

# The Problem of Extended Inquiry in Science Teaching:

## Technology-Rich Curricula to the Rescue

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### THE IMPORTANCE OF STUDENT INQUIRY

Genuine student inquiry and investigations are the most powerful way to build student understanding of mathematics and science. It is only through their own inquiry that students learn the content and process of science. The late Lewis Thomas, the master of words and consummate writer, captured the importance of investigations and chastised educators for not communicating it:

It is the very strangeness of nature that makes science engrossing, that keeps bright people at it, and that ought to be at the center of science teaching. I believe that the worst thing that has happened to science education is that the great fun has gone out of it...Very few see science as the high adventure it really is, the wildest of all explorations ever taken by human beings, the chance to catch close views of things never seen before, the shrewdest maneuver for discovering how the world works. (Thomas, 1981)

Unfortunately, this wildest of explorations has been squeezed out of most science education. In the rush to put more science content into science education, to prepare students for the next exam, the essence of science has been lost. Science education has developed into a separate entity divorced from science and research. From kindergarten through college, students rarely **do** math and science, they seldom see these topics as creative, they do not view them as open-ended.

By ignoring real investigations, we not only fail to convey an accurate impression of what mathematics and science is, we miss out on a teaching strategy that is fun, motivating, inspiring, and educationally sound. Kids say this in their own words:

Yeah, building solar houses, it was fun building them, cause we got to design our own and we got to record all like our materials and stuff. **We got to use our own imagination... to create.**

They [the activities] are different, yeah, a lot different, 'cause I mean you have more hands-on and **there's no real boundary to what we can do.** (Wier, et al, 1992)

### EXTENDED INQUIRY IN THE SCIENCE STANDARDS

The new standards are crystal clear about the importance of student inquiry in teaching. By place of honor and sheer bulk, the AAAS Benchmarks place student inquiry front and center. In each section of the Benchmarks, inquiry is addressed first. The Benchmarks ask that students be able to “frame the question, design the approach, estimate the time and costs involved, calibrate the instruments, conduct trial runs, write a report, and finally, respond to criticism.” (p. 9). A majority of the benchmarks are related to the skills students need to undertake and understand their own extended investigations and design projects; fewer than half of the Benchmarks address traditional science and math content such as energy conservation, plate tectonics, and evolution.

Similarly, the NRC Science Standards emphasize inquiry: “For students to develop the abilities that characterize science as inquiry, they must actively participate in scientific investigations.” (p. 173) The NRC definition of inquiry is similar to the Benchmark’s: “..asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments.” (p. 105)

Both standards identify two different kinds of student inquiry: “inquiry-based learning” and what is being called “extended inquiry”. The former is a teaching technique that should be used pervasively at all grades. Students should have their first experience with most ideas of science in an experimental learning context where they can ask their own questions and construct their own understandings. But extended inquiry pushes this idea further, asking that students have opportunities to undertake real research projects that extend over weeks. This gives students unique opportunities to experience for themselves the process of science and the “high adventure” Thomas advocates. Meeting this central aspect of the science standards, and similar frameworks being developed at the state and local levels, is **the most difficult aspect of implementing the standards** and realizing the reform they envision.

Offering extended investigations is a major challenge to teachers. Clearly, one cannot simply ask students to do major investigations without preparation; they must walk before they run. Extended investigations require a spectrum of inquiry skills be marshaled to attack a new problem. The skills needed include modes of thinking (posing good questions, developing experimental strategies, debugging), procedural skills (calibration, data collection), familiarity with design and construction (soldering, shop skills, safety procedures), and analytical techniques (graphing, modeling, statistics). This requires a through-going change in the overall science curriculum and the introduction of new materials that address these skills. Using these materials and teaching these skills implies a major shift in instructional techniques and strategies. Many teachers are relatively unprepared to offer extended inquiry because they have never experienced it themselves and are unfamiliar with these skills. Obviously, we will need new approaches to teacher professional development.

Supplying the curricula materials and teacher professional development needed to meet the extended investigation standards will require novel approaches and a major commitment of resources. But, of course, that is what educational reform is all about. These changes are at the heart of the new standards and no one promised that the required changes would be easy. Fortunately, information technologies are beginning to mature to the point that they offer new resources and new ways of disseminating these resources. In a real sense, information technologies can help meet this challenge.

## **THE IMPORTANCE OF TECHNOLOGY-RICH CURRICULA**

Information technologies are essential to implementing extended inquiry because flexible tools are needed for student-initiated inquiry. Unlike traditional curricula, there is no way to know where an extended investigation might lead. Each student project can lead in directions and require measurements and analysis that are unanticipated. The information technology tools explicitly mentioned in the science standards because they support inquiry include MBL (probeware), spreadsheets, data analysis and graphing tools, modeling software, electronics, and instrumentation.

Few teachers are familiar with the full range of these technologies or the ways in which they could be taught and applied to supporting extended student inquiry. Therefore, there is a urgent need for curricula that integrate student mastery of these tools in situations that also prepare them for extended inquiry. Three NSF-funded projects which I direct respond directly to this need.

### **The Global Lab**

The Global Lab Curriculum project at TERC responds directly to the need for curriculum support for extended inquiry. Designed as a middle school introduction to science, Global Lab is the culmination of a seven-year effort to develop a year-long curriculum that provides the content, skills, technology, and context for extended inquiry. The curriculum is organized around a study site that students investigate. Using their own senses, inexpensive electronic instrumentation, chemical tests, and experimental chambers students build a comprehensive understanding of the air, soil, and biota at their site. Students use networking to share their results with others around the world making similar measurements. Integral to this process is the acquisition of experimental skills and background knowledge that are essential to extended inquiry. As the year progresses, students invariably develop questions they want to explore further individually, in groups within the class, and in virtual groups across the globe. The year ends with several months devoted to undertaking and then sharing these extended investigations.

## **Student Learning in Context**

Personal, portable computers have revolutionized business but have yet to impact student learning. This is, in part, because schools seldom provide truly personal computers that students own, can take home, and have time to master. This will change as the boundary between calculators and computers is erased in the future. The first inkling of this kind of technology is the new eMate educational computer from Apple. The eMate is easy to overlook because it is not a top-of-the-line portable for the rich executive and lacks many of the features executives need. Instead, it has been designed with the needs of education in mind and offers these at a cost well below the \$1,000 cost of most new computers. Schools can afford to supply each student with a portable such as the eMate and its successors. When that happens, student learning can soar.

Anticipating this revolution, two years ago we obtained funding to study the best applications of this mobile, pen-based technology. One of the most exciting aspects of this work is that science learning can be moved outside the lab and lecture hall into the real-world contexts of home, car, mall, and field. This is why we call our work in this area "Student Learning in Context". In our studies, we regularly see students deeply engaged in investigations, fully in control of the technology, and learning both the content and process of science. Coming out of this research is a set of hardware, software, and curriculum that is now ready for dissemination on the eMate. We have materials developed to support secondary-level water quality studies and upper-elementary/middle school general science investigations.

## **Hands on Physics**

Hands On Physics (HOP) features a sequence of hands-on investigative projects that involve building sophisticated physics experiments out of common parts and electronics. This has proven to be a refreshing alternative to the standard physics courses at the high school or college level. The course consists of a series of eight-week long student projects and investigations. In the process of doing the projects, students gain essential experimental skills and build valuable instrumentation for their labs. The modular nature of the material gives educators the ability to tailor a course to their level and curriculum goals. The sequence of projects has been selected to cover the major topics in physics in the approximate order usually covered in courses, to develop measuring and analysis capacity, to build student sophistication and independence, and to include options for articulation with various technical areas. The projects illustrate important physics concepts treating mechanics, gravity, sound, waves, electricity and magnetism, light, electromagnetic radiation, and nuclear physics. The projects introduce advanced technical topics such as the use of computers for measurement and control (MBL), computer-based data analysis and modeling, telecommunications, and instrumentation.

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These and other technology-rich curricula are beginning to emerge from the work of educational researchers. This is fortunate, because they help solve the biggest dilemma facing SMET education: revamping the curriculum to support extended investigations.

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Robert Tinker is PhD physicist who has made important contributions to science education, including the idea of equipping computers with probes for real-time measurements and of using the network for collaborative student data sharing and investigations. Two years ago he started the non-profit Concord Consortium where he directs six major research and development projects exploring uses of computers, electronics, and networks in student learning and teacher professional development.

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