Choosing Middle School Science Textbooks: Is North Carolina Failing Its Students?

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Choosing Middle School Science Textbooks: Is North Carolina Failing Its Students? is a publication of the N.C. Education Alliance. Its purpose is to inform North Carolinians about their public schools and promote debate and discussion about the future of education reform. It is not intended to advance or impede legislation before local, state, or federal lawmaking bodies.

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Choosing Middle School Science Textbooks: Is North Carolina Failing Its Students?

Many middle school science teachers in North Carolina have to teach physical science, which is required for middle school students in North Carolina public schools. Unfortunately, both in North Carolina and across the country, often these teachers lack the appropriate academic qualifications to be teaching these courses. In fact, in many instances these materials form the teacher's own introduction to the subject. Naturally, with their limited backgrounds, they are heavily dependent on the materials from which they teach. It is especially important, therefore, that the textbooks and other materials that teachers and students are forced to use get it right.

There are five state-approved textbook series to choose from for Grades 6 through 8 in North Carolina's public schools. In judging the quality of these texts there are two important questions to ask: do they present accurate, i.e., error free, information to our students? And do they cover "the basics" of scientific investigation needed for more advanced studies that will come in high school? Unfortunately, the texts used in North Carolina's middle schools are inadequate in both of these areas.

Middle school science texts tend to be filled with irrelevant information and errors. Furthermore, in their attempt to be "relevant" the texts often deal with controversial subjects that are far too complicated for students at this level. Since it would be too difficult to sort through the scientific questions that surround the subjects, the discussions often devolve into what can only be considered political advocacy.

Part of the problem can be attributed to the textbook selection process, which is very bureaucratic.

In order for textbooks to be considered, they must meet a host of mandates that, in large part, do not contribute to the process of learning the scientific method. Because of this, it is too costly for many publishers and authors to submit books for consideration.

Scientists should be writing the texts in conjunction with, and guided by, teachers who know their audience. Books should be tested on students to determine if revisions are necessary. This is the kind of process that takes place both at the college level and in private and home school markets, where the real test is whether or not the text conveys sound information to the students, not whether it has conformed to a bureaucratic process.

Introduction: Choosing Middle School Science Textbooks

Middle-school science teachers have the toughest job of all. With most kids either approaching puberty or in the midst of it, teachers have a mix of highly active students. Those teachers that continue to teach at this level tend to be extremely creative, very committed, and most of all, patient. All of them have to teach physical science, which is a required course for middle school students in North Carolina's public schools.

Unfortunately, both in North Carolina and across the country, many who teach middle school science lack the academic qualifications necessary to be teaching a course in physical science.[1] Naturally, with their limited backgrounds, they are heavily dependent on the materials from which they teach. In many instances these materials form the teacher's own introduction to the subjects. The question is, are the physical science textbooks used in North Carolina's public middle schools up to the task?

The physical sciences consist of astronomy (often taught as an application of physics), chemistry, geology (Earth Science), and physics. Each of these disciplines has its own characteristic approach and method for presenting its conceptual framework. Generally, a chemist would have difficulties presenting a solid physics course and vice versa. Each sees the universe through a different lens and it is important for students to experience these differences regardless of whether or not they intend to pursue a branch of science. Mixing the sciences (hyphenated courses) produces mush. Later in their careers, scientists come together to solve problems of an interdisciplinary nature and bring to bear tools that no one scientist possesses. Hyphenated scientists attempt to know a little something about all the sciences, usually enough to solve yesterday's problems.

There are five textbook series to choose from for Grades 6 through 8 in the public schools of North Carolina (See box). The purpose of this essay is to 1) discover whether or not these texts are presenting accurate, i.e., error free, information to our students and 2) whether they are covering the basics of scientific investigation needed for more advanced studies that will come in high school. Unfortunately, it appears that these texts are inadequate in both of these areas.

Keeping It Basic: A Simple Example

Disciplines

Science, at the middle school level, should be kept basic and should avoid trendy and controversial topics that are likely to be too complex for neophytes. By far, physics at this level is the simplest of all the sciences. Experiments can be performed with equipment that is readily available, that is meaningful for the student, that requires no specialized skill at manipulation, and that produces results that can be easily interpreted.

In biology and chemistry, changing one variable in an experiment often changes several others, making it difficult for beginners in science to determine what is significant. In physics, many experiments can be designed in which changing one variable results in a significant change in one other variable. Therefore, studying basic physics at this level allows students to understand the scientific method of inquiry in a relatively simple setting. Further sophistication in the art of experimenting can be encouraged, showing the student that being careful can lead to discoveries not immediately obvious.

Instruments of Science

Middle school students should be taught how to use the basic instruments of science: meter sticks, timing devices, and simple balances, such as mass and weight measurements. Students should then become active at carrying out measurements in a wide variety of situations around the home and classroom, and then learn how to report their results to others. Experimenting and reporting results are part of all scientific endeavors. Making use of mathematics, including graphs and tables, should also be a priority. In addition, students should become familiar with SI units, which are basic scientific units of measurement. Combining the math with the use of the basic units of measure will impress on students that their courses are linked.

Obviously, how the instruments work should be clear to the students. Sophisticated measuring devices, calculators, digital scales, etc., that magically provide distances, times, and masses from black boxes should be avoided until much later. Only when the students have learned the physics principles involved in their operation should they be used.

Texts Reviewed

Integrated Science, (Carolina Academic Press, Durham, NC), 3 volumes, Lee Anne Stiffler, et. al., (1994, 1995, 2000)

Glencoe Science Voyages (McGraw-Hill / Glencoe, Columbus, OH) Biggs, et. al., (2000)

Harcourt Science, (Harcourt School Publishers, Orlando, FL), (2000)

Science Explorer, (Prentice-Hall, Upper Saddle River, NJ), 3 volumes, Michael J. Padilla, Ph.D., et. al. (2000, 2002)

Scott Foresman Science (Scott Foresman). See Addison-Wesley and Pearson / Prentice-Hall (2000)

A Basic Experiment

A middle school level experiment that could be performed literally anywhere involves taking measurements of a swinging object. All students will get some meaningful results, but there are many interesting side questions that, when answered, will improve the student's understanding of the scientific approach to solving problems (i.e. answering questions about nature.)

First, we note that a swinging object is *not* a pendulum. Even this simple fact is mistaken in some of our texts. Simply, it is a very heavy object suspended from a rigid point of support, by a string that will not stretch. In this experiment, we make timing measurements for a complete swing from one side of the rest position to the other, and back again using various string lengths, and objects of different mass. The method of timing is something that should be discussed among the students so they will come to understand inherent problems with some of the possible methods. Most students find that there is almost a linear relationship between the time taken and the length of the string, and little if any relationship to the mass of the object that is attached. The precise relationship is linear with respect to the square root of the string length. Comparing results presents an ideal opportunity for the teacher, or perhaps for the students who were a bit more careful, to show that the results could be improved.

Discussion Points

After the initial timing trials, countless questions could be asked, including:

- How many swings should we time?
- How did you measure the length?
- What was the nature of the link to the point of support?
- What was the shape of the suspended object?
- What was the angle that the string made with the vertical?
- Does the result hold for large angles? How large?
- Suppose that you had used wire rather than string. Would that make a difference?
- Would the result hold for small masses? How small?

Although not needed, a protractor could be introduced to make angle measurements easier. (I have found that many college students do not know the proper way to use a protractor.)

Deeper Inquiry

The first round of questions will likely generate further inquiries. A discussion about whether the second swing takes more or less time than the first swing always generates heated discussion (shorter swing distance so it takes less time, or it slows down therefore taking more time.) Should we time 5 swings, then 10, then 20, and then 30 to answer this question?

It also turns out that measuring the string length raises new problems and new questions:

- Does the length change if the string wraps around the point of support?
- Do you measure to the top, middle, or bottom of the suspended object?
- Does friction at the point of support influence the results?
- Is it better to use a symmetrical suspended object to make measuring easier?
- Is there an angle dependence?

Clarifying several of these points leads to more rounds of experimentation, which allow students to take more sophisticated measurements while using tables and graphs to report their results. The very act of reporting these finer results will make the students recognize that they and their classmates can ask questions of nature and get increasingly better and more sophisticated answers. All students will have made great strides toward understanding what it is that scientists are about.

This approach gives students the foundation for the more complicated chemistry, geology, and biology they will study later.

Are the Texts Doing Their Job?

The approach taken in the simple experiment just described conveys what our middle school graduate needs to understand about the nature of science and how it is carried out. How well do the texts used in North Carolina's schools do the job? Unfortunately, not very well. Middle school science texts tend to be filled with irrelevant information and errors.

> *Most of this is not material for an introduction to science. Too much is irrelevant, too much is outside the scope of a middle school curriculum, and generally unnecessary. Unfortunately, other texts are much the same.*

First, a middle school science course should not be about the latest scientific discoveries or complex subjects like black holes, the quantum theory, or the theory of relativity. The latest scientific findings cannot be meaningful to students with little or no background. In order to appear current, all of the books selected devote valuable space to these issues.

Questionable Topics

The texts should avoid controversial subjects that have many unresolved questions. Issues related to the environment such as nuclear power, global warming, the ozone hole, acid rain, etc., should be avoided. These are very complicated and controversial issues about which many fundamental questions remain unanswered.

Discussions of these topics can easily devolve into political advocacy. For example, *Integrated Science* might well have been commissioned by the Sierra Club to recruit middle schoolers by scaring them. In Chapter 2 on page 18, there is a list of 10 items to be answered true or false after class discussion. Some are legitimate scientific questions that should be investigated, including air and other gases being weightless, or that in the lower atmosphere, air temperature usually increases as altitude rises. (Both are false).

Still others, such as the ones contending that air pollution first occurred during the industrial revolution or that pollution control has not improved overall air quality, are outside the realm of the students' and possibly the teacher's knowledge. Both are false, but many environmentalists and others in the popular culture would say otherwise. Who is going to monitor the responses, particularly if the teacher does not have the appropriate scientific background?

After some fairly conventional material, *Integrated Science* launches into some very elaborate physics topics, presenting material still being debated by scientists. These topics that include acid rain, ozone pollution, the greenhouse effect, and airplane exhaust. All of these problems (real and perceived) are blamed on human activity. At the same time the text invokes many qualifying statements to indicate that not enough is yet known. This is confusing to both the students and the teachers.

Mistakes and Measurment Gaffes

In addition to controversial issues, the same section of *Integrated Science* contains statements that are simply not true. For example, in referring to the gases that make up the atmosphere, the book states that the amount of each gas is usually very constant from the surface of the planet up to an altitude of about 25 kilometers**.** If this were true, there would be no need for mountain climbers to take oxygen tanks to the top of Mt. Everest, which is only one-third that height. To add to the confusion, the material that follows contradicts the statement. Most of this is not material for an introduction to science**,** too much is irrelevant, too much is outside the scope of a middle school curriculum, and generally unnecessary. Unfortunately, other texts are much the same.

Making measurements is probably one of the most important activities that students at this level should undertake. Since this is a fundamental activity for scientific experimentation in general, texts must be especially precise when it comes to instructing students in this area.

A typical example of the kinds of problems that might be found in discussing measurements comes from *Science Explorer* (all grades). Under Making Measurements (page 582 in the Grade 6 text) a seashell is being measured. The tip of the shell is shown at the end of the meter stick. This is a poor practice. The ends of any measuring stick tend to be worn down, leading to incorrect measurements.

The correct approach would be to take a reading at each end of the object being measured and subtract to get the length. For example, if one were trying to measure the length of a business card, the most accurate approach is to place the entire card along the interior of a ruler. If we placed the edge of the card at the two-inch mark and it ran to the five-inch mark, we would get the length of the card by subtracting two inches from five inches. The card is three inches long. This approach ensures that our beginning and end points are accurate.

In a table of what *Science Explorer* refers to as Common SI Prefixes (SI prefixes are prefixes that refer to measurements such as centi in centimeter or milli in millimeter), both hecto- and deka- are listed. These prefixes are actually uncommon at all and rarely used.

In the same section, the mass of a red apple is shown being determined on a digital scale. But, as noted, at this age and knowledge level, tools like digital scales should be avoided. For the same reasons that students should not use calculators until they understand the mathematical operations, they should not use other black boxes like digital scales. The mass of the apple, according to the illustration in the book, is 0.1 kg. This is completely unrealistic. A few pages later, we see a more realistic apple on a triple-beam-balance, a more accurate manual device for measuring mass, showing a mass of 181.5 grams. The way this type of measuring device works is clear and gives the student a much better understanding of what the measurement means. The radical departure from the reading displayed in the previous picture is not explained, nor can it be.

Students frequently encounter errors when the text correctly describes a procedure, such as measuring average speed or average acceleration, but then writes a formula that says something different. For example, *Science Explorer: Grade 6,* pages 84 to 107, confuses ideas about motion. The text gives a prescription for determining speed, which is actually closer to average speed. That fact is not made clear. Furthermore, the formula is ambiguous, using distance rather than distance traveled, and time rather than time taken. This leads to confusion later. Velocity is correctly described and then misused in the equation for acceleration.

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Confusion is again introduced in topics covering magnetism and electricity. All metals are not magnetic, yet some books suggest that stationary magnets affect metals. For example, *Integrated Science: Change Within Systems,* pages 251-2, do not make clear that the electromagnet is picking up the material because of the iron content, not because it was made from metal. *Science Explorer: Grade 6* on page 101 states that a magnet is a material that attracts certain metals. The fact is that magnets attract only three metals: iron, cobalt and nickel. Students will not understand this from the presentation in the text.

Masses and weight are a problem in most texts. On page 5 in *Integrated Science: Systems and Diversity***,** in a section ironically titled “To Help Your Understanding,” it states that “mass is different from weight because weight depends on the pull of gravity. You would weigh less on the moon than on the earth (sic) because of less gravity, but you would have the same mass because you would still be made of the same amount of matter. On earth (sic) your mass and weight are the same.” The book gets it wrong. Mass and weight are two different concepts measured in different units and are not the same on Earth or anywhere else! That error is carried on throughout the chapter.

Errors also appear in illustrations. The same text depicts three objects in glasses of water without the expected bending at the air-water interface. All one need do is stick a pencil in a glass of water to see that the pencil seems to be bent.

Too Much Information

The volume of information in North Carolina's middle school science texts poses a further problem. There are special sections on science and society, connections to social studies, guides for further reading, sections to check your progress, and section reviews. While some of this is useful to an adult or more advanced student, a typical middle school student approaching this maze of information can only be overwhelmed. Not having the tools or background for interpreting much of what they read or see in terms of pictures, charts and graphs, they have very few clues for discerning what is important and what is not. And, unfortunately, given their lack of background and training, the teacher may not to be of much help in this regard.

How Are Textbooks Chosen?

North Carolina is not unique in its selection of poor materials. The textbook selection process is similar in other states where it has led to similarly poor results.[3]

The Commission

Every four years the state Superintendent of Public Instruction recommends candidates to the governor to be considered for appointment to the textbook commission. The governor appoints 23 members to serve four-year terms. The commission is made up of five elementary teachers *or principals*, five middle school teachers *or principals*, four high school teachers *or principals*, three parents of elementary students in grades K-5, three parents of middle school students in grades 6-8, two parents of high school students in grades 9-12, and *a local school superintendent*. In reality, the commission could be comprised of only administrators and parents with no classroom teachers participating.

Consequently, only those teachers who know their subject are able to convince their administrators to adopt a real science book as opposed to one of the state adopted texts.

Request for Submissions

Each year an invitation to submit textbooks for evaluation and adoption in North Carolina is sent to publishers as the state requests submission of textbooks and other instructional materials for evaluation.[4] Before the call goes out, a curriculum review committee is appointed from qualified educators across the state to review relevant curricula and to write the criteria for submission of materials. The criteria are included in the call letter that is sent to publishers. Evaluation sheets are written using the same criteria. The adoption process stresses compatibility with the standard course of study and the appropriateness of the materials for the teachers and students who will be the users.

This process results in the loss of competently written books. Small publishers cannot afford the cost of keeping up with the procedures. They also recognize that because so much of the nonsense required by the above criteria is not relevant to the science, they cannot bring themselves to cheat their readers. Consequently, only those teachers who know their subject are able to convince their administrators to adopt a real science book as opposed to one of the state-adopted texts.

The Evaluation Process

The textbook commission appoints a regional textbook advisory committee to review and evaluate materials that are submitted by publishers. Committee members are selected based upon their training and experience in the discipline, and are paid a mere $100.per day for not more than ten days. This pay rate makes it difficult to attract qualified experts. It amounts to $1,000 for the ten day maximum. Because the work takes place in the middle of summer, it screens out teachers who wish to supplement their salary through a summer-long job. I have received more than $1,000 to review a new edition of a single book that has already been tested in the marketplace. Furthermore, I was given a month to write the review and wasn't burdened with the additional work of checking it against an outside set of criteria. These people are being asked to review five books at about $7per hour, based on 14-hour days that would be necessary to complete the task.

During July, evaluators attend special training sessions about the curriculum and the evaluation instruments that were developed by the curriculum review committee. Evaluation of materials immediately follows training, and takes place for a number of days specified by the textbook commission. Upon completion of their work, evaluators file written and verbal reports of their findings with the commission. The commission then convenes to discuss both the evaluators' conclusions and their own findings, and to draft a list of recommendations to present to the State Board of Education.

Post-Recommendation Process

After the list of recommendations has been formulated, sealed bids are opened and bid prices are added to the list of recommendations. Price is not considered by the commission when drafting its list of recommendations. For each textbook or program, the textbook commission is required to submit a written evaluation signed by the submitting commission member. At its October state meeting, the State Board of Education formally adopts the list of materials. It considers several factors, including:

- The recommendations of the textbook commission.
- The extent to which the books conform with requirements in the invitation to submit text books for evaluation and adoption in North Carolina.
- The extent to which the books are consistent with the standard course of study.

- The price.
- The needs of the public schools.

Upon adoption of materials, contracts are sent to the submitting publishers and are in effect for five years with no escalation of prices. For example, materials adopted in 2001 would go on contract February 1, 2002 and are introduced into the schools for the 2002-2003 academic year. (Typically, they will be used for a minimum of five years.)

After the state adoption, local textbook selection committees begin another round of review and evaluation to determine which materials best suit the needs of their students. The Department of Public Instruction sponsors several regional presentations of the newly adopted instructional materials each November.

Most publishers are scared away by these rules and regulations. The process is expensive. The cost of including scores of pages of irrelevant material, none of which defines what it means to be a good science text, is high.

Conclusions: Toward a More Productive Process

Unfortunately, the textbook customer is the education establishment, not the classroom teacher. Scientists should be writing the texts in conjunction with, and guided by, teachers who know their audience. Books would then be tested on students to determine if revisions are necessary. This kind of process takes place both at the college level, and in private and home school markets. If teachers are not prepared to handle the material, workshops should be conducted to bring them up to speed. Students working their way through the texts will be able to meet any set of objectives that test real knowledge of science and eschew frivolous and trendy material.

Middle school teachers already have the skills to teach students how to interact with the author, and how to extract information from textual material, diagrams, photographs, and graphs. They should also have dictionaries, encyclopedias, and other resource material readily available for reference. They may have to force the students to get away from dependence on the aids at the end of topics or chapters, but the result will be more enthusiastic and better-educated students.

Notes

1. See *Transforming Middle School Science Education*, Paul Dehart Hurd, Teachers College Press, 2000, p. 36, and my reviews of many other texts and hints for Middle School teachers at http://www.science-house.org/middleschool/).

2. For example see *Science Explorer Grade 7*, p. 201.

3. See http://www.ncpublicschools.org/textbook/2002_Invitation .pdf and other documents at this site.

4 There is a definition of textbook on the site that includes the possibility of other formats being considered. Apparently, none of the programs available were found suitable.

About the NC Education Alliance

The North Carolina Education Alliance is dedicated to fundamental reform of our state's education system. We believe that the focus of education should be on students rather than the system, because the system exists to serve the students.

The mission of the Alliance is to identify and publicize innovative, effective solutions to educational problems.

The Alliance was created in 1998 as a special project of the John Locke Foundation, and is directed by Lindalyn Kakadelis, a former teacher and Charlotte school board member. Its Steering Committee is made up of reform-minded school board members, county commissioners, business executives, educators, and other local leaders.

About John L. Hubisz

John Hubisz is a Visiting Professor of Physics at North Carolina State University. He has had a long-time interest in the quality of pre-college science teaching and learning, especially in the Middle Schools. He sees the middle school years as crucial for the development of critical and skeptical thinking through the use of the scientific approach to answering questions. He is the author of *Middle School Physical Science Texts*, funded by a grant from the David and Lucille Packard Foundation, which is a comprehensive review of texts used in middle schools nationwide. This study can be accessed at www.science-house.org/middleschool/reviews/textreview.html. Dr. Hubisz received his Ph.D. in physics & space science from York University's Centre for Research in Experimental Space Science. He can be contacted at hubisz@unity.ncsu.edu.

"I look to the diffusion of light and education as the resource most to be relied on for ameliorating the condition, promoting the virtue, and advancing the happiness of man."

Thomas Jefferson, 1822

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