Inquiry by Design

Creating a Standards-based high school science program

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In 1995, the Attleboro High School science program resembled most other traditional programs. Students were placed in courses based on fuzzy criteria, usually without making their own informed choices. Science disciplines were assigned levels of difficulty according to unwritten rules (for instance, Earth science was considered to be easier than biology, both of these courses being easier than physics). Our program served special needs, honors, college-prep, noncollege-prep, and vocational students, but it was unclear whether or not it was meeting each population's needs. Students were required to pass two years of science to graduate, but this was difficult for some. Few were motivated to pursue more.

The schedule allotted no extended lab periods; each science course met for 53 minutes. Our nine-person science faculty was a mixture of veteran and new teachers. All held certifications in at least one science; some held dual science certifications, and a few also held general science certifications. Though the group was social and respectful of one another, there was little collegial collaboration. By most measures, we had an ordinary U.S. high school science program (Figure 1) serving ordinary U.S. high school students.

Framing the inquiry

In 1995, in her first year, our high school science coordinator began to examine the design of the science program. She wondered if the program made sense for student learning and if it could be adapted to meet newly drafted state standards and prepare students to pass high stakes exams. She took her queries to the department, but was wary of her colleagues' reactions. She knew from experience that such questioning can feel like an inquisition rather than an inquiry, and she wanted honest, not defensive, answers.

If educational leaders were more like scientists, they would realize that answers to the most important and fundamental questions cannot be predetermined; they must be only the result of unbiased inquiry. Our science coor-dinator's commitment to an open-ended discourse was essential to the success of the inquiry. She believed that teacher empowerment, not obedience, was the key to true programmatic reform, and she reassured the department that her questions were grounded in honest resolve. With a bit of trepidation, the department agreed to investigate the tenets of the science program during a series of department meetings.

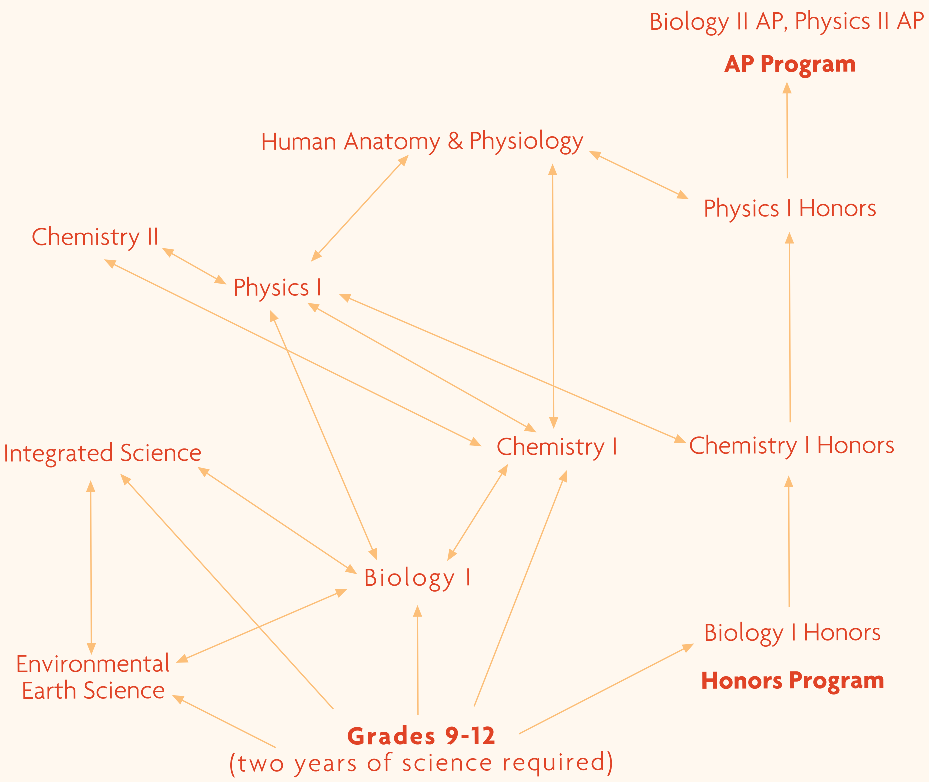
In the spirit of scientific inquiry, our department asked a basic question, knowing it would require a multifaceted investigation. We wanted to know if the school's science program was adequately designed to meet the needs of students and the new science standards. It is one thing to believe that certain methods are valid, but an entirely different task to demonstrate their

validity. Though discussions were heated at times, the faculty worked in concert to ascertain why the current program evolved the way it did. Readers who believe such an investigation would benefit their own department should realize that it is a mistake to assign a timeline to such a discourse. When all concerns are satisfactorily addressed, this phase of the inquiry will come to a natural conclusion.

By the spring of 1996, the faculty determined that the science program was based on few science education tenets. We could not demonstrate that all students had access to all science disciplines at appropriate proficiency and developmental levels. We could not prove our program made sense for student learning or that it was readily adaptable to the new standards. We gained confidence in our own perspectives on issues in science education and were able to see this outcome as a challenge, not a problem. There was an honest impetus for departmental col-

FIGURE 1

AHS science course schema 1995–1996.



laboration. At the same time the *National Science Education Standards* went to print, we rolled up our sleeves and got to work (National Research Council, 1996).

As a department, we were inspired, but a bit daunted. We knew our science program lacked clear goals but also realized that creating our own might result in ideals ungrounded in the realities of current practice. When we turned to the national and state standards documents, we viewed them as a resource for our own work rather than a manifesto of someone else's. We used the standards to help us define grade 12 curriculum goals for our broad student population.

Did we agree with the inclusion of every standard? No. Would we have written them differently? Possibly. But we admitted that if we had sat down together to compose similar guidelines, ours would not have looked much different. We initially acknowledged but then promptly abandoned our egotistic and territorial emotions. We did not have all the answers, and we had a less-than-perfect program to revamp.

We were convinced by our research findings—the integration of the science disciplines is an ideal context for learning science and for meeting standards.

Envisioning an optimized curriculum

We searched for the most sensible ways to learn science, regardless of any implementation fears. Being both the designers and implementers of our program, we investigated with both roles in mind but did not allow the design to become mired in premature logistical concerns. We decided that if the technology (the curricula) were not yet available, we would find a way to develop it. The most important part of our inquiry was the pursuit of our questions: What are the best ways to help students appreciate and understand the natural world? What kinds of curricular programs optimize student learning? Can our standards-based goals be attained through these strategies?

The Third International Mathematics and Science Study (TIMSS) informed us that science students in other countries were surpassing ours for various reasons. Apparently, U.S. high school students tend to experience an incoherent progression from one science discipline to another, while 60 percent of students from other countries in the study take more than one science course simultaneously (National Research Council, 1999). For instance, students in the Netherlands are required to take "combined physics and chemistry, biology, and geography and Earth science in grades 9 through 11" (National Research Council, 1999, 35).

Reading the first drafts of both the national and Massachusetts science standards, we saw that they promoted the coherence of disciplines that the TIMSS found lacking in U.S. science programs. The first complete edition of the *National Science Education Standards* states, "Understanding science requires that an individual integrate a complex structure of many types of knowledge" (National Research Council, 1996, 23). And the first complete edition of *The Massachusetts Science and Technology Curriculum Framework* states, "Although each domain of science has its particular approach and area of concern, students need to see how the domains together present a coherent view of the world" (Commonwealth of Massachusetts, Department of Education, 1997, 15).

These ideas made sense to us. One of our courses was already based on integrated science, but this was only a small step. The curriculum was unwieldy and could never be completed in a single year. But we were convinced by our research findings—the integration of the science disciplines is an ideal context for learning science *and* for meeting standards.

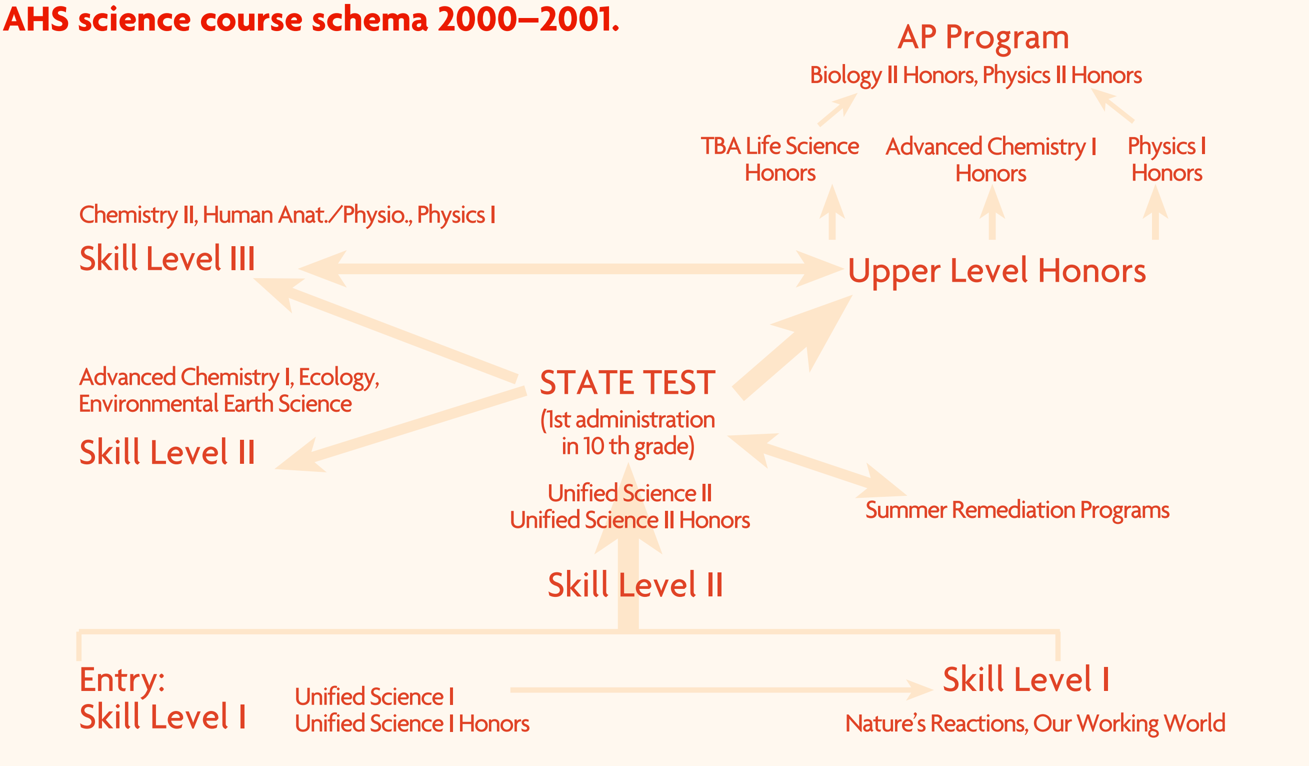
But how could we implement this integrated science thing? How would it look? Were we equipped to address its implications? We had experienced the full force of inquiry; our well-researched answer had presented more implementation questions than we could handle. So, like all science educators in need of time to do "R and D," we organized a summer workshop to hammer out the logistics.

The program design

Integrated science became the foundation of our program. We opted for a two-year integrated sequence,

FIGURE 2

AHS science course schema 2000–2001.



Unified Science I and Unified Science II, to address more than 90 percent of our state science and technology standards. To disrupt the schedules of the fewest number of students (students would either go through the old program or the new, but not a combined version), we constructed a five-year plan to phase in the new program (Figure 2). The remodeled ninth and tenth grade courses presented major implications for the design of the upper class courses. We were well aware of the ecology of our science program—if we replaced one species with another, niches within the whole ecosystem would be affected.

We also established clear promotional requirements, whereby ninth grade students needed to show proficiency in Unified Science I content and skills before being allowed to enroll in Unified Science II, and no students repeated Unified Science I. For those students needing new ways to master the same content and skills, we created two new courses (Nature's Reactions and Our Working World) to address them in other contexts. Unified Science I was and still is based on the yearlong theme "Matter, Energy, and Their Interactions," the concepts of which build on one another to elucidate the micro and macro levels of Earth's organization. Unified Science II's theme of "Change Over Time," builds chronologically from the Big Bang theory to human evolution. Students investigate content on a "need-to-know" basis, where one series of questions segues into another according to the theme, and all science disciplines are explored in both years. No inquiry-based course would be complete without asking the question, "How do we know what we know?" The technology standards are addressed nicely by revisiting this question.

To prepare students for college and to respect individual student interests, we determined there was still a place for specialized sciences. However, an integrated grade 9–10 sequence would best empower students to make informed choices about additional course work. It also meant that specialized courses could be more specialized, because we did not have to spend time on "the basics."

So far, things looked good for our students, but what did this mean for us teachers? Were we qualified to teach integrated courses? We believed that the ability to think scientifically goes a long way, that science teachers are learning coaches, and that the natural world is truly an integration of common phenomena manifested in different ways. To fill in the gaps in our content knowledge, we tapped our own departmental science expertise and were pleased to discover how well we self-educated through academic collaboration. Staff members were phased into the courses just as students were—no one was "thrown to the wolves."

Our shared commitment to a better program drove the inquiry and design processes—individual personalities did not. We were an ordinary faculty with ordinary students. Yet by simply seeking to optimize our situation, we accomplished the extraordinary, even in the face of increasing enrollment and personnel issues. Since 1995, enrollment has increased by 391 students to a total of 1875, and the science faculty has grown from 9 to 15 teachers with only 3 of the original 1995 faculty remaining. At the same time, we have had administrative turnover that included a new superintendent, assistant superintendent, principal, assistant principal, and science coordinator; and two science faculty members passed away in the span of seven months. Good science education relies on the programs, not the creators of those programs. As readers review the results of our reformed science program, they should ask themselves whether or not the legacy of their own science programs will disappear when they leave.

Quantitative results

Despite these changes and setbacks, our program has enjoyed tremendous success. Comparing Figure 1 (a schematic of our old program in 1995) with Figure 2 (a diagram of what our program looks like now) shows how far we have come. Now, our courses are grouped together so that they share similar levels of articulated science skill development, as guided by state and national standards.

Figures 3 and 4 display impressive quantitative results. Figure 3 shows how science enrollment has increased since the inception of our new program. Numbers represent absolute science enrollment by grade; percentages indicate the proportion of science enrollment to total grade level population. The numbers refer to spots in a given course, meaning a single student may be counted twice if enrolled in two courses. The percentages represent true student-grade level ratios for freshmen and sophomores. Even where juniors and seniors opt for more than one science, we must consider them as "different students" in each course. Figure 4 compares statistics of the classes of 1995 and 2001, giving readers a better sense of the upper class science course demographics. Percentages indicate the proportion of seniors graduating with three to eight full years of science, indicating that more than half the class chose to take elective science courses. State testing data remains statistically insignificant due to changing test formats and reporting

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FIGURE 3

AHS science student enrollment by grade and school year.

Percentages show proportion of science student spots per total student population at that grade level (a single student may be counted more than once if enrolled in multiple science courses).

Grade/Year	1995–1996	1996–1997	1997–1998	1998–1999	1999–2000	2000–2001
Freshmen	411 (82%)	413 (83%)	503 (93%)	498 (93%)	525 (96%)	562 (99%)
Sophomores	341 (86%)	415 (85%)	410 (87%)	447 (88%)	442 (87%)	486 (92%)
Juniors	226 (72%)	309 (83%)	425 (97%)	385 (96%)	431 (95%)	441 (110%)
Seniors	135 (47%)	154 (51%)	307 (91%)	315 (85%)	279 (75%)	311 (83%)
Science Totals	1113 (75%)	1291 (78%)	1645 (92%)	1645 (91%)	1677 (89%)	1800 (96%)

FIGURE 4

AHS Class of 2001—Students graduating with three (required) or more full-year science courses.

Number of full-year science courses	Percentage of the class of 1995	Percentage of the class of 2001
3	n/a (only two years required for graduation)	42% (required for graduation)
4	9%	38%
5	1%	12%
6	0%	6%
7	0%	1.6%
8	0%	0.4%

categories, and thus year-to-year comparisons cannot be made with confidence.

We can say that between 1998 and 2000, the number of students ranked as "Advanced" increased from 1 to 3 percent, the number of "Proficient" students increased from 21 to 23 percent, the number of "Needs Improvement" students decreased from 45 to 39 percent, and the number of "'Failing" students decreased from 33 to 31 percent (we now have 4 percent of our students ranked in a miscellaneous "Other" category). We also asked various Unified Science students about their comfort level in taking tests and compared their answers with those of students from the former program. Unified Science students said they felt very comfortable with nearly all the content and skills that the test assesses, while other students felt more handicapped by their traditional course sequence.

Qualitative results

Teachers report several changes in student attitudes toward their high school science experience. Students feel more empowered to make choices about their science pathway and thus take more science courses. Science interests, not social pressures (for example, "it's what my brother took," or "it's what my friends are taking") drive their choices. Upper class students now vie for work-intensive lab aide positions to replace study halls, and students engage in informal science discussions outside the classroom. Students offer their unsolicited approval of teacher collaboration, and teachers find that this lends credibility to course work. Teachers also report the near absence of the question "why do we have to learn this?" Further, there is something for everybody—not only within Unified Science but also among the upper class courses.

Teachers also note a changed parental response to their children's science experience. We used to hear many complaints that students were not interested in science, or that they were not succeeding in science. Parents also questioned, and even fought, the Unified Science program when it was new. Now, some parents say they wish they had taken similar classes when they were in school. Based on conferences, parents no longer have concerns about whether their students are receiving an appropriate and rigorous science education, regardless of post-high school plans. Recently, some parents have even been wondering why their children are enrolling in so many upper-level science courses. We get a kick out of that!

Upon reflection, which has also increased since 1995, we note some changes in our pedagogy and professional growth. Collectively, we have expanded our understanding of science, are more cognizant of potential student misconceptions, are more willing to try new strategies in our classrooms, and volunteer our time to improve and reflect on the program. Our classes are spending more time conducting experiments, and we now need to sign up in advance for lab space that can serve 24 classes a day at maximum capacity! In short, our professional growth mirrors the growth of the program itself. We remain an ordinary group of science teachers serving an ordinary group of high school students, enjoying extraordinary success in the science classroom.

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References

Commonwealth of Massachusetts, Department of Education. 1997. *The Massachusetts Science and Technology Curriculum Framework.* Malden, Mass.: Department of Education.

National Research Council. 1996. *National Science Education Standards.* Washington, D.C.: National Academy Press.

National Research Council. 1999. *Global Perspectives for Local Action: Using TIMSS to Improve U.S. Mathematics and Science Education.* Washington, D.C.: National Academy Press.