fermilab. This allowed our teachers to be funded for summer curriculum development projects and release time during the school year, independent of any financial commitments from the District Office. For three summers prior to implementation, participants met at Fermilab to be introduced to recent research in science education and techniques in engaged learning and problem solving. The year before implementation three teachers were given a common release period (and taught one less class) to work on the development of the course. Planning time continues to be a problem as we are in year four of implementation of the program.

We also had financial support from the grant for equipment and technology needs. Participants were awarded graduate hours at a very low cost for their efforts during the summer and throughout the school year. We have had excellent support from our administration by allowing us freedom to take risks and attempt something totally new.

Teams should make sure not to look at change as strictly curriculum change. Instruction shapes curriculum, so school reform leaders need to look at curriculum and instruction. It is much more challenging to change instruction than it is to change curriculum. Time and resources must be allocated to have teachers internalize current "best practices" involved in engaged learning.

In order to develop a coherent science program that incorporates the disciplines of biology, chemistry, earth/space science and physics, you need a team of three or four equally enthusiastic teachers committed over at least four years. At some point during the development, the science teachers will need to work with mathematics teachers also.

A physics-first curriculum (physics ninth grade, chemistry eleventh grade, physics twelfth grade), while it is not integrated science, does certainly require some significant strategy on the part of all the teachers involved. For example, moving a physics course from eleventh grade to ninth grade involves making important adjustments. Content will likely have to be more conceptual and less quantitative; and more difficult and broad as an issue is the fact that ninth graders do learn differently from eleventh graders. Each of the courses in the sequence cannot, must not, be taught simply as a discrete unit, but rather connections between physics, chemistry, and biology have to be brought in constantly—students need to be made aware of those connections. This mentality of connecting the three subjects requires that the teachers involved work together; and ideally, each of those teachers should teach in two of the disciplines. (Choate Rosemary Hall School)

<u>Belmont Public Schools</u>
Belmont provides several options for students in the high school science program. For twelve years we have offered freshman physics and biology as first-year options. For the past seven years we have also offered integrated science. We have a four-year science requirement. Our integrated course has a one- or two-year sequence. Students select the courses and sequence.

Our planning process began with a Science Steering Committee recommendation for teaching physics to freshman. This option was widely accepted, and as a result of our internal and external evaluation, we began the process of planning for integrated science in 1993. This planning was supported by a state framework that mandated integrated science as an option for all ninth- and tenth-grade students. A team of four teachers (physics, chemistry, and biology) used three summers to plan for the implementation of the integrated science course. Since K-8 science has been an integrated program for more than 25 years, this was an easy transition for parents and community.

The planning process and implementation was supported by a combination of district budget, grants and university staff development partnerships. The ongoing work of refining and adjusting to current student needs and change in state standards keeps new and veteran staff engaged in the process of continuous improvement. As a result of this work, the number of students who graduate with a full year of physics has grown from 25% to 91%.

There are several identified areas that are common to all schools planning and developing integrated science and physics-first courses.

<u>Teachers</u>
- Certification and preparation
- Predisposition
- Planning and development time
- Assignment (# of separate preparations)
- Common planning time during the school day
- Teacher turnover
- Network between physics and math
- Network between physics and chemistry
- Ongoing staff development

<u>Curriculum Leaders</u>
- Create the culture for successful planning and development.
- Empower the teachers.
- Liaison with administration/guidance/community

<u>Administrators</u>
- May be leaders of change.

- May be followers and supporters.
- Burden to staff courses

<u>Students</u>
- Choice
- Engagement
- Increased participation

<u>Parents and Community</u>
- Public relations is essential initially and over time.
- Make parents and community part of the planning process.

<u>Guidance</u>
- Understanding the science sequence and program is essential.
- Empower counselors as active promoters.

<u>Graduation Requirements</u>
- Range from 1-4 years
- Measurable increase in participation

<u>College Admissions</u>
- Cultivate college/university participation.
- Monitor trends (leaps or changes).

<u>Culture</u>
- Maintain broad constituent awareness of users of the model.
- Essential long-term effectiveness
- Embed curriculum in the local culture.

<u>Material Resources</u>
- Lack of appropriate integrated textbooks

<u>Addressing State/National Standards and Assessments</u>
- Make sure your school/district is part of the standards conversation locally and at the state level.

<u>Oak Park and River Forest High School</u>
At our school we had planning and development support through the Fermilab ARISE program. We had some compensated summer time during several summers as well as a release period for one year. This gave the teachers time to develop the curriculum for the program. Unfortunately all of the teachers were not always able to participate in this planning time, which did reduce progress. We also had to plan time to explain the program to all of the stakeholders and get their support for the course. The teachers involved have continued to promote the program.

Group Members:
K. Bardeen, M. Brito, J. Ford, T. Knutson, D. McNeil, L. Nyckel, L. Sorrell

Professional Development
Group A

Fermilab, Saturday, December 1, 2001

General Description:
Professional development is essential to planning, implementing, and sustaining any curriculum initiative. We defined professional development opportunities to include the following different approaches. System-wide staff development in content and pedagogy contributes to a structure that supports ongoing support for improving professional practice. Department collaboration using discipline and course-based teams provide rigorous and long-term staff development frameworks. Content workshops and institutes offered by districts, universities, collaboratives and others also contribute to ongoing staff development. Another source of professional development is television and Web-based courses such as those offered by the University of Montana and the Annenberg Foundation.

Recommendations:
<u>Recognize the difference in needs for Integrated Science courses and Physics-First courses</u>.
Transitioning to Integrated Science courses requires a focus on content-based professional development, whereas transitioning to Physics First requires a focus on pedagogy. For example, a physics teacher who traditionally teaches twelfth-grade physics will need professional development to be able to effectively teach ninth graders physics.

<u>Facilitate department-based, homegrown professional development</u>.
Teachers will benefit greatly from weekly collaboration in which they can create and share curriculum, support new teachers, do labs together, and discuss pedagogical strategies. Incentives for weekly meetings can include pay, movement on salary scale, and the professional benefit of collaboration. When these meetings are well organized and productive, teachers grow to depend on them, as the culture of teaching shifts from a closed-door one, to one of interdependence and collaboration.

<u>Devote district- and school-wide professional development time to science department needs</u>.
Hire specialists or join local education collaboratives to bring fresh ideas to the district

<u>Take advantage of regional and national professional development opportunities</u>.
Opportunities include:
- Distance learning (Annenberg courses).
- Online courses (University of Montana and NSTA).
- Statewide DOE summer institutes.
- Educational research collaboratives (BSCS, WestEd, TERC, EDC).
- National NSF teacher education projects (Kitt Peak).
- Advanced Placement workshops (typically regional).
- University/Community College partnerships.
- Museum and Science Center partnerships.
- Conferences at professional organizations (AAPT, NSTA, ACS).

Comments:

Belmont Public Schools

Belmont Public Schools has a systemic approach to professional development for all teachers in all disciplines. We have a system-wide planning committee that is made up of teachers and other staff. There are three concurrent strands each year. The strands are the focus for multiple years. We provide two courses for all teachers: Understanding Teaching and Empowering Multicultural Initiatives. We belong to EDCO, which is a greater Boston education collaborative that offers institutes in pedagogy and content by discipline. We are members of a second collaborative with Harvard Teachers as Scholars. They provide content institutes and workshops by discipline. We are currently working with *Understanding by Design* by Jay McTighe and Grant Wiggins. This focus has defined our curriculum work and professional development around the ideas of enduring understandings and essential questions.

Perhaps the most significant professional development in science is the intensive collaboration of teachers of the same courses. These teachers work to plan and implement the courses they teach. They identify pedagogy needs and content to address. The curriculum director provides time and resources for this collaboration.

Individual teachers take advantage of a variety of national and local professional development opportunities: AP institutes, BSCS institutes, EDC workshops, TERC workshops, NOAA programs, NSF projects and university institutes and workshops and others. Online courses such as those offered by the University of Montana and others provide opportunities for professional growth.

Cambridge Rindge and Latin School

The Science Department at Cambridge Rindge and Latin School offers much of its own professional development for K-12 teachers. There is strong support from the K-12 science coordinator and the central administration, including some financial support, for professional development. The Science Department spent several years developing an interdisciplinary science course for the ninth grade. When the decision was made to teach physics to all ninth graders, the department already had a great deal of experience developing curriculum. Much of this curriculum development happened in paid summer workshops. One additional model that was found to be effective last year was weekly meetings of teachers teaching the interdisciplinary course. When physics was implemented for ninth graders, it was almost a given that those weekly meetings would continue. They have become very valuable and were attended by up to 15 teachers regularly, including special education and math teachers. The value of a shared curriculum and collaboration has become addictive and has spread to other group meetings of teachers.

Glenbard North High School

In Glenbard District 87 we have no organized science professional development program. Most of our inservice/professional development is multidisciplinary/cross-curricular and very general. In the designing our integrated science curriculum, the professional development we received was through the ARISE program activities, not through the district. Our teachers have been able to take classes through the local community college and get salary schedule credit, but this was at their own expense. As new teachers come into the integrated sequence, veteran teachers have passed along binders of the complete curriculum and helped them along the way, meeting informally during planning periods, lunch and after school.

Westminster Schools
At the Westminster Schools we switched to teaching physics to all ninth-grade students three years ago. In preparation for the transition there was very little organized professional development. Essentially, individual teachers in the department were asked if they would be willing to teach a first-year physics course. Fortunately, two chemistry teachers and one biology teacher agreed to teach regular physics to ninth graders the first year of the transition. Two of these teachers continued to teach physics the next year to accommodate the additional sections of physics as the transition continued. To accommodate the increase in chemistry the second year into the sequence, we taught three sections of chemistry during summer school.

I sense a need for professional development in the areas of content as well as pedagogy for science teachers asked to participate in a transition into a new sequence. A continuous opportunity should be available for all educators to continue learning content and to develop pedagogy that will make instruction in the classroom effective for learners. I question how well non-science administrators/directors of schools understand the unique needs for science education. For example, science is a process, not just a bundle of knowledge. It requires not only the dissemination of knowledge but the introduction of skills and the nature of inquiry. Science is a collection of disciplines (i.e., biology, chemistry, geology, etc.) and within those disciplines information is constantly changing ("theories" change as new information becomes available). Therefore, for science to be real and applicable to students, it would benefit teachers to have the opportunity to continue learning and to be exposed to new technologies. This can be accomplished by using local resources (colleges and universities), attending professional conferences and watching instructional videos as well as distant learning opportunities.

Group Members:
K. Newton, L. Nyckel, A. Prybylski, E. Sorrell, E. Stellman

Students' Math Skills
Group A
Fermilab, Saturday, December 1, 2001

General Description:
We discussed concerns about the nature and extent of students' math preparation for success in ninth-grade physics.

Recommendations:

- Build a relationship with math department based on common goals and a spirit of cooperation in order to effectively coordinate the sequencing of math so that it supports science.

- Make sure students are grounded in basic math procedures.

- Develop a common vocabulary that is used to teach students in both courses.

- Encourage science and math projects where real lab data can be shared.

- Model application skills in physics and mathematics classes.

- Find a developmental assessment tool to determine students' capacity for abstraction.

Comments:
<u>How much math do students really need to succeed in ninth-grade physics</u>? Students need a basic facility with the procedural skills in mathematics: adding, subtracting, multiplying, dividing, fractions, decimals, exponents, order of operations, commutative, associative and distributive properties, ratio and proportion, percent, graphical analysis, and the significance of these procedures. Math that is taught without applications is a problem.

<u>Are ninth graders up to the math involved with ninth-grade physics</u>? Yes, but don't expect math application skills from ninth graders.

<u>Should/would math departments change their sequence of topics to facilitate physics learning</u>? Building a relationship between the math and science departments helps to develop common goals and a spirit of cooperation. Students need grounding in basic procedures and graphing skills. They *should* change their sequence to the extent that students are provided with the basic underpinnings mentioned above. If math departments would change their sequence to introduce graphing and functions earlier in their curriculum, it could be very useful. If the math and science departments could agree on a common vocabulary to describe like phenomena, it would be easier for students to see connections between the disciplines. Methods of developmental assessment such as TOLT (Test of Logical Thinking, Formal Reasoning Test) would be useful.

<u>Is teaching first-year physics math-free very difficult</u>? Teaching first-year physics math-free is not really teaching physics.

Are students able to access appropriate levels of math? Yes

Is it necessary to make 8th grade algebra a prerequisite? Not necessarily. A full year of algebra isn't really necessary as long as they have the procedural skills mentioned above.

Group Members
J. Ford, M. Fowler, E. Goldstone, P. McConnell, C. Megowan

Student Placement
Group A
Fermilab, Saturday, December 1, 2001

General Description:
One important and potentially controversial topic for a school adopting a new science program, especially a non-traditional "physics-first" program, is that of student placement. The phrase "student placement" itself can evoke debate about what it encompasses. This paper addresses four issues related to the placement of students in a "physics-first" science program, and offers recommendations to schools that are either implementing or seriously examining such a program.

Recommendations:
Math Skills
The decision that must be made before placing students in physics courses is how the physics course(s) will be taught. Physics can be taught with varying degrees of math, ranging from purely conceptual (little to no math), algebra/trigonometry-based, to calculus-based (often Advanced Placement Physics). Once this decision is made, this will allow teachers to identify the math skills required, which seems to be a major concern in student placement.

If a conceptual physics course is chosen, then math skills are not a significant issue; students from any level of math can enroll in this class. For algebra/trigonometry based-courses, there are three options. For the first option, physics teachers will address the math skills as they come up. The second option is to integrate and coordinate curriculum with the math department. The third option is to create an additional support/enrichment section in which students of different skill levels can participate.

Low math ability need not be the determining factor in physics placement. Students are capable of acquiring the necessary math skills through the physics class.

Sequence
There are two recommended three-year sequences. One is physics, chemistry and biology, taken in this order.
The second is a spiraled, integrated course. In their fourth year, students can take an elective course such as astronomy, anatomy and physiology, marine biology, robotics, or any other course the science teachers can offer.

Special Education
A natural consequence of an increased enrollment in physics is a larger number of students with learning disabilities and special needs. The traditional sequencing did not see a large number of LD students as they did not elect to take physics. Most high schools across the country participate in mainstream/inclusion settings rather than pulling LD students out of the regular education class as is often seen in elementary settings. Consequently, our recommendations are based on the assumption that the physics course is heterogeneous.

When implementing a course, which accounts for individual learning styles, the following have been found critical for student success.

Mechanisms in place for immediate feedback (online quizzes and tutorials, self-guided modules which facilitate remediation).
Emphasis needs to be placed on visual components (appropriate use of color such as coding information to assist learning, concept mapping).
Kinesthetic activities that allow for freedom of movement and ensure students employ all their senses in acquiring concepts.
Instruction and student activities must be varied (lecture mixed with demonstration, hands-on laboratory work, review games, etc.). This includes use of different instructional audiovisual media.

Whenever possible, it is highly recommended that physics teachers become involved in a team-teaching situation with a full-time special educator. The above recommendations are a result of such a collaboration. If a teaming collaboration is not feasible, then physics instructors should avail themselves of the opportunity to participate in workshops or similar training in the needs of students with different learning styles.

<u>Middle to High School Transition</u>
Issues involving transition from middle to upper school
Skills in rising ninth graders:
Some schools or school districts track math skills as early as grade 5. This results in a multi-tiered system where only some rising ninth graders have algebra skills. Algebra skills are instrumental in determining the level of physics offered to ninth graders.

In some school districts there are many feeder schools leading to one high school. This can mean that there are differing levels of both math and laboratory skills for rising ninth graders.

Instructors should be aware that some rising ninth-grade students and their parent(s) might suffer from *physics phobia*. Some anecdotal evidence has suggested that freshmen who have taken physics first have done well on SAT II in physics. Other evidence suggests that the physics-first sequence has led to a dramatic increase in the number of seniors taking AP science courses and science electives.

Whether the district or school is just starting with physics first or has already committed to this program, the issues in regard to placement surrounding transitions from middle school remain the same.

Rising ninth graders who have already had algebra in middle school would be more prepared for a more advanced or honors physics track.
Rising ninth graders who have not had algebra should be enrolled in an algebra course in grade 9.
Grade 9 classes with students having a broad range of laboratory skills and science reasoning abilities will need to be assessed by the instructor and any deficiencies addressed on an individual basis.
Instructors need to reassure students and parents that conceptual physics has proven to be age appropriate and that they can be successful in this course.

Administrators and counselors should tell perspective ninth-grade students and parents that the physics-first options has created more opportunities for taking advanced science courses in their senior year.

Public Relations

When a school or district transitions to a physics-first science program, many aspects of public relations need to be considered. A thoughtful, proactive approach to the transition will help lead to desirable results and helps alleviate some of the misconceptions and concerns about the program.

A first approach is to consider the stakeholders involved and take steps to explain the rationale for the program change to each of the stakeholder groups. An understanding of the rationale helps eliminate misconceptions and phobias. Open discussion sessions encourage the airing of concerns, help resolve concerns and get stakeholders on board. Important stakeholder groups include the parents, various community members, the board of education, administrators, guidance counselors, teachers and students.

The placement of students into the best science courses flows from having the stakeholders well informed regarding the initiative. If the adults who give the students advice understand the underpinnings of the science sequence, it is more likely for the students to receive good advice. The key players in this arena are the parents, the guidance counselors and the teachers.

Related Issues:
- What happens with transfer students?
- Is remedial education an option?
- What about advising students beyond the sequence?

Comments:

Albion High School

Albion High School is in a rural district. It is heterogeneous in all subjects with no tracks. Students can self-select science courses. The numbers of students in freshman physics ranges from 10%-25% of the freshman class. The same physics course is taught to all students, since the state Regent exam dictates that all of the physics classes are the same.

Box Elder High School

Box Elder High School is tenth, eleventh and twelfth grade only. Utah has a two-year science requirement for high school graduation. This was impetus for the creation of physics first. For many students physics is their last science experience.

Cambridge Rindge & Latin School

With 1800 students, CRLS is the only public high school in the city of Cambridge. CRLS serves a diverse group of students, ranging from children of MIT and Harvard professors to children of recent immigrants and low-income parents. Historically, the high school has been tracked which served high socio-economic students very well but underserved a vast majority of low socio-economic students.

This is the first year that physics first was introduced into the science department. All freshmen are required to take physics first and those classes all follow the same curriculum. Of the 25 sections of Physics First, five sections are co-taught with special education teachers. These classes are offered to students who have been identified with low literacy skills. All of the Physics First teachers meet weekly to plan curriculum, along with several special education teachers and math teachers.

Dwight-Englewood
Dwight-Englewood has a three-year spiral sequence (most physics is done in second year). There is a high degree of coordination with math courses and among teachers. The school has a commitment to making special attention to teachers in different disciplines and time to work with math teachers.

Farmington High School
Farmington High School has 1200-1300 students and is in its eighth year of doing physics first. There are two levels: honors and regular. Honors prerequisite is Algebra I in eighth grade. About 50% of the students do this, but only 30% of them enroll in Honors Algebra. Tenth graders take chemistry and eleventh graders take biology. The tenth-grade students have a choice of chemistry, honors chemistry or advanced placement chemistry. The eleventh-grade students have a choice of biology, honors biology, or advanced placement biology. One real benefit is the effect on the Advanced Placement program. In the past years about 50 students enrolled in AP sciences; this year 261 students are enrolled in AP classes. The mean scores have remained the same. We were worried that this wouldn't be "real physics," but the mean scores on SAT II have been around 600.

Girls Preparatory School
We are a private all girls day school in Chattanooga, Tennessee. We are in the second year where all freshmen take Physics I using the *Conceptual Physics* with Hewitt text. The math level of the students is Algebra I or Geometry. We have honors and regular level physics. All regular classes are mixed in terms of the math background. Tenth graders take Chemistry. After this, students can choose from Biology, Physics II, AP Biology, AP Chemistry, AP Physics, Human Biology, Forensics Science, Marine Science or Astronomy. We require two science credits for graduation, but in reality, 85% of our students take three or more science courses because of college entrance requirements.

Pinnacle High School
Pinnacle High School has 1500 students and is in its second year of existence. All students take physics, but those that have completed Algebra are placed in Advanced Physics, while those who are currently taking Algebra are placed in regular physics.

Group Members:
P. McConnell, F. Myers, M. Pagnotta, C. Savin, E. Smith, E. Stellman, M. Vanacore

Student Placement
Group C

San Diego, Thursday, March 28, 2002

General Description:
One of the central issues of science curriculum arrangement is that of student placement. There are three facets to this issue: underlying philosophy for the program, factors affecting students prior to entering the program, and factors that affect students exiting the program.

Recommendations:

The school needs to determine a philosophy that will guide all other decisions.

A consistent set of policies to deal with students entering and leaving the program needs to be established. These should foster appropriate student placement and be consistent with the guiding philosophy.

Sufficient time for teacher collaboration needs to be made available so that accommodations can be made for transfer students.

Opportunities for advanced courses (honors and second year) must be maintained.

Comments:
Understanding the philosophy and design of the physics-first class will influence student placement. Design issues include leveling (honors vs. non-honors) and heterogeneity (diverse students taking the same course), special education inclusion, and whether the course is a prerequisite for further coursework,

A school needs to decide whether it wants to offer different levels of Physics First. Designing a single course in which students with diverse math skills (and possible special education background) can succeed is a worthwhile challenge. The curricula for these classes must be accessible to a diverse population; students needing support and those needing enrichment must be accommodated.

Schools that choose to offer more than one level of Physics First will have to make additional decisions on how many levels to offer and how these levels are differentiated.

Is the physics-first class a prerequisite for further course work? What happens if students don't pass the class or transfer in during the school year?

<u>Classical High School, Providence</u>
Certain fundamental issues involving student placement arise dealing with the issues of preparation to enter into a physics-first class. These issues involve:

1. What mathematics level is expected for success in a program?
2. What criteria will be used to place the student into the program? Will there be a placement instrument?
3. Is there diversity of background regarding the number of feeder schools?
4. How are transfer students placed in the program? What type of grading system will be used?
5. What support measures will be in place for the unsuccessful or failing student?
6. What are the clear expectations for the class?

Another major area of concern resulting from changing the sequence of high school science content is what happens to students after they exit the program. This area can be divided into three distinct issues. One major concern is what options are available to students after they finish the core courses. The second issue is what happens to students who fail a part of the core curriculum. Lastly, there are issues surrounding students who are transferring to another program.

Most states only require two years of science to graduate from high school. Students who are in an integrated science program may have an advantage over students in a physics-first program in that they have had a taste of the four major science disciplines. Therefore, they are able to take more advanced or specialized courses their last two years of high school. With this type of program, as well as others, it is crucial that AP and higher-level courses be offered so that students may challenge themselves in the sciences the remaining two years of high school. This also allows them to find their niche in scientific fields that they may explore as a future career.

In a three-year science program (physics, chemistry, and biology) students often only have one year to take an advanced science course. Additionally, it may lead to the exclusion of biology for a large percentage of students (as it currently does for the exclusion of physics) due to the two-year graduation requirement. The tradeoff for this type of program is, perhaps, a more extensive exposure to these three content areas as the core curriculum.

Failure in the appropriate science curriculum sequence has the same difficulties as failure in the traditional science program. These include the reasons for failure and the consequences of failure. Students fail for a number of reasons, including being ill-prepared, lack of interest in topic, lack of interest in education, socioeconomic, and transience. Once a student has failed, the decision to have a student repeat the course or be allowed to proceed to the subsequent course has inherent consequences. For example, if a student is forced to repeat the course, he will be out of sync with his classmates. In addition, the student's future science class options are reduced. If the student proceeds to the next course, he may not have the foundation to succeed in the following course.

Students transferring in midstream of an integrated program face enormous difficulties when transferring to a school on a different program. Complications in determining what courses they have credit for and will need to take and courses they will need to take in their new school abound. These are less in nature if they have completed the two-year core program. Students in a three-year core curriculum students that transfer mid-course are usually only harmed if the course in their new school has higher prerequisites than their original school. Students transferring from an alternative program may be out of sync with their classmates.

Group Members:
B. Christopherson, J. Dufort, S. Greenhalgh, P. Saxby, E. Stellman

Teacher Fears/Resistance
Group A

Fermilab, Saturday, December 1, 2001

General Description:
One of the barriers to implementation of the physics, chemistry, and biology sequence is the fears that stockholders in the process bring to the table. These can be grouped into the following categories:

- Sense of physics without higher math not being as valid a course as physics with the higher math
- Issues related to teacher credentials (teaching content out of comfort zone, temporary assignments during transition period—and beyond if it results in increased physics enrollment)
- Missing physics concepts in the curriculum
- Reduced enrollment in upper end physics courses
- Developmental capacity of freshmen
- Issues of teacher inertia
- Additional implications of the above relevant to integrated science delivery

Recommendations:
Missing Concepts
Less is more**.** Relevant information presented in context taught in an engaging manner leads to more learning. Building a contextual framework is more important than the volume of content. Data is available to show that "less is more." Brain research supports this concept (depth vs. breadth).

Math Concerns
Don't shy away because of math capability. Freshman = as present. Older students may have higher math skills, but they still have difficulty in applying what they know to physics applications. The suggestion is to still spend time teaching them the application as you would older students; just spend a little more time checking for understanding.

Do not let math ability concerns overshadow other issues in the decision to go to Physics First.

Fears/Resistance
There is not an integrated curriculum available. Can we get enough time to develop the course properly? Administrative support is essential. See the staff development component in this report. Released time and or paid summer time is necessary for developing pedagogical skill and curriculum. Time available in the school day during implementation years is essential for proper curriculum development.

Addressing Fears/Resistance
Inadequate physics preparation for college physics due to reduced math component and to time lapse from frosh year to college

- All students have difficulty in transferring math concepts to physics (and other courses) applications; don't let this red herring stop the process: spend time teaching/showing the necessary math concepts.
- Physics is what you make it in terms of rigor, whether it is conceptual or math-

based.

Teaching outside of expertise area due to integrated approach and to temporary adjustment from alignment change

- This should be viewed as an opportunity for professional development of all teachers (should be encouraged through incentives such as salary advancement, release time).
- Additional benefit comes to the physics course with the fresh approach from a non-physics perspective.
- Additional benefit comes to subsequent courses taught by the non-physics teachers with the additional understanding that comes from learning/teaching physics.

Reduced enrollment in "real" physics (consequently 2nd year)

- Perhaps, but overall the second year courses should flourish.
- Alternatively, if the math concepts are taught in the frosh-level course, this point is not true.
- Alternatively, more students may take some physics because it is a frosh course without the higher math.

Have to spend more time talking/teaching about math, resulting in less physics content

- Teaching fewer concepts doesn't necessarily mean less physics concepts are learned: building a conceptual framework is more important than the volume of content. This is borne out in numerous research articles.
- On the New York Regents' tests, scores on math exams were 10% higher if they had taken frosh physics.

  Are freshman mentally capable to handle conceptual physics or math-rich physics?
- Physics is the easiest science field to understand on the concrete level: numerous examples about that are in each student's daily experience.

Additional problems arise from implementing an integrated science program: lost physics and other content, teaching out of comfort zone, additional planning time

- The first two items have been previously dealt with.
- Additional planning time needs to be offered to teachers implementing integrated programs.

<u>Issues of Inertia</u>:
Going from homogeneous (tracked) to heterogeneous classrooms mean a "lower" standard of students in that teacher's classes.
Feeling of academic fraud because the conceptual physics isn't the same thing as "real" physics

These are personal issues that are natural and common amongst teachers (especially those with greater years of experience). Although they need to be acknowledged, they should not be elevated to valid reasons for preventing the transition. With time and experience in the alternative sequence these usually go away.

Comments:

Albion High School

Our biggest fear was working with mixed grade levels as well as mixed ability levels. In the end both fears turned out to be insignificant. The math level differences turned out to be much smaller than expected. Students in mixed grade levels worked well together. This may have been a result of the small school district.

Glenbard North High School

Fears at our school concerned adding another layer to our regular track science curriculum. The integrated program has a slightly higher math requirement. The fear was that this would take the better students away from IPS and reduce the quality of that program. After four years this has not happened. We still have about 16 sections of IPS and 3 or 4 sections of the integrated program. There have been no negative reports.

Oak Park and River Forest High School

Teachers at our school have two main fears—having to teach outside of their subject area and not having the time and support to develop the integrated curriculum. Whenever possible we have scheduled two classes during the same period in adjoining rooms. We have then paired two teachers with complimentary backgrounds to teach the two classes. They have been able to have joint class discussions and to assist each other when problems come up. We have also tried to have common planning periods for these teachers so that they can prepare and discuss curriculum together. Through the Fermilab ARISE program we gave each teacher a release period the year before we implemented the program. Teachers also had some summer development time before each new course was implemented. This gave the teachers time needed to work together to develop the integrated curriculum used in the course.

Group Members:

K. Bardeen, C. Chiaverina, S. Greenhalgh, T. Knutson, E. Smith, M. Vanacore

APPENDIX B: HIGH SCHOOL DESCRIPTIONS

Albion Central School District
302 East Avenue
Albion, NY 14411
Telephone: 585-589-2040
URL: www.albion.wnyric.org

Albion Central School District - students: 2700, Pre-K–12
Albion High School - students: 850, 9-12

Science Classes Taught: Earth Science, Biology, Chemistry, Physics, College Biology (6 hours) and AP Biology

Students self-select all their science classes. There are no prerequisites or sequences. All classes are heterogeneously grouped and mixed grade levels. Approximately 10-25% of freshmen take physics as freshmen.

Belmont High School
221 Concord Avenue
Belmont, MA 02478
Telephone: 617-484-4700
URL: www.belmont.k12.ma.us

This suburban high school (1,000 students, grades 9-12) is located in an affluent community adjacent to Cambridge and eight miles from Boston. The student body is culturally, ethnically and economically diverse. Sixty percent of the students go home to families whose first language is not English. Ten percent of the student body represents a variety of racial minority groups. Asian students represent 6% of the minority population. Because of the proximity to Boston and Cambridge, many of the residents of Belmont are in the education profession at local universities.

Belmont is a small community of 26,000 residents with 3,600 students in the public school. Approximately 6% of school-age children attend independent schools.

The school requires four years of lab science for graduation. The district has K-12 curriculum directors for all disciplines. There is a superintendent for curriculum and instruction. We have curriculum steering committees that plan and evaluate curriculum initiatives. There is an integrated science curriculum in grades K-8.

Belmont High School has offered physics for ninth graders since 1989. In 1993 we began planning for an integrated science course as another choice for ninth graders. The integrated science course was implemented in 1995. This course development and implementation was guided by the education reform efforts in Massachusetts. There was a mandatory integrated science test in grade 10. Some students continued with physics first and chemistry second while the majority of students took integrated science as ninth graders and biology as tenth graders. In 1999, the Massachusetts Science and Technology/Engineering Frameworks were revised and the testing policy changed to end-of-course tests. Students now take a test at the completion of the ninth and tenth grade. The test is an end-of-course test. We currently offer physics, integrated science and biology as choices for ninth graders. Most students choose chemistry in grade 10. A few students choose a two-year integrated science sequence and take a second year in grade 10. Juniors take the course they did not take as a freshman at the college preparatory, honors, or advanced placement level. Seniors take a variety of electives. About 150 students take two sciences in their junior and/or senior year. Ninety-one percent of all students have a full year of physics.

Berkeley Preparatory School
4811 Kelly Road
Tampa, FL 33615
Telephone: 813-885-1673
URL: www.berkeleyprep.org

Founded in 1960, Berkeley Preparatory School is a coeducational preparatory day school, pre-kindergarten through grade 12, serving the Tampa Bay area. The Lower Division is comprised of grades Pre-K through 5, the Middle Division includes grades 6 through 8, and the Upper Division is comprised of grades 9 through 12. Traditionally, 100% of Berkeley's graduates continue their education at four-year institutions. In 2001, 74% entered out-of-state colleges and universities. Berkeley's total enrollment for 2000-2001 was 1174, with 480 students in grades 9-12. Berkeley enrolls students on a competitive basis of admission. It is a selective process based on information from the application, candidate's record, teacher recommendations, interviews and admission tests.

The upper division program is designed to provide students with the atmosphere and advantages of a small liberal arts college. Science content, processes, applications, and promotion of sound student character values are the four cornerstones that support Berkeley science activities. One credit each in the areas of biology, physics and chemistry is required in the upper division for graduation. The sequence of study is biology, physics, chemistry—taken in the ninth, tenth and eleventh grades respectively. Advanced placement courses are offered in biology, chemistry, physics and environmental science. Advanced topics courses are offered, when there is sufficient demand, in anatomy and physiology, genetics, organic chemistry, astronomy and microbiology.

Box Elder High School
380 South 600 West
Brigham City, UT 84302
Telephone: 435-734-4840
URL: www.boxelder.k12.ut.us/behs/index.htm

BEHS is one of two high schools in the Box Elder County School District in northern Utah. ThiPropulsions and several other engineering firms are based in Brigham City.

Brigham City is also renown across the state for its fruit farming, namely peaches. The school population is approximately 1500 students in grades 10, 11 and 12. The school is economically diverse with an estimated 25% eligible for free or reduced lunch. Minorities, most of whom are Hispanic, comprise about 15-20% of the student body.

The state of Utah has a two-year science requirement for high school graduation while the major state universities and colleges employ three- or four-year requirement policies. In 1997, Science Department Chair Bob Cefalo initiated a change in our course sequencing. Under the former system, freshmen completed earth systems followed by biology. Only students interested in science or who were college-bound enrolled in physics their senior year. The new sequence encourages students to complete earth systems in the ninth grade, as biology is now a senior class. All incoming sophomores are then enrolled in physics. Consequently, many students have completed their science requirements at the end of tenth grade. The physics-first approach was implemented with a twofold purpose. One, to provide a readily applicable science literacy for students who will not be continuing on in science. Second, to coordinate the science curriculum so chemistry may build upon physics and, likewise, biology then builds on both physics and chemistry.

Utah has mandated testing for all juniors and students complete a Utah State Core test at the end of each of their science courses. The physics core test is designed for seniors who have completed the traditional biology, chemistry, and physics sequence, as Box Elder High School is the only school in the state with the physics, chemistry, and biology curriculum.

Cambridge Rindge and Latin School
459 Broadway
Cambridge, MA 02138
Telephone: 617-349-6400
URL: www.crls.org

Cambridge is a city of 98,000 people representing a broad cross-section of customs, talents and backgrounds. Fourteen elementary schools feed into Cambridge Rindge and Latin School, a comprehensive high school of close to 2,000 students. The Cambridge Rindge and Latin School was formed in 1977 when the Rindge Technical School merged with Cambridge High and Latin. In 1999 CRLS was redesigned and divided into five small schools, each of which reflects the diversity in race, culture, and socioeconomic class that makes the Cambridge community unique. The five schools are designed to promote high levels of learning and achievement for all students.

Beginning in September 2000, all ninth- and tenth-grade students take CORE classes. The CORE consists of language arts, social studies, mathematics, and science. In addition to their CORE, students choose a foreign language, an elective, and a support and enrichment class. As of September 2001, the Science Department began teaching physics to all ninth graders in the CORE program. The transition to a physics-first program stemmed from the desire to offer one science class to all ninth graders. In the past, students chose between intensive (honors) biology and an interdisciplinary science course. Due to student self-selection, these two courses became segregated by socioeconomic status and race; an unfortunate outcome. The shift to physics first allows the Science Department to address both pedagogical concerns of science sequencing as well as social concerns of equity.

The Science Department is currently in the process of defining the course sequence for tenth and eleventh graders. Regardless of sequence, by the end of eleventh grade all students will have taken physics, chemistry and biology. In their senior year, students can select from a wide range of science electives. These electives include: Advanced Placement Biology, Chemistry, Physics, Marine Biology, Anatomy and Physiology, Engineering Design, Astronomy, Ecology, Designer Genes and Infectious Diseases.

Casa Grande Union High School
2730 N. Trekell Road
Casa Grande, AZ 85222
Telephone: 520-836-5280
URL: www.cguhs.org

Casa Grande Union High School is an irrigation-based farming area halfway between Phoenix and Tucson. The school has 2300 students with a Hispanic majority.

This year 2001-2002 is our first year of teaching physics first. We have two sections of physics first for freshmen and three sections for juniors. Contrary to our expectations, the freshmen have on average performed as well as the juniors on exams, in classroom work and in their laboratory work. Next year we expect to have all our freshmen start out with some form of physical science on three different levels. The lowest level will be physical science for students simultaneously taking pre-algebra; the middle level will be conceptual physics for students simultaneously taking algebra; the top level will be accelerated physics for students who have taken algebra in 8^{th} grade. Our curriculum follows that devised by the Physical Science Study Committee. We want to give our freshmen a coherent story about the discovery and properties of the Bohr atom.

Choate Rosemary Hall School
333 Christian Street
Wallingford, CT 06492
Telephone: 203-697-2000
URL: www.choate.edu/

Choate Rosemary Hall is a boarding and day secondary school of 850 talented students and 120 dedicated faculty from diverse backgrounds who genuinely enjoy living together and learning from each other. For graduation, we require two years of laboratory science—one must be physics or chemistry, the other biology. All first-year courses are taught on two levels, regular and honors. Virtually all ninth graders take physics, more than half take "regular" physics which is a conceptual course, uses Paul Hewitt's text supplemented by some extra quantitative problems. The other first-year physics course that ninth graders take is more "conventional"; most of those students take the SAT-2 in physics and score very well. About 85% of the tenth graders follow their physics with chemistry, and then all students will take biology in either eleventh or in twelfth grade. Many students (75%) take a fourth science course, either an advanced placement course (we offer Advanced Placement Chemistry and both B- and C-level Advanced Placement Physics, but we don't offer Advanced Placement Biology), or a 2nd-year, advanced course; some of those advanced courses are full year, and some are for just one or two trimesters.

Clinton Middle School
P.O. Box 729
Clinton, OK 73601
Telephone: 580-323-4228
URL: www.clintonms.k12.ok.us

Clinton is a town of 10,000 located in western Oklahoma. The major industry is agriculture. There is a meat processing industry and dog food factory. There is a large immigrant labor population. Most of the immigrants have not been to formal schools and lack literacy skills in their native language and English.

Clinton Middle School serves grades 7 and 8 with elementary schools that serve K-2, 3-4, and 5-6. There is one comprehensive high school in Clinton. There are 650 students in the high school and 350 in the middle school.

Currently the high school science sequence is non-honors physical science in grade 9 or honors chemistry. Grade 10 is biology or physics. Grade 11 is advanced placement biology, human anatomy or botany. Grade 12 is advanced placement chemistry or Chem 2 or Physics 2.

Dublin Coffman High School
6780 Coffman Road
Dublin, OH 43017
Telephone: 614-764-5900
URL: www.dublinschools.net/high/coffman/coffman.html

Dublin Coffman is a suburban school in northern Franklin Co., Ohio. It is an extremely affluent school district, the wealthiest in the Columbus metro area. Ninety-eight percent of our graduates go on for further study in higher education. The parents are extremely pro-active, pro-educational. We have a course sequence featuring physics first. All freshmen must take the physics course. We then have biology open for sophomores, chemistry as juniors, and finally physics again as seniors. We have three advanced placement courses also in biology, chemistry and physics. Our last science choice would be an earth science derivative known as Systems of the Earth. Ohio will have a graduation test online in two years that all students will have to pass to graduate. Right now we are dealing with the proficiency problems inherent with this test. We also have one other high school in Dublin and are currently building our third high school.

Dwight-Englewood School
315 East Palisade Avenue
Englewood, NJ 07631
Telephone: 201-569-9500
URL: www.d-e.org

Dwight-Englewood School is a coed K-12 independent day school located in northeast New Jersey. The school is in a suburban setting near New York City, and students come from 60+ communities. The students are from a variety of cultural backgrounds, reflecting the diversity of the area. All the graduates continue on to college, many of them attending very competitive schools.

The Upper School, which has an enrollment 475 students, now requires all students to complete a three-year, 9 through 11 Math/Science/Technology curricula. Students take five periods of science, four periods of math and two periods of technology. The curricula in each are coordinated. Each year of science focuses primarily on two of the three traditional disciplines (biology, chemistry, physics), and the disciplines are integrated at various points. Students are challenged to build upon their knowledge from previous years as the program progresses.

The MST program began with ninth graders in 1995. Previously, most students took physical science in ninth grade followed by biology in tenth grade (a few strong students took biology in ninth grade). Many students took chemistry followed by physics; some took a slightly less challenging conceptual physics course. Advanced placement biology was the only other senior elective.

In our MST program, grades 9, 10 and 11 students learn mathematics, science and technology with teams of teachers who coordinate their instruction across disciplines. A "hands-on," problem-solving orientation is frequently the basis for the approach to learning in all three of these areas. This allows students, guided by a teacher in both classroom and individual settings, to build their own scientific and mathematical knowledge and to apply what they learn in each area. The "hands-on" approach enables students to construct their own understanding of topics being studied, and the problem-solving emphasis uses "real-world" applications that often incorporate both math and tech skills.

When students finish the three-year MST sequence, a large majority of them take a science elective. Three advanced placement courses are now offered and have full or near full enrollment (biology, physics, environmental science). Four semester elective courses are also offered (environmental science, bioethics, organic chemistry, engineering). Several students take more than one science course in their senior year.

Edison Schools
105 Wilmont Drive
Kingsport, TN 37663
Telephone: 423-239-5347
URL: Edisonschools.com

Edison Schools, founded in 1992 as The Edison Project, is the country's leading private manager of public schools. Edison has now implemented its school design in 136 public schools, including many charter schools, which it operates under management contracts with local school districts and charter boards. More than 75,000 students currently attend Edison partnership schools. Most schools are primary/elementary. We have 11 high schools in five states. Edison contracts typically are for K–12 schools, which usually open as K–5 schools and expand each year, one academy at a time.

All students take physics as freshmen, chemistry as sophomores, biology as juniors, and choose advanced placement biology or environmental science as seniors. There are no prerequisites for entering the physics class but it is a prerequisite for chemistry which is a prerequisite for biology.

Farmington High School
10 Monteith Drive
Farmington, CT 06034
Telephone: 860-673-9753
URL: www.fpsct.org/

This is a moderately sized suburban high school (1300 students, grades 9-12) in a relatively affluent suburb of Hartford, CT. The student body is culturally, ethnically and economically diverse, as the geographic area includes:

- A large university hospital that draws its staff from a variety of foreign countries; immigrants from central Europe.
- Project Choice, a program bringing students from inner-city Hartford.

  About 15% of the students who are minorities—equally divided between Black, Asian and Hispanic. About 3% of the students at the school are eligible for a federally subsidized reduced-price lunch; five percent of the total student body is enrolled in the ESL program.

The school requires three credits of lab science for graduation, one of which must be biology. The state's graduation requirement is two credits of high school science.

Seven years ago we began implementation of a change in curriculum from the traditional sequence that started with earth science or honors biology in freshman year to one in which all freshmen take physics (honors or academic). During grade 10, all students take either chemistry, honors chemistry, or advanced placement chemistry. During grade 11, all students take either biology, honors biology, or advanced placement biology. During grade 12, students elect to take advanced placement chemistry, advanced placement environmental science, advanced placement physics B, advanced placement physics C, or single-semester electives that include biotechnology, anatomy and physiology, astrophysics, and environmental chemistry. This change has been marked by a quadrupling of the enrollment in advanced placement science courses without a significant drop in average achievement level.

Farmington Public Schools has developed K-12 Essential Science Understandings (paralleling national and state standards) that are used in curriculum development. Yet to be done is the total coordination of the K-12 content and instruction.

Our state has mandated testing for all sophomores. The test is the Connecticut Academic Performance Test, and includes a section that tests science processes and knowledge in life science, earth science, and the physical sciences.

Forest Ridge School of the Sacred Heart
4800 139th Avenue, SE
Bellevue, WA 98006
Telephone: 425-641-0700
URL: www.forestridge.org

Forest Ridge School is a small private Catholic girls school, grades 5-12. Our population is 356. Our school serves a suburban neighborhood with approximately 15% of our students coming from diverse backgrounds. We are part of the Sacred Heart Network of schools encompassing 70 nations globally, with 17 in the United States.

In 1995 Forest Ridge began a transition in the science curriculum from the standard biology, chemistry, physics to the physics-first concept. Both John Fenoli and Karen Hinkley decided at that time that with the wave of biology topics heading towards biotechnology and cellular biology, it would be beneficial to have a full year of chemistry behind each student. Physics was only taught to a small population of students who chose it as a senior elective. We believed conceptual physics taught at the freshman level would be a good preparation for life and chemistry and developmentally appropriate for freshwomen. It took four years to make the transition, and now, seven years later, our graduates tell us they think it was a very successful way of educating them in the sciences.

Most students will actually graduate from our school with four years of science. This is two more than the Washington state requirement. Our sequence allows for students to take two sciences both junior and senior year. Many of our students leave with six full years of science.

Girls Preparatory School
205 Island Avenue, P.O. Box 4736
Chattanooga, TN 37405
Telephone: 423-634-7600
URL: www.gps.edu

GPS is the largest independent, secondary day school for girls in grades 6-12 in the country. The Girls Preparatory School is, as its name implies, a college preparatory school. Since its founding, over 99% of its graduates have attended college or have pursued some form of higher education. There are 88 teaching faculty and a total student enrollment of 767. The average class size is 15, and the student/teacher ratio is 9:1. The school requires two science credits for graduation, but 90% of the students complete three or more years of science. For the last two years, all of our ninth grade students have taken physics. They take chemistry as tenth graders and the options after that include biology, Physics II, and advanced placement courses in biology, chemistry and physics, forensic science and human biology.

Glenbard North High School
990 Kuhn Road
Carol Stream, IL 60188
Telephone: 630-653-7000
URL: www.glenbard.org

This large suburban high school (2,800 students, grades 9-12) is located in a middle class suburb west of Chicago. The student body is culturally, ethnically and economically diverse.

> A number of manufacturing centers are in the larger area around our school which attract a number of highly educated workers.
> Several manufacturing concerns in our district employ a large number workers. Many of the workers are recent immigrants.

The school requires one year of lab science for graduation. The state universities require three years for graduation; therefore most students take three years. Approximately 82% of our students take science each year. (This number includes students who take more than one science course during the year.)

Four years ago Glenbard North implemented a three-year integrated science course called ISciS, Integrated Science Sequence. The program is designed for regular level freshmen and integrates physical science, chemistry, biology, earth science and space science over the three years. The program development was part of the Illinois Fermilab ARISE project.

The first group of students has completed the sequence. Anecdotal data supports the success of the sequence, and we are cautiously optimistic regarding the first year of standardized testing data which shows some increased scores compared to students who completed the standard sequence.

Glenbard North is one of four high schools in the district. The schools share most courses in common but have the autonomy to develop courses to fit its own students.

Our state has mandated testing for all juniors. The test includes the ACT as well as test items tied to state learner outcomes.

The Hockaday School
11600 Welch Road
Dallas, TX 75229
Telephone: 214-363-6311
URL: www.hockaday.org

The Hockaday School is located in an affluent area of North Dallas. The school has an enrollment of about 1,100 girls in grades pre-k through 12. There are approximately 100 girls in each of the upper grades that make up the upper school. We are a private college preparatory institution. We have 100% of our students attend college immediately after high school. In recent years, we have had over 95% of the graduates complete a four-year college program.

Our science department is one of the strengths of the school. We require only two years of science in grades 9-12, but for the past three years, we have only had 12% of our students graduate with less than four years of science. Our offerings range from the standards, (chemistry, physics, biology) to some unique offerings such as multimedia engineering, microbiology, human diseases, astronomy and meteorology. Our students can also choose from a full complement of advanced placement courses. This coming year (2002-03) we will be restructuring the curriculum to the physics-first format. We will have physics offered in grades 8 and 9 followed by chemistry and then biology.

The Jess Schwartz Jewish Community High School
4645 E. Marilyn Road
Phoenix, AZ 85032
Telephone: 602-385-5100
URL: www.jessschwartz.com

The Jess Schwartz Jewish Community High School opened in Phoenix on 8-20-01 with 22 students—18 freshmen and 4 sophomores. It is a private pluralistic Jewish college-prep high school that emphasizes rigorous academics while offering a comprehensive program of Judaic studies as well. The school day runs from 7:45 a.m. to 4:10 p.m. Class size is small: the largest class is 11 students and the smallest is 2.

Freshmen take physics and sophomores take chemistry; juniors will take biology and seniors will have a choice of advanced or advanced placement physics, advanced or advanced placement chemistry, or advanced or advanced placement biology, or earth science. Algebra students have their math program fully integrated with their physics course. Arizona State University's modeling physics curriculum materials are used for mechanics and Hewitt's *Conceptual Physics* is used for other physics topics.

Although it is a very new school, Jess Schwartz hired an experienced science and math faculty. Our chemistry teacher is a retired college chemistry professor and research biochemist, and our physics/algebra teacher is experienced in modeling methodology and an experienced physics-first teacher, having successfully instituted the inverted sequence in her previous school seven years ago.

Junipero Serra High School
5156 Santo Road
San Diego, CA 92124
Telephone: 858-496-8342
URL: serra.sandi.net

Serra High School, one of twelve 9-12 comprehensive high schools in the San Diego School District, was built in 1976. The district prides itself on being the third largest URBAN district in the United States.

The district is spending millions of dollars to institute "Physics First" using the *Active Physics Curriculum* developed in New York Science. Science courses offered include: Physical Science 1,2, Life Science 1,2, Marine Science 1,2, Biology 1,2, Advanced Biology 1,2, Physiology 1,2, Advanced Placement Biology 1,2, Chemistry 1,2, Advanced Placement Chemistry 1,2, Physics 1,2. Advanced Placement Physics 1,2 and Science Research techniques 1,2.

Loretto High School
2360 El Camino Avenue
Sacramento, CA 95821
Telephone: 916-482-7793
URL: loretto.room.net/Main.html

Loretto High School is a college preparatory private school for girls located in Sacramento, California. The school was instituted by the order of the Sisters of Loretto, IBVM. There are three other Catholic high schools in the city, but Loretto is the only one that uses a physics-first program. The population of the school is 500 students from the greater Sacramento Valley area and includes girls from a wide variety of social, economic and cultural backgrounds.

The science sequence at Loretto includes physics for freshmen, chemistry for sophomores and biology for juniors. Beginning in the junior year, students may add other advanced and enrichment science courses as their schedules permit. The electives include honors courses in physics, chemistry and biology, natural history and several earth science electives. Students must take three science courses for graduation, and all incoming freshmen take physics.

The physics-first approach was begun in 1995 by the science chair, Colleen Kozumplik Megowan, and was implemented for two reasons. First, the program provides a common experience and science language for all students. Second, fundamental physical concepts, and graphing and measuring skills can be practiced and lab procedure can be ingrained. The chemistry program builds on the concepts developed in the physics class, and the biology program is chemistry-based. The biology teacher reports that the students are very well prepared to go into the chemistry behind the biological systems.

Loretto students graduate with at least three lab sciences on their transcripts, and often four or five, as well as a single trimester of "snack classes" such as an earth science class that they have taken just for fun. Many of our graduates go on to study science in college. The physics-first program has been successful at Loretto.

Millard North High School
1010 South 144th Street
Omaha, NE 68154
Telephone: 402-691-1365
URL: www.millard.esu3.org/mnhs

Millard South High School
14905 Q Street
Omaha, NE 68137
Telephone: 402-895-8268
URL: www.millard.esu3.org/mshs/homepage/home1.html

Millard North and South High Schools are two of three high schools in the Millard Public School District. MPS is a suburban Omaha school district. The district has approximately 20,000 students and the high school population is unevenly divided between North (2,400), South (1,850) and West (1,200). All high schools are 9-12. MPS has a graduation requirement of 2.5 years. The sequence is integrated physical science, biology and an elective OR biology, chemistry or physics and an elective.

The district prides itself on having one of the lowest per-pupil costs of like districts.

In 1992, we started the curriculum cycle for revamping science. The cycle began with our writing a district frameworks document. (We worked from *AAAS Benchmarks* and the draft of the National Standards.) We then piloted several programs. Finally, in 1994 we adopted a program that included a ninth-grade integrated physical science course. All incoming ninth graders were originally scheduled to take the IPS course. However, after concerns voiced from parents of gifted and talented students, the district allowed gifted (self-identified) students to skip IPS and move to biology. If students skip IPS they must take chemistry or physics as sophomores.

The concerns about the course came when the course became an earth science course and was not an integrated course.

Mission Bay High School
2475 Grand Avenue
San Diego, CA 92109-4898
Telephone: 858-273-1313
URL: www.missionbayhighschool.com/

Mission Bay High School is one of twelve 9-12 comprehensive high schools in the San Diego School District. The district prides itself on being the third largest URBAN district in the United States.

MBHS is a relatively small high school in terms of California. There are only 1600 students; 75% of these students are bused in to the school. The cultural diversity of this campus serves as a healthy and positive environment for all our students to integrate ideas and to promote acceptance, tolerance, and unity among all the peers.

The district is spending millions of dollars to institute "physics first" using the *Active Physics Curriculum* developed in New York. Science courses offered include Physics Science 1-2, Biology 1-2, Advanced Biology 1-2, AP Biology 1-2, Physiology (anatomy) 1-2, Physics 1-2, Marine Science 1-2, Chemistry 1-2 and Advanced Chemistry 1-2.

Piedmont High School
800 Magnolia Avenue
Piedmont, CA 94611
Telephone: 510-594-2600
URL: www.piedmont.k12.ca.us/phs/

Piedmont High School is the only comprehensive high school in the Piedmont Unified School District, a K-12 school district in the San Francisco Bay Area. There are approximately 1000 students enrolled in a typically college preparatory program. The community is affluent, and the parents have very high expectations of the schools and their students. Our students typically perform well on standardized tests, and the school has received a '10' API rating from the state.

The state of California has a two-year science requirement for high school graduation while the major state universities and colleges employ three- or four-year lab science requirement policies.

In 1996, the science department members proposed converting the traditional curriculum sequence to a two-year integrated science. Consequently, many students have completed their science requirements at the end of tenth grade. In 2001 the Piedmont Unified School District adopted the California State Standards for Science Education. Our current goal is to teach the content guided by these standards in the two-year course, yet we struggle to address the state standards in all four disciplines, earth science, chemistry, physics and biology.

Our current concern is with the California Star Standards Test designed for students in an integrated or coordinated science course. The teachers at Piedmont High School have designed a two-year course that meets the needs of the students at that school. The test is designed with someone else's concept of the course coverage for ninth versus tenth grade. This brings up the issue of which comes first, the curriculum or the test?

Pinnacle High School
3535 E. Mayo Boulevard
Phoenix, AZ 85050
Telephone: 480-419-4400
URL: pinnacle.pvusd.k12.az.us

Pinnacle High School is a medium-sized, suburban high school (1500 students, grades

9-12) in an upper middle-class neighborhood in the sixth largest city in the nation. The student body is ethnically and economically diverse. Ten percent of the student population is Hispanic; 0.8% is on reduced lunch programs. The attendance area is largely residential and commercial, but there is a large silicon chip manufacturing plant in the vicinity.

The Paradise Valley School District has changed its science requirement and now requires three years of lab science for graduation for the class of 2005. The state universities also have this requirement for admission.

Pinnacle High School is the fifth high school in the district and opened in August 2000 with freshmen, sophomores, and those juniors that chose to attend this new school. We are the only high school in the district that offers physics (and Physics A) as the freshman science class. The students then take chemistry (or Chem A) as sophomores and biology (or Bio A) as a junior-level class. There is one class of freshman taking earth science. These students have math deficiencies and are not taking algebra. This is our second year piloting the physics-first curriculum. We also offer advanced placement physics, advanced placement chemistry, advanced placement biology, and advanced anatomy and physiology. Students could elect to take these classes in their senior year.

The other four high schools offer a traditional course sequence of earth science, biology and chemistry.

Arizona has established state standards for all courses and is developing tests to measure these standards. AIMS (Arizona Instrument to Measure Standards) tests are currently given in math, reading and writing. The science standards are not tested yet.

Oak Park and River Forest High School
201 N. Scoville Avenue
Oak Park, IL 60302
Telephone: 708-383-0700
URL: www.oprfhs.org

This large suburban high school serves two communities located near Chicago. The communities are primarily residential with the school systems and two hospitals as the primary employers within the district. This single-school district has an enrollment of 2800 students in grades nine to twelve.

About 37% of the students are minorities—30% Black, 4% Hispanic, and 3% Asian.
About 6% of the students at the school are low income.
About 1% of the students are enrolled in the ESL program.
There is a 17% mobility rate.

The school requires one year of lab science for graduation. The state universities have a three-year science requirement for admission.

Three years ago we implemented an integrated curriculum in addition to the traditional sequence of freshman biology, then chemistry, and physics. The integrated curriculum incorporates physics, earth science, chemistry and biology over a three-year sequence. We also offer earth science, environmental science and other specialized electives in addition to the advanced placement biology, advanced placement chemistry and advanced placement physics offered to seniors.

Our state has mandated testing for all juniors. The test includes the ACT as well as test items tied to state learner outcomes.

St. Mary's Academy
1615 S.W. Fifth Avenue
Portland, OR 97201
Telephone: 503-228-8306
URL: www.stmaryspdx.org/FrontPage.html

St. Mary's Academy, a private, Catholic preparatory high school, is the only single-sex school in the state of Oregon. Located in downtown Portland, it was founded in 1859 by the Sisters of the Holy Names of Jesus and Mary and has an enrollment of 550 students.

In 1991 the physics-first curriculum was implemented. In 1993 the change was complete, with all students required to take physics during their freshman or sophomore year (concurrently with geometry or better), chemistry in the sophomore or junior year and biology in their junior or senior year. An optional fourth-year science course (calculus-based physics or science research methods) is offered to students who wish to continue their science education. In a typical year, 50 students elect to enroll in a fourth-year science course; half of which choose to take calculus-based physics. Science classes taught include physics, chemistry, biology, advanced physics and science research methods.

St. Philip's Academy
18 Washington Place
Newark, NJ 07102
Telephone: 973-624-0644
URL: www.stphilipsacademy.org

St. Philip's Academy exists to provide a rigorous educational and personal growth opportunity for the children of the city of Newark and its environs, thereby enabling them to succeed at competitive college preparatory schools. The curriculum offerings include a wide array of basic and accelerated learning experiences: hands-on mathematics (honors courses are offered in grades 5-8); laboratory science program including earth and environmental sciences, physics and chemistry, and meteorology; literature-based and phonics language arts program, including regular creative and expository writing, research projects; French, Russian, Latin, physical education, music, art and drama.

In 1988, a vacant house in the heart of downtown Newark, New Jersey was selected as the site of a very special project. Dismayed by the inequality of education for children of the inner city, the late Dean Dillard Robinson and members of Trinity and St. Philip's Cathedral founded St. Philip's Academy in the Episcopal tradition. The founders were determined to prove that if time and effort were invested wisely in students, they would thrive. The Academy began with ten first-graders. In 1996, St. Philip's moved to its current home at 18 Washington Place. Enrollment has reached 210 for the 2000-2001 school year. The 24,000 square-foot facility, on the Registry of National Historic Buildings, is situated in Newark's historical and cultural district. Neighbors include The New Jersey Performing Arts Center, The New Jersey Symphony Orchestra, The Newark Museum, and The New Jersey Historical Society.

South Pasadena High School
1401 Fremont Avenue
South Pasadena, CA 91030
Telephone: 626-441-5730
URL: www.chemmybear.com

This suburban high school (1,300 students, grades 9-12) is located about 15 minutes from downtown Los Angeles. The student body is comprised of a large percentage of White and Asian students with a smaller number of other ethnic groups.

The school requires two years of science plus a third year that can be from science or mathematics. Many students will take the three-year lab science sequence that universities require. Our sequence includes taking physics in the tenth grade (physics-first), followed by chemistry and then biology in the senior year. Students are not required to take science in the ninth grade, although this is something that we are possibly going to change. Each lab science has two levels. Chemistry and biology each have regular and advanced placement levels while physics replaces the advanced placement with honors physics. For those students who do not take the lab sciences, they may select from five semester science courses that may also include some laboratory investigations. These include courses in life science, human physiology, oceanography, science issues, principles and techniques of science and earth science or physical science. We have had the non-traditional physics-first sequence for at least 40 years.

We are considering introducing a new course in the future that will be called "Science Principles" and would be taken by ninth-grade students. This course would replace four of the six semester sciences listed above and keep the Life Science and Science Issues.

Our students in the lab sciences of physics, chemistry, and biology all take a standardized state test called the "Golden State Exam" in physics, chemistry or biology. They take this test in the spring and it is not used as a entrance requirement for students into the next level of science. It is taken in the spring of each year.

We have just one high school and one middle school and three elementary schools in the South Pasadena Unified School District.

Tempe High School
1730 S. Mill Avenue
Tempe, AZ 85281
Telephone: 480-967-1661
URL: www.tuhsd.k12.az.us/Tempe_HS

This medium-sized (1,400) urban high school has a largely lower socioeconomic clientele. The student body is diverse, consisting of approximately 50% minorities (18% African/American, 26% Hispanic, 4% Native American, 4% Asian/Pacific Islander).

The state requires two years of lab science (one life, one physical) for graduation and the state universities require three years of lab science for admission. The state adopted science course (and all other disciplines) standards five years ago, but has no exit test for science.

Prior to the 1995-96 school year, the Tempe High School Science Department decided to rearrange the honors level science courses to align with the AAAS suggestion of physics, chemistry and biology for the core science sequence. This also moved the honors level curriculum into closer alignment with the standard level sequence of chem/physics, biology, chemistry, physics. (The chem/physics course consists of a semester of physics and a semester of chemistry, with the sequence varying according to individual teacher preference and lab availability. Only 1/2 of the biology enrollment takes chemistry, and only 1/4-1/3 of those students enroll in physics.) The realignment of the honors level lasted for four years before the political climate of the department changed again, and the department voted to return to a traditional sequence (biology, chemistry, physics), while keeping the regular level science sequence the same.

We currently suggest the following course sequences:

Honors Course Sequence		**Regular Sequence**	
9th	biology	9th	chem/physics
10th	chemistry	10th	biology
11th	physics	11th & 12th	choose from earth/space science, anatomy and physiology, Physics 3/4
12th	choose from earth/space science, anatomy and physiology, Physics 3/4		

We have offered a second-year biology course in the past, which has not made it in the last 10 years due to insufficient enrollment. Beginning next year, we will have a segment of the students that will take a biotechnology course instead of biology, as part of a health-related occupations preparatory program.

Tombstone High School
605 Fremont
Tombstone, AZ 85638
Telephone: 520-457-2215
URL: www.tombstone.k12.az.us

Tombstone High School is a small rural high school located in Southeastern Arizona, only 25 miles from the border of Sonora, Mexico. There are only 350 students of mixed ethnicity and educational background. Most students when they graduates will go to a community college for a one- or two-year technical training course.

At the present time, students may track into one of two curricula. Students may track into a college-bound curriculum where they will graduate with three years of math and laboratory science. There are no gifted programs or advanced placement elective courses, however, the science and math departments, working with Cochise Community College prepare many students to take college classes for dual credit, provided they pass the entrance exams for the college. Students who do not take the college-bound track, are required to take two years of math and two years of laboratory science.

The Tombstone Unified School District is presently attempting to align their science curriculums from kindergarten through twelfth grade along state and national standards. All sophomore students (Class of 2004) are required to pass the State AIMS test in math and writing before they can graduate from high school. The science department chairman, working with elementary and middle school teachers, is attempting to initiate a plan of teaching an integrated, physics-first approach to teaching science that will focus on helping all students pass the state-mandated exams.

Although the district does not officially offer physics-first curricula, there has been a conscious effort to teach an effective physical science, algebra-based first-year laboratory science at the high school. This class is usually followed by a process-oriented biology class integrating fundamental biological concepts with real-world community-based projects requiring the use of statistical analysis and developing technical writing skills. The chemistry course is the same course offered to freshman students at the University of Arizona taking inorganic chemistry using the same texts, and laboratory experiences. Finally, many students end up taking a physics course primarily founded in traditional mechanics, but with the primary focus of conducting an original science fair project that is entered into a regional science competition.

Walter Payton College Prep
1034 N. Wells Street
Chicago, IL 60610
Telephone: 773-534-0034
URL: www.wpcp.org

This Chicago public high school is a magnet school for science, math and foreign languages. The school was established in 2000. There are 500 students in grades 9 and 10. A new class will be added in 2003 and 2004. Full capacity is targeted at 800 students.

The students come from public and private schools throughout Chicago. The class entering in 2003 has more than 25% coming from private schools. The students are evenly distributed between Hispanic, White and Black. This is a selective entrance school by exam. About 6,000 students applied for 200 spots in the class entering in 2003.

There are 10 science labs, language lab, a distance learning lab, a planetarium (seats 25-

30), roof-top deck for observations, and a one-to-one ratio of students to computers.

The Westminster Schools
1424 W. Paces Ferry Road, NW
Atlanta, GA 30327
Telephone: 404-355-8673
URL: www.westminster.net

The Westminster Schools is a Christian, independent, college preparatory day school with approximately 1,740 students in grades pre-first through 12. The school accepts students based on standardized test scores, recommendations, as well as individual interviews and writing samples. Hence, our student body is made up of highly motivated and academically talented individuals. Financial aid is available, and we strive to attract students from diverse backgrounds. Approximately 13% of the students currently enrolled represent minority groups.

The Science Department oversees the science curriculum for grades 6 through 12. Students in grade six currently take a full year of life science. In seventh grade students take one semester of earth science, and eighth grade students take a full year of physical science. The science course sequence in the high school includes physics or honors physics for all ninth graders; regular, honors, or advanced placement chemistry for tenth graders; regular, honors, or advanced placement biology for eleventh graders; and advanced placement physics B, advanced placement physics C, advanced placement environmental science, or a choice of one-semester electives for seniors. Some eleventh-grade students may opt to take advanced placement environmental science in lieu of a biology course.

Physics is a prerequisite for chemistry, and chemistry is a prerequisite for biology. Students can take advanced placement environmental science without having a year of biology but must have taken chemistry and can earn a year credit of life science. Students must be recommended for honors and advanced placement-level courses by their current teacher and the science department chairperson. Members of the science department also teach two experiential summer courses, marine science or field geology, that students can take to earn science graduation credits.

To earn a graduation diploma from The Westminster Schools, students must have taken at least two years of a laboratory-based course; one year of a physical science and one year of a life science. However, 99% of our graduates will have taken three or more years of science.