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The State of Physics-First Programs

A report for Project ARISE (American Renaissance in Science Education)

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Executive Summary

One of the goals of Project ARISE (American Renaissance in Science Education) has been an effort to develop and disseminate a framework for a three-year core curriculum for high school science. A white paper on the framework was released in 1998, and one of its key elements was an inversion of the traditional order in which biology, chemistry, and physics are taught in high school. This report is the first effort to aggregate the experiences of schools that have performed this inversion.

Fifty-eight schools responded to requests for information about their physics-first curricula. Roughly half of these schools are public, and half private. They range in experience from schools just completing their first year of the new sequence to schools that have been using it for twenty-five years or more. They are more likely to be in suburban or urban settings than the national distribution of high schools would suggest, and they are also more likely to be in the Northeast or West regions of the United States.

Interviews with teachers at these schools revealed several commonalities in their experiences and attitudes. They tend to be satisfied with their curricula, and especially with an increased emphasis on the science process over specific content, but concerned about the appropriate level of mathematics for the introductory physics course. Another major issue most schools had to address was the necessity that some teachers teach out of their primary field, especially in the first two years following the curriculum inversion. Along with the curriculum itself, teachers discussed the process of implementation.

Two school visits offer detailed views of schools that have implemented physics-first curricula. One visit was to a rural private school in the Northeast during its sixth year of teaching physics first; the other, to a suburban public school in the Midwest during its second year of teaching physics first.

One significant finding is that almost none of these schools have been collecting quantitative data for self-evaluation. The conclusion includes ideas for ways in which existing quantitative information might be analyzed and other suggestions for future study.

Introduction

Project ARISE (American Renaissance in Science Education) was born from a workshop held in September 1995 in Naperville, Illinois. The project's goal has been the development and dissemination of a framework that schools and districts can use to develop a three-year core curriculum for high school science. It convened a workshop in Chicago in February 1998 to develop the framework, and released it that July.

One of the key components of the framework is a reversal of the sequence in which the three primary disciplines in high school education—biology, chemistry and physics—have been taught since the late nineteenth century. In the ARISE framework, physics becomes the focus of the first year of high school science study, chemistry remains the second, and biology becomes the third.

The rationale for this change is the change the three sciences, especially biology, have undergone over the last hundred years. Biology and chemistry are no longer the purely descriptive sciences they once were. Comprehending chemistry in terms of the structure and behavior of atoms relies on an understanding of physical principles, and modern biology requires understanding the chemical functions of molecules such as DNA and proteins.

This report is a first effort to examine schools who have reorganized their science sequence in this way. It consists of three main sections: first, a demographic summary of schools who have implemented a curriculum in which physics is the focus of the first-year course; second, an aggregate description of the experiences of these schools; and third, school visits to two schools at different stages of the process.

What Type of School Teaches Physics First?

It is instructive as a first step in studying schools teaching physics first to look at characteristics of schools that have switched to this type of curriculum. This exercise can help to determine if they are a representative subset of U.S. schools, and if not, what type of school may be more likely to attempt such an endeavor.

Fifty-eight schools responded to a survey asking for information about physics-first schools. A small majority of them were private schools (53%). This is significantly greater than the fraction of secondary schools nationwide which are private (30%),[1] indicating that private schools may be better able, more willing, or both, to undertake a wholesale curriculum revision such as this.

The average enrollment in private schools in this study was 380, similar to the average of 321 for all private secondary schools.[2] For public schools in this study, however, the average enrollment was 1,528, almost double that of the average public secondary school, 786.[3] This is explained in part by the settings of schools in the study: 33% were urban schools; 56%, suburban; and only 11% rural, compared to the national distribution of 25%, 39%, and 36%, respectively.[4] The urban / suburban / rural distribution of private schools in this study was not as different from the national distribution of all private schools, though it also shows a paucity of rural schools (45% / 45% / 10% in this study vs. 40% / 37% / 23% nationally[5]).

Schools in this study tended to be geographically congregated in the Northeast (47% vs. 23% of all secondary schools[6]) and to a lesser extent the West (29% vs. 25%[7]). They moderately underrepresent the Central Region (17% vs. 30%[8]), and are sparsely scattered about the Southeast (7% vs. 21%[9]).[10] Overall, twenty-six states and the District of Columbia are represented in this study by at least one school.

The mean graduation requirement for science coursework in schools in this study was 2.6 years, which fairly accurately reflects the distribution of requirements. The public schools in the study were more likely to require four years of science, but they were also more likely to settle for two or even one.

[1] *Digest of Education Statistics 2000*, National Center for Education Statistics, Table 87.

[2] *Ibid.*, Table 60.

[3] *Ibid.*, Table 94.

[4] *Ibid.*, Table 86.

[5] *Ibid.*, Table 60.

[6] *Ibid.*, Tables 64 and 99.

[7] *Ibid.*

[8] *Ibid.*

[9] *Ibid.*

[10] Geographic regions are those used by the Bureau of Economic Analysis of the U.S. Department of Commerce, the National Assessment of Educational Progress, and the National Education Association. See *Ibid.*, p. 527.

Experiences of Physics-First Schools

Thirteen teachers, some of them science department chairs, from schools that have developed and implemented a physics-first science curriculum were interviewed for this part of the study. These schools were selected randomly from the schools surveyed for the previous section. A wide variety of schools is represented here: seven public and six private; four urban, six suburban, and three rural; five with 1-4 years of experience with their physics-first curriculum, four schools with 5-8 years of experience, and four schools with more than nine years of experience.

Overall Satisfaction

Teachers interviewed claimed to be satisfied with their curriculum, most of them exuberantly so. Specific comments ranged from "It's going pretty well" to "I love it" and from "It's the best thing ever" to "It's the only thing that makes any sense."

Many of the teachers interviewed struck similar themes. One of the most frequently mentioned was that they enjoy teaching freshmen. This is very significant, as one of the arguments frequently cited against converting to a physics-first curriculum is that physics teachers long accustomed to having only the brightest juniors and seniors might balk at teaching freshmen. That appears not to be the case. One veteran traditional physics teacher who started teaching freshman physics less than ten years ago especially likes that when students enter his traditional physics course now, he knows what physics they've seen because he taught it to them.

The level of mathematics in the introductory physics course was a common area of concern. Most freshman-physics teachers want to keep as much math as possible out of their courses, instead focusing on physics concepts and "real-world" applications. However, many of them are finding teaching a "math-free" physics course very difficult. They have developed a variety of strategies for dealing with this problem. Some have made algebra a prerequisite for the introductory physics course so their students will be prepared to handle some math. Typically in these cases, students will be able to take algebra as eighth graders so they can begin the high school science sequence as freshmen. One school offered two versions of their freshmen physics course, one for students who had taken algebra in eighth grade, and one for students who were taking algebra as freshmen. Another school coordinated their freshman physics course with their freshman algebra course to ensure that students will have the math they need when they need it.

Teachers were also asked about their perceptions of their colleagues' satisfaction with the curriculum. Generally, they were quite positive, with the most frequent comment being that chemistry and biology teachers find it very helpful that students now come to them with a base of knowledge they can utilize in their own courses. Several teachers also said their colleagues are finding that students who took physics as freshmen can "think better" about science.

Chemistry teachers (who in most schools are the second-year science teachers) have said they appreciate getting students in their class who have even rudimentary understandings of light, heat, and electrons, topics taught in introductory physics, but traditionally not in biology. They also like that students come to them with skills such as writing lab reports, using scientific notation, and carrying out dimensional analyses.

Biology teachers, according to their colleagues, have been capitalizing on their students' knowledge of chemistry to introduce modern topics, often including molecular biology. Interviewees frequently reported that the biology courses in their departments have become oriented more toward understanding the science of biology and less toward memorizing facts related to it.

One significant concern among teachers is that there is a glut of physics students and not enough teachers prepared to teach physics, especially in the first two to three years after inverting the curriculum. Initially, this happens because juniors and seniors finishing the curriculum and freshmen starting it are all taking physics at the same time, but even after that situation passes, a greater proportion of physics teachers are needed than were previously. Consequently, biology teachers can end up teaching physics, which they are often uncomfortable doing.

Student attitudes about physics-first curricula seem to be very positive, when they know there's a difference. Eight of the thirteen schools that took part in the teacher interviews have been teaching physics for more than four years, and in many of those cases, teachers reported that their students didn't seem to know it was unusual for them to be taking physics as their first high school science course.

That doesn't appear to dampen student enthusiasm, though. In most cases, teachers said their students' favorite part of physics was the labs. Several teachers take advantage of this, using labs to work a bit of math into what are often (as described above) "math-light" courses.

Teachers in schools that more recently inverted their curricula said there was apprehension and "physics phobia" from students and parents, especially in the first year, but students tended to enjoy the physics course enough that the initial apprehension quickly faded. In addition, concerns of parents decreased as the new curriculum becomes the modus operandi.

Getting Out of the Blocks

Getting started is certainly a primary area of interest to schools that may be considering revising their curriculum. Interviewees raised several issues that came up when putting their new program into place.

The standards movement and the (sometimes high-stakes) testing often associated with it are pervasive issues in education today. Many of the teachers and department chairs interviewed for this study stated that the standards and testing were not problems for their schools, especially where state tests are well-balanced among disciplines. Those who did express concerns said their state tests are given to sophomores (tenth graders), and are biology-heavy. Obviously, physics-first schools in such a situation would be at a disadvantage on state tests. This problem can be exacerbated if the tests are "high-stakes" and if the public or school administration expects to see results immediately.

One teacher issue cited in the last section bears another mention: the importance of teachers who both want to teach freshmen and are qualified to teach physics. This is especially important in the first two years of a new program, when an excess of students will be taking physics, but the presence of those teachers remains important to keep a program strong.

A potential problem with any curriculum overhaul can be resistance from people or groups. Fortunately for schools involved in this study, that seemed not to be as significant a problem as one might expect. Teachers from schools that successfully overcame opposition emphasized the importance of having internal agreement within the department and support from school administration before announcing plans for a new curriculum.

One expected source of opposition might be from parents, and a few teachers reported that that was the case at their school. In those instances, science department teachers had sought and received the support of their building administration and school board beforehand, and were able to engage parents in discussion with the knowledge that they had that backing. In most cases, the parents had reasonable concerns, which were allayed by simple conversations with teachers.

An unexpected source of resistance for one school was the school counselors. They feared that expanding the core science curriculum would force the elimination of upper-level science electives, which would weaken the school's science program. Again, open discussion among the concerned parties led to a better understanding of the planned curriculum and its effects on both the science program and the school as a whole.

Interviewees raised several other potential issues:

- Coherence with the middle school curriculum: Teachers emphasized the importance of reviewing the middle school science curriculum to ensure that it was both a good complement to and good preparation for the new high school curriculum.

- Parental pressure: As mentioned earlier, some schools chose to make eighth-grade algebra a prerequisite for freshman physics. Two of those schools stated that there was pressure from parents for their children to take the freshman physics course despite not having met that prerequisite. In both cases, teachers felt that resolute and supportive building administration was important to maintaining the integrity of the program.
- Transfer students: Students transferring into a physics-first school from a traditional program may not fit easily into the course sequence for science. All of the teachers who addressed this said their schools handle transfer student placement on a case-by-case basis.
- Upper-level science enrollment: There was concern at some schools that expanding the core curriculum and moving physics to the freshman year would decrease enrollment in upper-level science courses generally, and in traditional physics courses specifically. This effect has varied, with some schools seeing those enrollments drop and others seeing them increase.
- Lab equipment: Most schools found appropriate equipment readily available, but quantity could be an issue for some. One school, on making the curriculum switch, went in one year from four sections of physics to thirteen, and had to scramble to acquire enough equipment.
- Textbooks: Many of the teachers who were interviewed said there is not a wide selection of textbooks appropriate for a freshman-level conceptual physics course. Most of the teachers, however, claimed to be happy with the book they are using.

Pulling the Trigger

Also of likely interest to schools considering switching is the question of who has made the decision to go to a physics-first curriculum in schools that have successfully completed their curriculum revision.

In almost half of the cases, a physics teacher who served as a leader started the process. Typically, this teacher got the idea by attending a presentation on teaching physics first at a conference or workshop, or by reading articles in professional newsletters or journals. The teacher brought the idea back to his department colleagues, convinced them of its merits, and then took it to the administration and board for approval. Almost as often, the science department chair was the motivating force, following a similar mechanism to implementation.

In one case, the science department was reviewing its curriculum to bring it into line with state standards and determined that teaching physics first was the most logical way to proceed. Twice, the idea came from administration: once at the building level, and once at the district level. When the decision was made at the district level, the reason cited was alignment with state standards.

Another decision schools need to make when implementing a new curriculum such as this is which students are going to take physics as freshmen. This can be a contentious issue, as can the very question of who should be addressing it—that is, who should be making the decisions about student placement into science courses.

Most schools avoid the issue altogether by enrolling all freshmen (or in one case, all sophomores) in the course. Two schools make students' math backgrounds the deciding factor: one requires that a student have a B in eighth-grade algebra to take physics as a freshman; another asks eighth-grade math teachers to identify students who should have another year of math before entering physics. Those students take physics as sophomores. Finally, one school includes counselors and the special education staff with the science department in the decision-making process.

Preparation and Support

One might think that a very important step in the conversion to any new curriculum, and especially to a non-traditional type of program, would be dedicating time to outlining the scope and sequence of the overall 9-12 curriculum. Surprisingly, that step seems to have been of minimal importance in many cases. Only four of the thirteen interviewees reported that their departments worked formally to plan their 9-12 scope and sequence. One science department met to discuss sequencing, but left the question of specific course content to individual teachers. Another department made the effort to visit a local school already teaching physics first to study their program. One school, as will be described in the school visit section, hired a consultant from a local university early in the process. Her primary goal was (and continues to be) helping the science department answer the question of what they want their graduates to "look like" from the point of view of their science knowledge and skills.

Schools are doing more in the area of curriculum revision and continuing development. Only one teacher said there hasn't been any interdisciplinary coordination. That teacher went on to say that there has been extensive intradisciplinary work to ensure course consistency among teachers. Another teacher said that despite a lack of formal time to focus on 9-12 curriculum cohesion, her department creates it informally by requiring each teacher to teach in more than one discipline. One school, currently in the first year of its new program, is encouraging its ninth-grade physics teachers to try different things with the intention of examining and comparing their experiences after one year teaching the course. In two schools, one or two lead teachers from each discipline do the bulk of the curriculum planning for the 9-12 sequence.

Most schools have set up a more formal structure. The most common is regular department meetings, with a typical frequency ranging from every two weeks to once per month. These meetings tend to focus on the entire 9-12 curriculum, but many schools devote some of them to smaller meetings among teachers within their disciplines.

One science department devised a straightforward method of keeping their curriculum up-to-date and cohesive, continuing professional development, and bringing new teachers on board with their program. Starting the year before implementing their physics-first program, they have reserved one week each summer for all of their teachers, including new hires, to work together to update and revise their curriculum.

Most schools involved in this part of the study allow teachers to guide their own development—the school approves teachers' plans and provides funding. However, only one school allows its science department to plan its own inservice days. Teachers attending specific workshops on physics-first programs prior to implementation (as opposed to having release time for development) were also rare. Only one teacher reported that all of the introductory physics teachers in her school went to a workshop before the first time they taught the course. Several teachers, however, reported that they have been to workshops since the initial implementations of their schools' physics-first programs.

Another issue of potential concern regarding teachers is integrating new teachers into an existing physics-first program. Because most people's high school science experience has been a traditional biology-chemistry-physics sequence, a new teacher (or even an experienced teacher taking a job in a new school) should have more than a superficial introduction to a school's program in order to be as effective as possible. One school, as mentioned earlier, devotes a week each summer to curriculum work, in part for this purpose. Another designates a lead teacher in each discipline to serve as a mentor for new teachers.

Most schools, however, claim to bring new teachers into their programs informally. Teachers and department chairs at those schools (and, to a lesser extent, at others) focused on the interview portion of the hiring process. They said the nature of the science curriculum is emphasized in the interview, and they look for candidates who are qualified to teach in a program based on physics.

Where's the Beef?

Unfortunately, one area in which these schools have been lacking is the collection of quantitative data to evaluate the success of their programs. Interviewees had numerous anecdotes to support their efforts, but most of their schools had collected no numerical data for evaluative purposes. One school (School Visit II in the next section) has been preparing for this by collecting baseline data on their previous program and making plans to collect data on their physics-first curriculum, but their program is too young for them to have any meaningful data at this time.

This may be the most significant finding of this study: Physics-first schools are not quantitatively documenting the degree of their success. Information such as standardized test scores (whether on state-mandated tests or on tests such as the ACT and SAT II), enrollment in advanced science courses in high school, numbers of students going on to major in science in college, or any other relevant data would be invaluable, not only for studies such as this, but also for the schools themselves to be able to justify what they are doing and identify areas in which they can improve.

School Visits

Two schools were selected for visits: one private and one public. The author spent two days at each school speaking with a wide variety of people, including science teachers, students, the headmaster or principal, a counselor, and other people mentioned below. The intent of the visits was to acquire a deeper perspective on the schools' physics-first programs and to acquire a better understanding of issues involved in implementation. The school visits are presented here in the order in which they occurred.

School Visit I

The first school visit was to a rural private school in the Northeast. This school has an enrollment of about one hundred students, roughly three percent of whom are members of ethnic minority groups. The school has been teaching physics first in its science sequence for six years. The official science requirement for graduation is three years of laboratory science, but almost all students take four. Most students take biology as sophomores and chemistry as juniors.

There seem to be two beliefs, common both to teachers and to administrators, that make up the school's philosophy on science education. One is that the process of science is more important for students to understand than the factual body of knowledge it has accumulated, and that students must be engaged in science and taught how to learn in order to fully appreciate it. The other is that physics is the basis of all the sciences, and the order of the science courses should reflect that. This second point was well confirmed when the biology and chemistry teacher said one of the department's goals was to have as many students as possible take a math-based physics course as seniors in addition to the conceptual physics course they take as freshmen.

The physics teacher spearheaded the change to a physics-first program in this school, bringing the idea to his colleagues after meeting and speaking with a physicist and a physics educator who are proponents of the idea. He proposed the switch to the school administration, which readily assented, and they implemented the new curriculum the next year.

Backing for the program within the school has been strong, especially from the administration. The headmaster, one of its staunchest proponents, says he gives the program wholehearted support because exposing kids to physics concepts "makes their minds open up." Emphasizing the level of the administration's support is the fact that sophomores transferring from a school in which they took biology as freshmen are required to take conceptual physics because of the course's vital importance to the science program.

The admissions officer claims to be totally supportive of the physics-first program, and the physics teacher agrees, saying the primary reason parent awareness of the program is high is the emphasis the admissions officer places on it when recruiting students and introducing the school to families. The academic director also gives credit to the physics teacher himself, saying parents who have met him have a high level of trust in his judgment and ability. None of the administrators could recall any concerns from parents about the physics-first curriculum.

When asked about the most innovative aspects of the physics-first course, the physics teacher focuses on modern physics. He says he strives to introduce some rudimentary modern physics ideas to freshmen near the end of the year. It is a point of pride that his freshmen have seen more modern physics as ninth graders than most students do in a full high school career.

The biology and chemistry teacher is very happy with the scope of the freshman physics course, as well. 2000-2001 was her first year teaching at this school (though not her first year teaching high school science). She says it's nice to hear students who have had physics say "I've done that before," when discussing a topic in biology or chemistry, and that the conceptual physics course seems to get students excited about science.

Students do like the course. The author spoke with a group of sophomores currently taking biology and a group of seniors currently taking a traditional physics course (all took conceptual physics as freshmen). The sophomores tended to appreciate the concrete nature of the conceptual physics course, despite feeling that it was difficult. They recalled several examples of experiments, demonstrations, and "toys" they used to see physics concepts.

The seniors said similar things about the conceptual physics course, and also said it was useful for their later courses. Specific things they mentioned as topics from conceptual physics that were useful in biology and chemistry were the structure of the atom and basics of energy. They also said it was useful to have seen some terms and measurement units as freshmen, although there was not an emphasis on memorization. One of the seniors suggested that the freshman physics course should be renamed "Introduction to Science" or "The Way Things Work." Another said simply, "I started liking science in that class."

The administration also sees the student excitement. Each administrator said the freshman physics course has encouraged more students to take advanced physics as seniors. The headmaster pointed out that physics has traditionally been reserved for "math kids," and that the freshman course has opened the subject up to all students, including those for whom math is a challenge.

The physics teacher goes one step further, saying that freshmen who enjoy physics often see that math will help them understand it better, getting them excited about math as well as science. He has striven to connect physics to other subjects as well. He works with a history teacher to coordinate the history of astronomy in his freshman physics course with concurrent topics in the freshman history course, and with the English teachers to select science books for the school's summer reading list.

One significant issue that needed to be addressed when moving to a physics-first curriculum was that of transfer students. Students coming in from a traditional (biology-chemistry-physics) program could be difficult to fit into the new sequence. One of the tools used to deal with that problem is their new environmental science course. This course has been very good for students transferring in as juniors who have taken biology and chemistry, but don't yet have the math background necessary for traditional physics. It has also been an excellent alternative for students not interested in taking traditional physics as seniors.

The physics-first program as a whole seems to have been beneficial to the school. It has brought intrigue to the science program, making it more interesting and inviting for parents. It has also (as mentioned previously) given students an early, positive exposure to physics and helped them to see it as fun.

One future goal for the school is developing a more formal cohesion among the science courses. Teachers are required to submit quarterly syllabi for their courses to the academic director. These syllabi serve as the school curriculum. In addition, the science teachers discuss their courses with each other informally every day. However, there is no formalized interdisciplinary scope for the science department. This seems not to have had a deleterious effect, but attaining a degree of formalization is certainly a worthy objective.

The science department has two other aims for the future. One is to complete the inversion of the curriculum by moving chemistry to the sophomore year and biology to the junior year. The other is to return to a schedule that includes longer blocks of time for science labs.

The school changed its schedule this year, and, as would be expected, it has had an effect on the science program. Previously, science courses met for ninety-minute periods during the first and fourth quarters of the school year. Starting this year, they met for forty-five-minute periods every day plus one ninety-minute lab period per week through the entire school year. The school is evaluating the impacts of the change, and trying to decide how best to address the conflict between the desire for longer lab periods and the desire for each science course to be continuous through the school year.

The schedule has been the only policy issue having a significant impact on the program. The physics-first curriculum has not presented any difficulties with the school's accrediting body, nor with the National Collegiate Athletic Association (NCAA). Neither have there been any problems with state certification nor with student performance on state-mandated tests, despite (or because of) the school not spending class time for standardized test preparation. (Though it is a private school, a number of students are required to take state-mandated tests.)

The only difficulty mentioned other than the schedule was fitting transfer students into the curriculum. The school, like most schools in this study, deals with transfer students on a case-by-case basis. The physics teacher also stated that in the first year of teaching the freshman physics course, he had to do a lot of improvisation, which wasn't a problem, but might be a concern for a new teacher.

Although there are a few minor bumps to be smoothed out, it seems this school has had a very successful and satisfying six years teaching physics first in its science curriculum. The program has been established as the modus operandi, and given the widespread support it has earned, there is every reason to suspect it will remain so for the foreseeable future.

School Visit II

The second school visit was to a suburban public school in the Midwest. This school has an enrollment of roughly 1700 students, about one quarter of whom are members of ethnic minority groups. African-Americans constitute the predominant ethnic minority. This school has just completed its second year teaching physics first in its science sequence. Its sophomores took chemistry this year and will take biology next year as juniors. The school's science requirement is two years, at least one of physical science and at least one of life science. The school has developed two conceptual physics courses: one for students who took algebra in eighth grade; the other, for students who took a pre-algebra course in eighth grade. The freshman physics courses cover the same content, differing primarily in the extent to which mathematical principles of physics are included.

The school's primary philosophy of science education is that teaching students how to think about science is more important than teaching them the specific details of the content. Everyone who was interviewed agreed on this point, but there was disagreement as to how well the philosophy is implemented across the curriculum. There is a clear effort, however, to emphasize scientific thinking and hands-on laboratory work in the freshman physics courses.

As part of making the change to a physics-first curriculum, the science department has undertaken the philosophical exercise of attempting to determine the minimum science a graduate of the school should know. It has been a difficult task, but it appears to have been valuable as a way of focusing effort. The possibility of an exit portfolio or exam has been raised, but most see it as unlikely to be employed.

The process of implementing the physics-first curriculum was very methodical and effective. One of the physics teachers brought the idea to the science department, which considered and discussed it, and decided to try to implement it. The science department then went to the school curriculum committee and the principal, all of whom were supportive, and from there to the school board. The school board authorized further study before making a final decision.

The district and school were very helpful and accommodating during this research. They hired a consultant from a local university to help guide the process, gave teachers release time to work, including time to visit a local school that had already implemented a physics-first curriculum, and established an advisory committee which included parents and students in the district and community members with experience in science-related fields. Science department members frequently reported to and received feedback from both this committee and the school board, and eventually received approval for implementation from the board.

Because of the high level of parental and community involvement, awareness of and support for the program are very good. Two other factors help keep community members informed and updated on the program. The science department teachers have held informational meetings for parents at middle school nights for the past three years. ("Middle school night" is an orientation to the high school for incoming freshmen.) In addition, the science department chair is eminently available to parents with questions. She reports that there are noticeably fewer this year than there were in the first year of the program. She also says parent questions are more easily addressed now than they were before the switch, because the new curriculum "makes more sense to the public."

Many parents' questions, especially in the first year of the new program, involved how students are placed in the two freshman physics courses. As mentioned earlier, this decision is made based on the math course each student takes in eighth grade. The high rate of questioning on this topic is likely an artifact of the old program, in which the two available freshman courses were substantially different, and the decision on placement was made more subjectively. Parents seem to be much happier with the objective placement criterion, and with the fact that students from both freshman physics courses have the opportunity to move into the same chemistry course in their sophomore year. Another parent concern was college acceptance of the freshman physics course, but that has not been a difficulty.

District support of the program has been as solid since implementation as it was before. The emphasis now is on formative evaluation of the new program with the goal of making it the best program possible for the school's students. In order to facilitate this evaluation, the district has retained the university consultant who worked with the science department on implementation.

Inevitably, one prominent evaluation of the new program will be the state-mandated science test. This could present an obstacle for the program, especially in public relations. The district's middle school curriculum currently has life science in the seventh grade and physical science in the eighth grade. The state's science test is given to tenth-grade students. Consequently, when students in this district take the test, they have not had a course focusing on life science for three years. Several people in the school and district are justifiably concerned that this will cause scores to go down. Because of the high publicity of the test scores, they further worry that the new high school curriculum will be quickly judged as failing, due in no small part to a simple scheduling quirk. They have begun to take some steps to address this problem. Some integration of courses, for example, including a few life science topics in biology and chemistry, is being considered, as is moving the middle school life science course to the eighth grade.

According to school staff, student reaction to the conceptual physics course has been mixed, but in a way that perhaps most educators would find heartening. On the positive side of the ledger, students seem to enjoy the course, but on the "negative" side, they expected it to be easier than it has been. Several people told me that many students who have always done well in science are finding freshman physics challenging. Happily, though, the course is not overwhelming students who have typically been in the middle of the pack. Most staff members who commented on the challenging nature of the course attributed it to the emphasis on the scientific way of thinking.

Students with whom the author spoke liked the freshman physics course overall, and were especially enthusiastic about its hands-on nature. They were able to quickly recall and describe in some detail several labs and demonstrations they had enjoyed. Their negative comments were almost exclusively reserved for times when they felt the math was overwhelming or when labs were boring.

The freshman physics teachers seem very happy with the direction the new program is taking, especially when compared with the old. The previous "standard" freshman course was a semester of physical science and a semester of life science, and teachers report that they felt physical science tended to get shortchanged. One teacher, excited about the switch, said, "I don't feel like I have to rush to get through physics anymore." Other teachers agreed, and emphasized that they used the "extra time" to incorporate some nontraditional elements into the course, such as aspects of the history of science. Along those lines, one teacher stated that he values the ability to focus on specific topics, teaching not only the ideas of physics, but also how those ideas were historically developed.

The teachers are also taking advantage of physics's reputation as a difficult subject to ensure their course's rigor; not out of any intrinsic desire to teach a difficult course, but to take advantage of an opportunity to create for all freshmen a solid knowledge base on which their future teachers can capitalize. With this goal in mind, they have created a Science Skills Workbook and given it to all freshman physics students (i.e., all freshmen). This workbook is a very useful collection of basic information and exercises on skills applicable to any science, such as measurement and graphing.

Course consistency between teachers is another objective of the freshman physics teachers. To that end, they meet regularly to discuss course content and planning. They have also begun to work together to make student assessment more uniform in both style and content. So far, this has included selecting core concepts and questions for evaluation, and creating a lab report template.

Chemistry teachers, who have just completed their first year with students who took physics as freshmen, observed that having all of their students come from essentially the same class helped the teachers know what to expect from them. They also were pleased at not having to spend as much time as before on topics such as the scientific method or the structure of the atom, as their students were familiar with them from the freshman course.

One difficulty this school has had which is common to schools making this change is that teachers who are not trained in physics have had to teach it for the past two years because of the lurch in enrollment numbers from biology to physics which occurs at the beginning of these programs. The school expects enrollments to return to equilibrium next year, and that most of the temporarily-displaced teachers will be able to return to teaching in their field. Another issue related to shifting enrollment numbers is that two elective courses had to be canceled for one year. This was somewhat surprising, but will likely be rectified as the new enrollment patterns are established.

College accreditation of the freshman physics course has not been a problem. A school counselor reports that the primary reason is that the course is lab-based. Colleges (and parents) also like that the course is called "Physics" instead of "Physical Science." It may seem a small thing, but the name itself seems to lend the course an additional amount of respectability.

When asked about professional development, the teachers lamented the scarcity of available opportunities, but say the district was very supportive of their efforts to prepare for the new curriculum. That is clearly true. Although there were not many opportunities for formal professional development, the school invested significant time and resources to help the teachers prepare for the change. As mentioned previously, the district provided teachers with copious release time for curriculum development and research visits to schools already teaching physics first, and hired a university consultant to facilitate the process. Teachers were very optimistic about continued support for their professional development.

During the school year, understandably, teachers are quite focused on their courses, and most curriculum development work done by teachers is intradisciplinary in nature. As a result, there is a perception that department-wide agreement and understanding about what content should be taught in the core three-year sequence is lacking. One teacher suggested that this may be in part because of the youth of the program; a significant number of teachers are still teaching courses to students who are in the old program, and therefore obviously cannot devote their full effort to the new program during the school year. This teacher also postulated that once all of the students from the old program have graduated, it will be easier for everyone to focus fully on the new curriculum. This certainly seems reasonable, and emphasizes the importance of the summer curriculum work the department strives to do every year.

This program, although young, appears to be on extremely solid footing. The effort the science department put into research and planning prior to implementation was invaluable in their bid for acceptance from the board, and will continue to prove priceless as they continue to develop individual courses and the 9-12 curriculum as a whole. Their continued hard work has also secured them the support of their building and district administrations, school board, and community as a whole. This support will likely help to see them through any problems that develop, such as the potential dip in state test scores mentioned previously. Their obvious commitment to continued self-evaluation will also be useful in this regard. Based on the diligence and thoughtfulness the department has exhibited to date, this program looks to have a very bright future.

Conclusion

It is important to note that schools taking part in this study were schools currently teaching physics first. That may have a tendency to skew perceptions positively, as those with sufficiently negative perceptions of the sequence would be more likely to return to a traditional program.

That said, it is clear that schools in this study are generally enthusiastic about their curricula. They have had some areas of concern, most notably the level of mathematics in the introductory physics course and the necessity for some teachers to teach out of their fields, especially in the first two or three years after the change. However, these problems and issues that have arisen during implementation have not proven intractable, and schools that have faced them either have solved them or are addressing them currently.

Further research on the effectiveness of physics-first curricula is clearly needed. With rare exception, schools making this change have been satisfied with informal assessments of their own efficacy in improving their science programs. While this is useful, studies such as this one should be balanced with quantitative studies, especially given the current federal emphasis on quantitative evidence.

Schools are already likely to have quantitative data available that may be helpful in understanding the effects of these programs. Such data might include:

- scores on local-, state-, or national-level standardized tests.
- the number of science electives in which students enroll.
- the number of advanced science courses in which students enroll (aggregate and by discipline).
- what fraction of students declare science majors on entering college.
- Future work should include collection and analysis of these data.

Further research should also include a comprehensive search for three types of schools: (a) more schools that are teaching physics first in their science sequence, (b) schools that have attempted to implement a physics-first program but either were unable to or decided not to, and (c) schools that implemented a physics-first curriculum but later returned to a traditional program. Qualitative studies of the latter two types of schools could provide lessons to those considering a physics-first implementation about possible pitfalls to avoid.

The title of this report, *The State of Physics-First Programs*, may in fact be somewhat misleading, as there are surely as many states as there are programs. Hopefully in focusing on the commonalities of development and implementation processes, the programs as they stand, and the concerns of schools and departments who have successfully implemented these programs, this report will be useful to those considering their own such implementation.

Appendixes

Appendix A: Summary of Demographic Information (*n*=58 schools)

School type:	Private	Public
In this study	53%	47%
Nationally[11]	30%	70%

Average Enrollment:	Private	Public	Overall
In this study	380	1528	914
Nationally	321[12]	786[13]	645[14]

Setting:	Private[15]			Public[16]			Overall[17]		
	Rural	Sub.	Urban	Rural	Sub.	Urban	Rural	Sub.	Urban
In this study	10%	45%	45%	11%	56%	33%	10%	50%	40%
Nationally	23%	37%	40%	36%	39%	25%	33%	39%	28%

Geographic Region:[18]	Private[19]				Public[20]				Overall[21]			
	NE	SE	C	W	NE	SE	C	W	NE	SE	C	W
In this study	52%	10%	6%	32%	41%	4%	30%	26%	47%	5%	17%	29%
Nationally	26%	21%	27%	26%	18%	22%	36%	25%	23%	21%	30%	25%

Science Requirement (years)	One	Two	Three	Four
Private	0%	32%	65%	3%
Public	7%	48%	30%	15%
Overall	3%	40%	48%	9%

Years teaching physics first:	1-4	5-8	9-12	13-16	17+
In this study	36%	31%	19%	7%	7%

[11] *Digest of Education Statistics 2000*, National Center for Education Statistics, Table 87.
[12] *Ibid.*, Table 60.
[13] *Ibid.*, Table 94.
[14] *Ibid.*, Derived from Tables 60, 87, & 94.
[15] National numbers from *Ibid.*, Table 60.
[16] National numbers from *Ibid.*, Table 86.
[17] National numbers from *Ibid.*, derived from Tables 60, 86, & 87.
[18] Geographic regions are those used by the Bureau of Economic Analysis of the U.S. Department of Commerce, the National Assessment of Educational Progress, and the National Education Association. See *Ibid.*, p. 527. *NE* represents the Northeast Region; *SE*, the Southeast; *C*, the Central; and *W*, the West.
[19] National numbers from *Ibid.*, Table 64.
[20] National numbers from *Ibid.*, Table 99.
[21] National numbers from *Ibid.*, derived from Tables 64, 87, & 99.

Percentage of students belonging to a minority group:	Private	Public	Overall
In this study	18%	26%	24%
Nationally[22]	N/A	37%[23]	N/A

Predominant minority group in the school:	African-American	Asian	Hispanic	Native American
Private	50%	38%	12%	0%
Public	33%	19%	40%	8%
Overall	42%	29%	25%	4%

Percentage of English-Language Learners:	Private	Public	Overall
In this study	18%	26%	24%

	In this study	Nationally
Percentage of students receiving federally-funded free or reduced-price lunch (public schools only):	18%	26%

[22] *Digest of Education Statistics 2000*, National Center for Education Statistics, Table 87.
[23] *Ibid.*, Table 44.

Appendix B: Summary of Responses to Specific Telephone Interview Questions

Below are the questions asked during the telephone interviews, with tabulated responses. The interview format was free-response, so responses listed are representative, not verbatim. Questions not suited to this sort of tabulation are not included. The questions and prompts are in **bold**. Please note that not every teacher responded to every part of every question, and that in some cases, teachers may have given more than one of the listed responses. Because of this, total responses do not always add up to the number of teachers.

Questions / Responses	Private (n=6)	Public (n=7)	Overall (n=13)
How do you like the physics-first curriculum? How's it going?			
"Like it" / "it's going well"	6	6	12
"Going pretty well"	0	1	1
How's it going for you?			
"Well" / "I enjoy it"	6	7	13
How's it going for other teachers in your department?			
"They feel it's been helpful"	4	3	7
"Haven't had much to compare against yet"	2	1	3
"Not a significant issue for them"	0	2	2
How's it going for the students?			
"They love it"	4	4	8
"They don't know the physics-first sequence is unusual"	1	1	2
Were there any major issues that came up when setting up the curriculum?			
No	3	1	4
People	3	3	6
Textbooks and supplementary materials	1	3	4
Labs / lab equipment availability	1	1	2
State standards	0	1	1
Standardized testing	0	2	2
College accreditation	1	0	1
Who made the decision [to go to a physics-first curriculum]?			
Physics teacher	3	2	5
Science department (as a whole)	0	4	4
Science department chair	2	0	2
Administration	1	1	2

Questions / Responses	Private (n=6)	Public (n=7)	Overall (n=13)
Other than the primary mover(s), who was involved in the decision process?			
Students	0	1	1
Parents	0	1	1
Teachers	2	2	4
Counselors	0	1	1
Administrators	2	5	7
School board	0	3	3
If not all students take physics first, who makes the decision about which students take physics first?			
All students take physics first	4	4	8
Counselors—transfer students coming from a traditional program don't take physics first	1	1	2
Math teachers—students with weak math backgrounds don't take physics first	1	1	2
Counselors—students with weak science backgrounds don't take physics first	1	0	1
A team of counselors and teachers (including special education teachers)	0	1	1
Were teachers prepared for the new curriculum? If so, how?			
Yes—as part of the standard, teacher-led professional development program	1	2	3
Yes—through summer work	2	1	3
Yes—informally	0	2	2
Yes—by attending workshops	1	0	1
Yes—by visiting schools already teaching physics first	1	0	1
No	2	2	4
Is support continuing?			
Yes—as part of the standard, teacher-led professional development program	2	2	4
Yes—informally	0	3	3
Yes—through summer work	1	0	1
Yes—by attending workshops	1	0	1
No	2	2	4
How are new teachers introduced to the system / philosophy?			
Mentoring	2	3	5
Hasn't been addressed	1	4	5
Through the interview process	2	0	2
Summer work with the department	1	0	1

Questions / Responses	Private (n=6)	Public (n=7)	Overall (n=13)
Did the science department meet and work as a team to implement the new curriculum?			
No	5	3	8
Yes—entire department	1	1	2
Yes—lead teachers from each discipline	0	2	2
Yes—teachers of the new freshman physics course	0	1	1
Does (the science department) still meet to continue development? How often?			
Informal discussions among teachers to share experiences	2	2	4
Yes—monthly	1	1	2
Yes—lead teachers from each discipline meet occasionally	0	2	2
Yes—twice monthly	0	2	2
Yes—in week-long summer institutes	1	0	1
No	2	0	2
Have you been able to collect any information on the success of physics first in your school?			
No	6	6	12
Yes—local-level assessments	0	1	1
What kinds of information might be available?			
Standardized tests (state or national)	1	3	4
Enrollment in AP physics	1	0	1
Local assessment information	0	1	1
Numbers of college science majors	0	1	1
Enrollment in advanced science courses	0	1	1

Appendix C: Survey and Interview Protocols

Initial Email Survey

How long has your school been teaching physics first?

How long have you personally been teaching physics first?

Approximately what percentage of students in your school take physics first?

Approximate number of students enrolled in school:

Is your school public or private?

Is your school inner city, urban, suburban, or rural?

What is the school's science requirement for graduation?

Approximately what percentage of the school's students are members of minority groups?

What is the predominant minority group in your school (e.g., African-American, Hispanic, Asian, etc.)?

Approximately what percentage of the school's students are English-language learners (ELL, LEP, etc.)?

Approximately what percentage of the school's students are eligible for free or reduced-price lunch?

Phone Interview Protocol

1. How do you like the physics first curriculum? How's it going?
   <u>Prompts:</u>
   How's it going for you?
   for other teachers in your department?
   for the students?

2. Were there any major issues that came up when setting up the curriculum?
   <u>After they talk:</u>
   I have a quick checklist of some other possible issues. Let me know (yes/no) if any of them were issues in your school during the implementation of physics first, and if so, tell me *briefly* what the issue was:
   People?
   Textbooks and supplementary materials?
   Labs/lab equipment availability?
   State standards?
   Standardized testing?
   College accreditation?

3. How was the decision made to go to a physics first curriculum? Who made the decision?
   <u>Prompt:</u> Other than the primary mover(s), who was involved in the decision process? What roles did they play?
   Checklist of people to bring up if not mentioned:
   Students?
   Parents?
   Teachers?
   Counselors?
   Administration? (building or district?)
   Extension question: If not all students take physics first, who makes the decision about which students take physics first?

4. Were teachers prepared for the new curriculum? If so, how? (Inservices? Outside training or classes?) Is the support continuing? How are new teachers introduced to the system/philosophy?
   Extension question: Did the science department meet and work as a team to implement the new curriculum? Does it still meet to continue development? How often?

5. Have you been able to collect any information on the success of physics first in your school?
   Extension question: What kind(s) of information might be available? (standardized tests? information on how many students go on to take "traditional" physics or an AP science course, information on graduates who go on to major in science in college, etc.)

School Visit Protocols:

Contact[24] Interview Protocol

1. What courses do you teach? How long have you been teaching it (them)? Are you the department chair? If so, for how long have you been the department chair?

2. What is your role among teachers who teach the introductory physics course?
   - To what extent are you in a leadership role?
   - What, if anything, has been difficult in promoting and implementing the school's physics-first curriculum?
   - Who are the major supporters of the school's physics-first curriculum?
   - Is anyone trying to create roadblocks?

3. What has been the most innovative aspect of your introductory physics course? of the curriculum as a whole?

4. What modifications, if any, are you making or considering making to your introductory physics course?

5. What modifications, if any, would you like to make to the curriculum as a whole (i.e., not necessarily just in your classroom)?

6. Have there been any policies or practices instituted in the department or school along with or since implementation of the physics-first curriculum that affected the curriculum or the science department? If so, how?
   - schedule changes (e.g., to or from a block schedule)?
   - new assessment or grading policies?
   - new policies regarding materials adoption?
   - new policies or programs implemented to more directly involve the community or parents in school decision-making?
   - other priorities such as literacy, reading and writing, etc.

7. Have there been any changes among the people who make administrative decisions in the school? If so, how has that affected the program?
   - the person who makes budget decisions for the school?
   - the person who makes budget decisions for the science department?
   - the person who makes decisions about materials adoption, selection, and distribution?

8. Do you think the physics-first curriculum has affected your school as a whole, i.e., subjects other than science (like math)? Does anyone outside the science department have regular input on the curriculum?

9. To what degree are parents aware and supportive of the physics-first curriculum? Have there been any conversations or meetings with parents to discuss the curriculum? If so, what comments have they made? What are their concerns, if any?

10. Do you feel that any of the following have been barriers to implementation or continuing development of the science curriculum in this school?

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[24] The "contact" was the person who responded to the email survey and the phone interview. In one of the school visits, the contact was interviewed together with two other teachers, so the science teachers group interview protocol was used.

- support from school and district administration?
- professional development for science teachers (including time to meet)?
- lack of materials, unavailability of materials, or inferior but mandated materials?
- mandated testing?
- other school, district, or state priorities?

11. How would you describe the philosophy of your science department, especially as it regards the ordering of your core courses?

Science Teachers Group Interview Protocol

1. What course(s) do you teach? How long have you been teaching it (them)?

2. How do you like the physics-first curriculum? How's it going for you?

3. Has the physics first curriculum affected any of the following, and if so, how?
   - the content you teach in your classes?
   - how you teach your classes on a daily basis?
   - the continuity and coherence of the 9-12 science curriculum?
   - assessment policies, in either your classroom or the department as a whole?

4. Is professional development in this school or district primarily mandated by the school, or self-guided? If mandated, who makes decisions about what will be done? If self-guided, who approves expenditures?

5. What is the science department and school vision for science in the classroom? Who are the people who best articulate the vision for science in this school?

6. How often do science teachers meet as a group such as in science department meetings? What sorts of things (other than normal department business) are discussed during those meetings?

7. What is the degree of department-wide understanding about what science concepts should be taught in each of the core (i.e., non-elective) courses in your science curriculum?

8. Is there regular time allocated for teachers to work together to discuss content and curriculum outside of department meetings?

9. What is the most important or most central aspect of your physics-first curriculum?

10. What are this year's department priorities and goals?

11. What are this year's district priorities and goals?

12. What is the school's science requirement for graduation (how many years **and** what, if any, specific courses)? Are all students beholden to that requirement, or are there exceptions?

Principal Interview Protocol

1. From your perspective, what has been the effect of the physics-first curriculum on:
   - the school's science program in general?
   - the school's science teachers? (morale, professionalism, etc.)
   - the school's students? (enrollment in science courses, performance in science courses, etc.)

2. To what extent were state standards involved in the development and implementation of the physics-first curriculum? What role will they continue to play in physics-first curriculum revision?

3. To what extent was standardized testing (state-mandated, ACT, SAT, etc.) a factor when developing and implementing the physics-first curriculum?

4. To what extent were the rest of the school (beyond the science department) and district involved in implementation of the physics-first curriculum?

5. To what extent were parents and students involved in implementation of the physics-first curriculum?

6. Have there been any changes in school restructuring such as block scheduling or any other changes that might affect science?

7. To what extent do science teachers get together to discuss what is taught in science and how science is taught?
   - Are there regular department meetings? How often?
   - What professional development opportunities do the school and district provide?
   - Was there any special training or orientation to prepare teachers already part of theschool staff to change to teaching physics first?

8. Has there been a change because of implementing the physics-first curriculum in:
   - how new teachers are oriented to the science program?
   - hiring and personnel evaluation practices?

9. Has a school vision for science in the classroom been established?

10. To what degree are parents aware and supportive of the physics-first curriculum? Has this changed since the original implementation of the curriculum?

11. To what degree do you feel the district supports the physics-first science program?

Counselor Interview Protocol

1. From your perspective, what has been the effect of the physics-first curriculum on:
   - the school's science program in general?
   - the school's students? (enrollment in science courses, performance in science courses, etc.)

2. To what extent were state standards involved in the development and implementation of the physics-first curriculum? What role will they continue to play in physics-first curriculum revision?

3. To what extent was standardized testing (state-mandated, ACT, SAT, etc.) a factor when developing and implementing the physics-first curriculum?

4. To what extent were considerations of college accreditation (of the conceptual physics course) and admission factors when implementing the physics-first curriculum?

5. To what extent were the rest of the school (beyond the science department) and district involved in implementation of the physics-first curriculum?

6. To what extent were parents and students involved in implementation of the physics-first curriculum?

7. Have there been any changes in school restructuring such as block scheduling or any other changes that might affect science?

8. Has there been a change because of implementing the physics-first curriculum in:
   - how middle school/junior high students are prepared for high school science?
   - how transfer students are brought in to the science curriculum?

9. Has a school vision for science in the classroom been established?

10. To what degree are parents aware and supportive of the physics-first curriculum? Has this changed since the original implementation of the curriculum?

11. To what degree do you feel the district supports the physics-first science program?

Student Interview Protocol

1. What do you like about science or physics? What do you not like about science or physics? Give specific examples.

2. Do you ever feel that you are unable to do science or physics because it is too hard or confusing?

3. Describe one of your favorite experiments or investigations. Why was it your favorite?

4. Describe one of your least favorite experiments or investigations. Why was it your least favorite?

5. How does what you do in science or physics relate to real life? Do you use science or physics outside the classroom? Give specific examples.

6. What tools of science do you use? For example, do you use computers, calculators, or microscopes (or other technology) during science? How often do you use them? How do you use them?

7. *(for students who are currently in chemistry or biology)* Do you think that having physics (and chemistry) has helped you in your chemistry (biology) class? Give examples of how.

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