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Sequencing Upper School Science and Math Curriculum

The "physics-first" sequence and other considerations for 6th–12th-grade science

by John Mays

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Putting Physics First

For several reasons, physics is the best choice in 9th grade for all students. This claim frequently surprises educators, especially those more familiar with the biology-chemistry-physics sequence. In this article, I will unpack this claim and also discuss the placement of chemistry and biology in a science curriculum.

When considering where to place physics in the high-school science program, it is important to keep in mind the distinction between an introductory physics course and a more advanced course that incorporates vector calculations and trigonometry into problem solutions. I will refer to these two courses as the *introductory course* and the *vector/trig course*. It is also important to note that I reference two different groups of 9th graders: grade-level students who do

not specifically excel in the study of science, and accelerated students who do. The assumption here is that your program is stratified into two different pathways (a.k.a., tracks): a grade-level pathway and an accelerated pathway. I will address this idea of stratification briefly later in this article.

One of Novare's objectives in creating a science curriculum is the development of a program that gives not just the top students, but *all* students a solid introduction to physics. Knowing full well that some states are insisting that all students take a vector/trig course, it is my opinion that vector/trig physics is very difficult and is not for everyone. As an educator who has taught physics for more than 20 years in public schools, private schools, and colleges, I can attest that making it a requirement for all students is a mistake. Private schools and homeschoolers should consider carefully whether they will follow the public schools or instead adopt sensible, logical programming that can serve the needs of all students.

To begin, there are essentially three options for placing physics in the high-school science sequence. The first is to offer only vector/trig physics to upper-level students (11th or 12th graders). This is the way it was when I was in high school. The problem with this option is that only a small percentage of a typical student body has the math skills to handle a course like this. When the vector/trig course is offered as an elective, typically about 10%–20% of the students will elect to take it, and those who do will have their work cut out for them. But if the vector/trig elective is the only choice, some 80%–90% of the students will not have a physics course in high school at all. This is not an acceptable scenario because any modern-day high school education should include a grounding in the study of physics, which is the study of how the world around us works.

Even students with modest ability can solve basic problems in motion, force, energy, density, and so on, and such computations should definitely be part of the introductory [physics] course.

The second and most common option is to require all students to take a vector/trig physics course in 11th grade. As I noted earlier, less than a quarter of a typical student body can handle a vector/trig course, even if it is watered down. From my own classroom observations, I have concluded that this approach is a significant mistake. When the class average on an exam in April is 63, and students are making pitiable jokes about their scores in the 40s (an actual example), you know that there is a problem.

The third option is known as the "physics-first" approach. In this approach, an Algebra I–based physics course is provided to all 9th graders, and then a vector/trig physics course is offered as an elective, along with other upper-level science electives. This option works very well and appropriately addresses the needs of all students. Students in 9th grade should take an introductory course that focuses on the basic principles of physics. The course should incorporate plenty of mathematics but restrict the math to what students concurrently taking Algebra I can handle.

The mathematics component is very important, and for this reason, I do not recommend so-called "conceptual physics"—a physics course without mathematics. Even students with modest ability can solve basic problems in motion, force, energy, density, and so on, and such computations should definitely be part of the introductory course. The course for accelerated or honors-level students should

incorporate introductory chemistry as well and grade-level students should take an introductory physics course. These two pathways correspond to the Novare Science texts *Introductory Physics* and *Accelerated Studies in Physics and Chemistry (ASPC)*, respectively. Our vector/trig physics text is *Physics: Modeling Nature*.

Benefits of Physics First

So far, we have seen that placing a physics-based course in 9th grade provides all students with an introduction to the subject while allowing students who so desire to take a more advanced vector/trig course later as an elective. A key justification for this sequence is the educational benefit of having a background in physics prior to taking chemistry or biology. The physics curriculum will include several topics important for chemistry, such as energy, heat, energy transfer, phases of matter, electrostatic attraction, temperature scales, light, types of substances, and the internal structure of the atom. Covering these topics in physics as 9th graders will pay large dividends when students encounter them later in chemistry.

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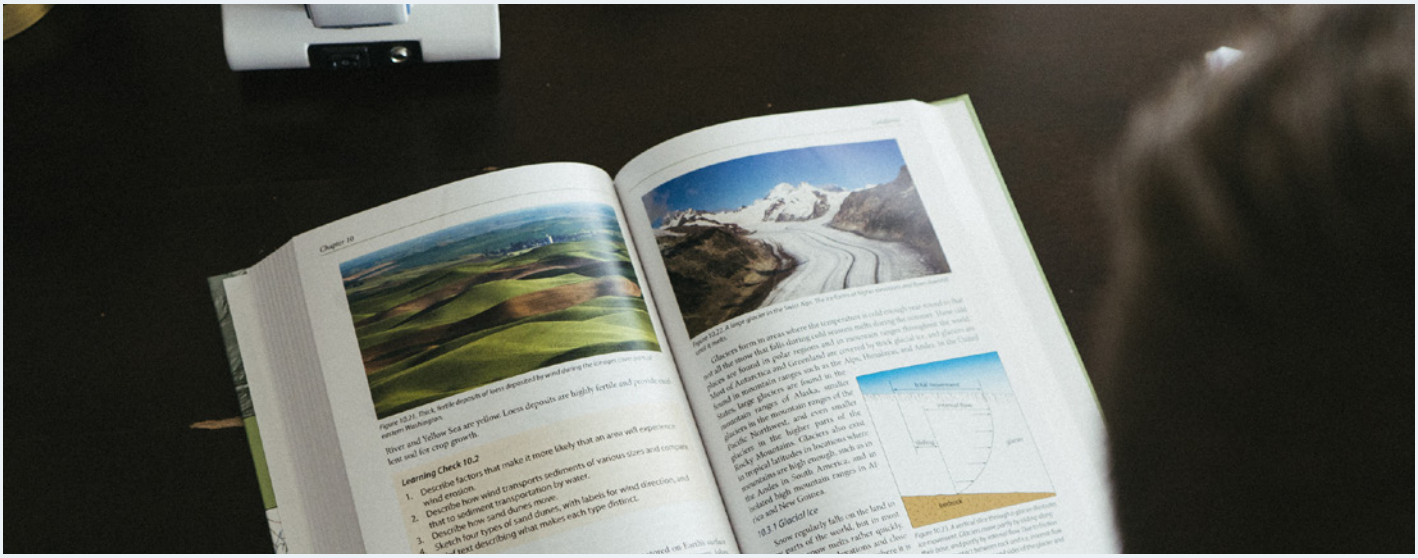
A well-designed physics course should also provide students with a significant amount of practice in basic scientific mathematical skills. Two skills of supreme importance in science are performing unit conversions and using scientific notation, which all students should master as 9th graders. Additionally, the course should introduce students to the roles of accuracy and precision in scientific measurements and give students considerable practice working with significant digits.

With a background in these important skills, students will be better prepared to tackle topics in chemistry. Chemistry is often perceived as difficult because students usually have to learn chemical principles and mathematical skills simultaneously. But when students arrive in chemistry having already mastered unit conversions, scientific notation, and significant digits, a lot of the perceived difficulty of chemistry simply disappears.

In summary, placing Algebra 1–based physics in 9th grade provides all students the best access to an appropriate introduction to physics. It also introduces all students to important fundamental topics that play major roles in chemistry. Finally, studying physics in 9th grade gives all students an opportunity to master the critical skills of performing unit conversions, using scientific notation, and dealing with significant digits. With these skills in their toolbox prior to taking chemistry, students will be equipped to tackle the basic topics in



chemistry without getting tangled up in learning the math skills at the same time. The Novare Science text that students would use after taking introductory physics is *General Chemistry*.

Dual Science and Math Pathways

Since homeschooling families have the freedom to customize each child's science courses to align with the appropriate math course, this section focuses on considerations for private schools and larger homeschool co-ops.

The majority of small private schools with whom I have talked place all students in algebra in 8th grade. When a school has fewer than 10–15 students per grade in middle and high school, a one-size-fits-all math program like this is more or less an economic necessity. But it is critically important that placing students this way be considered a *temporary* measure. The fact is that on average, roughly half of the students in a typical school will be ready for algebra in 8th grade. The other half will need an additional year of pre-algebra before taking algebra in 9th grade.

While there is much to say on this topic, suffice it to say that stratification is essential. As soon as the number of students in each grade can support it, separate pathways should be created for grade-level students who take algebra in 9th grade and accelerated students who take algebra in 8th grade. (One percent or so of students will be ready for algebra in 7th grade; they can be placed with the 8th graders.)

When students are stratified into two pathways, or tracks, in math, the same stratification should generally apply to the high-school science courses as well. Splitting students into two science pathways allows the school to provide a solid, basic sequence of courses for grade-level students

Physics-First Sequence

PATHWAY	GRADE-LEVEL	ACCELERATED
9th	Introductory Physics	Accelerated Studies in Physics and Chemistry
10th	General Biology	Chemistry for Accelerated Students
11th	General Chemistry	General Biology or Advanced Biology
12th	Anatomy/Physiology or Environmental Science	Physics: Modeling Nature or Molecular Biology

while enabling accelerated students to undertake a challenging curriculum of science courses that can enable them to compete for admission into technical majors at more selective colleges and universities.

We will get into some important details regarding the two course sequences in the next two sections. To aid that discussion, the physics-first sequence chart shows what I propose for the two pathways.

Science and Math Linkage

A key linkage connects students' math placement and the science courses they undertake each year. This linkage relates to the math prerequisites for studying chemistry and is one of the factors influencing science-course sequencing in both grade-level and accelerated pathways. The prerequisite in question is the need for students to be taking (or to have completed) Algebra 2 at the same time they are studying chemistry. Assuming a standard sequence in math courses (Algebra, Geometry, Algebra 2), grade-level students take Algebra 2 in 11th grade and accelerated students take Algebra 2 in 10th grade. Many topics from Algebra 2 come up naturally in the study of chemistry. The definitions of pH and pOH are logarithmic expressions, and solving pH problems involves both logarithms and exponential functions. Reaction rates and chemical equilibrium involve power functions. The inclusion of these topics in chemistry requires that students take chemistry concurrently with (or after) their second year of algebra. In turn, this places chemistry in either 10th or 11th grade, depending on math placement. The placement of chemistry in one of two different years allows for putting some key distinctions in place in the two science-course sequences, distinctions that allow the school to serve each group of students appropriately. We will look at these in the next section.

The Complete Science-Math Course Sequence

Putting the science and math courses together for both pathways results in the program shown in the pathways chart. Three points should be noted right away. First, Anatomy & Physiology

Pathways

	GRADE-LEVEL PATHWAY		ACCELERATED PATHWAY	
	SCIENCE	MATH	SCIENCE	MATH
9th	Introductory Physics	Algebra	Introductory Physics and Chemistry	Geometry
10th	General Biology	Geometry	Advanced Chemistry	Algebra 2
11th	General Chemistry	Algebra 2	Advanced Biology	Precalculus
12th	Anatomy and Physiology	Statistics	Molecular Biology and/or Vector/Trig Physics	Calculus

> With physics first, subjects naturally build upon and complement one another, and that results in better learning and longer-term retention of course content.

is a very good fit for grade-level students in 12th grade. The topics covered align closely with their natural interests, and the course is good preparation for college study. Novare Science hopes to publish a text for this course in the future.

Second, the math course shown in the chart for grade-level 12th graders is statistics. (I recommend that this course be AP Statistics. The alignment between the AP Statistics syllabus and what would be taught in the course anyway is nearly 100%.) Setting up the course with the College Board as an AP course puts a highlight in the transcript of grade-level students. I have taught statistics at both the high-school and college levels to students with extremely limited math ability and found that, when taught well, virtually anyone of average ability can handle it.

I do not recommend precalculus as a 12th-grade course for grade-level students. I have found that the material is unnecessarily challenging for them. On the other hand, statistics is accessible to everyone and is useful preparation for nearly every college major.

Third, when student numbers permit, it is useful to stratify the 11th- and 12th-grade math offerings for accelerated students one step further. Students with appropriate aptitude and interest can be placed in an honors or advanced precalculus course, followed by AP Calculus. Bright students who aren't quite up for the extreme rigors of AP Calculus should take a separate precalculus class followed by a non-AP Calculus course. Just as with vector/trig physics, there will be many students—even those in the accelerated pathway—who cannot handle AP Calculus. The non-AP course will be just right for them.

To be competitive at highly selective colleges and universities, the accelerated students will need a heavy dose of cell chemistry in their biology course. This will be much easier to accomplish if chemistry precedes biology. Happily, the math alignment in the accelerated pathway facilitates this sequencing.

Consider the line-up we have in the accelerated science-course sequence (see the physics-first sequence chart). The 9th-grade physics/chemistry course (the course we call *ASPC*) should cover the physics material by mid-to-late February and then switch to chemistry. In the final three months of the year, the students can get an excellent head start in chemistry, allowing us to denote the 10th-grade chemistry course as advanced chemistry. The

Novare Science text that corresponds with this course is *Chemistry for Accelerated Students*. The introductory chemistry material covered in students' previous year will allow them to move quickly into more advanced topics in 10th grade. With chemistry covered in 10th grade, the 11th-grade biology course can include a full semester of cell chemistry, along with other standard topics, such as Mendelian genetics. To make room in this course for a full semester of cell chemistry, less sophisticated topics, such as human organ systems, should be moved down to the middle-school life-science course, where they are quite age appropriate.

After taking advanced biology as 11th graders, students will be ready in 12th grade for a solid course in molecular biology, a course that is always impressive to colleges. (Novare Science does not yet have such a text but hopes to publish one in the future.) Alternatively, students can take the vector/trig physics class. Schedules permitting, some science-minded students will want to take both. At one school where I taught for 13 years, most of the components of the program outlined above were in place and the program served the students very well. Students from both grade-level and accelerated pathways returned to visit from their first or second year in college and often commented on how well prepared they were.

Considerations for Middle School

I will conclude with a few considerations for middle-school science. The best courses to offer are life science, physical science, and earth science. An astronomy component in the earth science course is a good idea and will make the course a lot of fun. I do not recommend omnibus courses with names such as "general science." Such courses tend to be amorphous, lacking in definition and focus. Middle-school students will learn more and remember more if they can focus on one basic discipline for the entire year. If your school includes 6th grade as part of the middle school, then I recommend life science, physical science, and earth science/astronomy as the sequence for 6th, 7th, and 8th grades, respectively.

If your middle school consists of only 7th and 8th grades, then you will need to pick two of these three courses to offer in middle school. One obvious way to do that is to schedule physical science and earth science/astronomy for 7th and 8th grades, respectively, and make life science the key topic for 6th grade, even though 6th grade is part of the elementary school. Another approach is to switch the physical science and life science years and still keep one of them in 6th grade. The only sequence I would not recommend is placing physical science in 8th grade when introductory physics occurs in 9th grade. There is a lot of overlap between these courses, and it is best to separate them by at least one year.

Summary

The physics-first science sequence is a needed update for high school. It takes into account the way physics, biology, and chemistry have evolved as school subjects in the last century, and it has clear advantages over the traditional biology-chemistry-physics sequence. Once considered the least demanding courses in the early 1900s, chemistry and biology have exploded in terms of human understanding and are now the more complex subjects. A physics-first curriculum provides a logical sequence that supplies foundational concepts and skills upon which to build the more abstract and challenging subjects of biology and chemistry. With physics first, subjects naturally build upon and complement one another, and that results in better learning and longer-term retention of course content.