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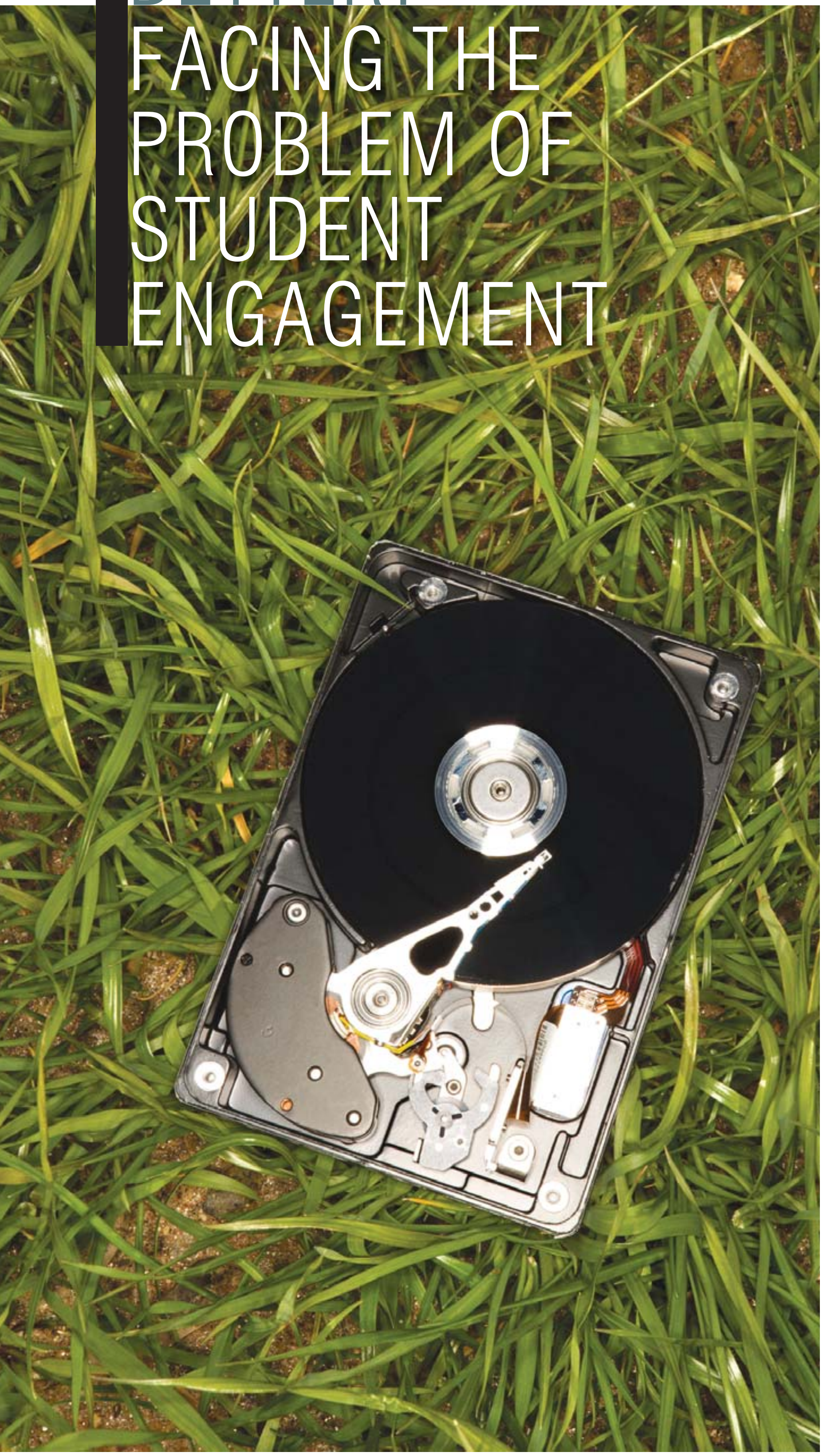
CAN WE DO SCHOOL SCIENCE BETTER?

FACING THE PROBLEM OF STUDENT ENGAGEMENT



This article, exploring ways to improve student engagement in the study of science, complements an article in our Winter issue by Carl Bereiter and Marlene Scardamalia entitled *Teaching How Science Really Works*. That article can be accessed on the CEA website at http://www.cea-ace.ca/media/en/TeachingHowScience_W08-09.pd

TODAY, PUBLIC DISCUSSIONS of school science and how to improve it hinge more and more on the comparative test data generated by the international Trends in International Mathematics and Science Study (TIMSS) and Programme for International Student Assessment (PISA) studies. In the hands of some media and political commentators, the international rankings drawn from these data are made to serve as a policy barometer, not only of school performance, but also of national competitiveness in the world economy. In reality, however, school science faces another, more insidious problem not easily addressed through data on comparative achievement.

Every experienced teacher knows that, somewhere between the ages of 11 and 16, significant numbers of students pass from a state of enthusiasm and engagement with the study of science to a state of indifference or disdain for the subject. Today a flood of new research is revealing the sheer dimensions of the engagement problem. It shows that students' basic attitudes about science study are set very early, in most cases by age 14 or 15, and are very hard to change later. Interest and engagement are factors that strongly influence students' later decisions about pursuing elective science and going on to science-related careers. They also affect the quality of citizenship in our techno-scientific world.[1]

ENGAGEMENT IN SCIENCE: AN INTERNATIONAL CONCERN

Interest in the engagement problem is surging internationally, in part because of results from Project Rose (Relevance of Science Education), launched by researchers at the University of Oslo. Project ROSE has surveyed the responses of 15-year-old students in twenty-five countries concerning their interest in science, their trust in science, their views of school science, and their future career hopes. When ROSE respondents were asked how they liked school science in comparison to other subjects, there was a 0.92 *negative* correlation between their responses and United Nations comparative national Index of Human Development. This means that the more advanced and economically prosperous a country is, the less its young people are drawn to the study of science and the less they are inclined to trust and value science. Even more unexpectedly, TIMSS data have revealed that at the national level, degree of achievement is *negatively* correlated with positive attitudes toward school science.[2] Clearly, achievement alone is not an adequate measure of engagement.

International attention to the engagement problem is also being driven by the growing interaction of two formally separate fields, namely science education research, and studies of the Public Understanding of Science (PUoS) among adults. Findings from the PUoS about adult attitudes closely mirror those from Project ROSE among adolescents. This

EN BREF **Les écoles font peu, actuellement, pour contrer le désintérêt massif des élèves face aux sciences. Les élèves tirent de leur expérience scolaire le message que la science à l'école est ardue, futile, impersonnelle, sans importance et, essentiellement, « pas cool ». Dans tous les pays, les élèves manifestent des attitudes et un intérêt plus positifs envers les sciences en général qu'envers la science à l'école. Pour résoudre ce problème, les écoles doivent enseigner que la science dépasse les connaissances et les méthodes, qu'elle constitue une entreprise culturelle et sociale qui inspire le dynamisme et l'espoir, parfois la crainte et la méfiance, mais qu'elle fait toujours partie de la vie. Nous devons persuader les jeunes que la science est essentielle à leur vie personnelle et à leur avenir en tant que citoyens.**

suggests the engagement problem is a larger cultural phenomenon that lies beyond formal science education itself. PUoS studies also reveal that adult attitudes toward science are little affected by what respondents may, as children, have learned about science in school.

But schools are not neutral factors in shaping attitudes toward science. The ROSE data show that students in all countries express more positive attitudes and interest toward science in general than toward school science. Seemingly, school science is currently doing little to reverse students' widespread disengagement; in fact, it may be aggravating the engagement problem. In a growing body of survey research that asks what they like and dislike about science in school, students complain about school science's perceived irrelevance, repetitiveness, fragmentation, and authoritarian presentation.

Is the engagement problem significant in Canada? Canada is not even participating in Project ROSE, but a recent survey of Canadian education concludes that "for the last three decades, in spite of changes in curriculum and intervention strategies, there does not seem to have been any significant increase in interest and enrolment in secondary and post-secondary science courses."[3] The engagement problem is real, and it is here.

THE CURRICULUM DILEMMA: PREPARATORY SCIENCE VERSUS SCIENCE FOR ALL

For a decade, an important body of research literature has linked the engagement problem to the charge that much school science simultaneously pursues two incompatible goals. On the one hand, school science at every level exists to prepare students for more advanced courses to come, feeding the metaphorical 'pipeline' of students who will go on to pursue post-secondary study in science-related fields and ultimately enter science-related careers. At the same time, school science exists to serve the large majority of students – perhaps 83 percent in Canada – who will not pursue advanced study or careers in science and who 'leak out of the pipeline' before graduation. Critics charge that the former goal continues to crowd out the latter, both in matters of curriculum design and delivery, and in teacher preparation. The result, as Robin Millar, Peter Fensham, Jonathan Osborne and other international critics have charged, is a science curriculum in most countries that is fragmented, repetitive, crammed to excess with content, and uncertain about its intellectual priorities. In the resulting welter of detail, content, and terminology, students notoriously fail to grasp the 'big pictures' that science offers about the natural world. Students experience the curriculum as remote from their personal lives.[4] This basic indecision about purposes and priorities permeates school science at all levels, but especially in the compulsory science classes at the later middle school level, where student disengagement from science study mainly occurs.

WHAT STUDENTS TAKE AWAY FROM THEIR SCHOOL EXPERIENCE IS THE MESSAGE THAT SCHOOL SCIENCE IS CONFUSING, TRIVIAL, DEPERSONALIZED, IRRELEVANT, AND DECIDEDLY UNCOOL.

Now, Canadian science educators and policy-makers are likely to find criticisms like this unfair and misdirected. At least since the Council of Ministers of Education released the *Pan-Canadian Framework* for Science Learning Outcomes in 1997, Canadian science education has enshrined the goal of 'scientific literacy for all' as the main objective of school science. 'Knowledge' of scientific concepts constitutes only one of the four foundations for scientific literacy, according to the Pan-Canadian Framework document. The Framework accords equal status to the three other foundations: teaching students about the social and environmental contexts of science and technology; promoting scientific skills; and encouraging proper attitudes.

We argue that while commitments like these might inform the 'intended curriculum', it is still the case in Canadian classrooms that what is most consistently addressed by teachers is 'knowledge', or 'science content'. We believe – and we think most experienced science teachers will agree with us – that exercises addressed to the other foundations are treated at best as 'add-ons' to the basic goal of transmitting science content in a manner implicitly consistent with a preparatory or propaedeutic mission. Not that the delivery of content knowledge escapes criticism. Educators complain that the science-content delivered in Canadian schools shows little connectedness from year to year or module to module, and that in its basic fragmentation, it fails to communicate a sense of awe or to instill a grasp of the 'big picture' that science draws of nature. The resulting 'attained curriculum' – what students take away from their school experience – is the message that school science is confusing, trivial, depersonalized, irrelevant, and decidedly uncool.

WHY IS TEACHING FOR SCIENTIFIC LITERACY SO HARD?

Many factors contribute to the gap that looms between the 'intended' and 'enacted' curricula. Most of the curriculum materials supplied to teachers reinforce the implicit message that 'knowledge' is the outcome to which most, if not all, science teaching should be oriented; standardized testing delivers much the same message to school administrators and to students. Political pressure from university science departments and parents concerned about post-secondary admissions keeps school systems geared to delivering a school science program that is predominantly preparatory in focus.

Science teachers themselves almost universally lack the training or encouragement to lead students in discussions of science-technology-society interactions; they may know little about the technological and real-world applications of the science they learned in university, and few have the background in philosophy, sociology, or history of science that would induce confidence in dealing with nature-of-science issues. Topics like these rarely figure in teachers' in-service education. Many teachers in the middle and lower grades lack the broad training in science to communicate comprehensive worldviews. On the other hand, those with deeper training may have a narrow view of science as exclusively knowledge and skills, causing them to regard 'science, technology, society, and environment' (STSE) issues or nature-of-science elements in the curriculum as 'soft' or somehow less than 'real science'.

Deeper problems in delivering science-for-all go back to fundamental indecision about what scientific literacy is and what teaching to promote it means. Scientific literacy emerges from curricular documents like the Pan-Canadian Framework as a blurry educational outcome: a loose and rhetorical compromise among several not-always-compatible educational goals and strategies, each of which presents its own special challenges. One goal is that of preparing students to become responsible citizens and decision-makers in a techno-scientific world, with curriculum development guided by what students need to know in order to participate in discussions of the technological controversies of our time. Such STSE approaches, however, face several difficulties, including the fact that their practicality for younger children is limited. Most complex civic controversies about techno-scientific issues hinge far more on political and ethical beliefs of the antagonists than on factual questions of science and technology themselves.

Another strand in the curricular mix, but one quite distinct from STSE, identifies scientific literacy with the possession of certain desirable, transferable skills, including the ability to formulate and conduct experiments, evaluate empirical evidence, appreciate quantitative arguments, carry out inductive generalizations, and engage in critical thinking. But the exercises that promote scientific skills are costly in class time and resources, and they may not always translate into learning, as a large literature on the inadequacy of 'cookbook' laboratory exercises can attest. More problematic, science skills are not necessarily life skills; the kinds of critical skills involved in scientific research and reasoning may not be as readily transferable from the artificial confines of the laboratory or the field survey to other life situations as tacitly assumed.

A third strand in the curricular mix virtually identifies scientific literacy with the outcome of inquiry learning. The Pan-Canadian Framework envisions scientific literacy as only achievable through a transformation of classroom practice toward inquiry methods, as do many science education theorists. Active inquiry, they urge, is the antidote to teacher-centered and transmission-based teaching methods that instill the image of science as authoritative, impersonal, and boring. Active minds, hands-on activity, problem-solving, and argument-making offer the means of sustaining students' engagement with science through the crucial middle school years. Buoyed by post-Kuhnian philosophy of science, educators argue that appropriate forms

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of science inquiry take students to the conceptual heart of the scientific method and allow them to experience authentic science in the classroom.

But inquiry methods themselves are hard to define and offer no exclusive road to the elusive goal of scientific literacy. At their more simplistic, inquiry methods confound science learning with the philosophically outdated concept of a universal scientific method. They trade upon concepts of the 'child as scientist' and school science as potentially isomorphic to research science. These concepts are questionable at best. Inquiry, because it is primarily a learning theory, is relatively indifferent to curricular content; yet many believe that school science requires radical reassessment of what science content we wish to teach, how the content is presented, and how it hangs together as a whole. Certainly inquiry methods may challenge and hold students' engagement, but the approach cannot be substituted for showing students why science and science study are important to their lives, their society, and their futures.[5]

The ambiguities that beset definitions of scientific literacy only reflect those that beset our cultural understanding of science itself. They point to the larger need for schools to instill an understanding that science is more than knowledge and more than method, but is also a cultural and social enterprise, an enterprise that evokes excitement and hope, sometimes fear and suspicion, but that never stands apart from life. That will not be easy. Designing and delivering an effective curriculum that addresses scientific literacy – and through it the engagement problem – must carefully balance the many cultural meanings of science and the investments we make in them. Challenging as the task may be, it requires clearer distinctions, harder decisions, and freer imaginations than those informing most planning for school science today.

MEETING THE CHALLENGE: TWENTY FIRST CENTURY SCIENCE

A bold effort to negotiate the challenges of a 'science for all' curriculum is being carried out today in the United Kingdom, where a new suite of courses, collectively called Twenty First Century Science, has been piloted with 15- and 16-year-olds. One of the courses is compulsory. It resembles a familiar Canadian middle-school general science course, with nine modules devoted to topics in physics, biology, and chemistry. Closer inspection, however, shows its commitment to very different principles. Although the course contains extensive science content, the focus is on telling big stories intended to capture students' imaginations. The module on 'The Earth in the Universe', for example, begins with 'time and space' and moves on to present the formation of the earth, the process of continental drift and plate tectonics, and the birth of stars and the solar system; it considers the question 'Are we alone?', and concludes with the origin of the universe in the big bang.

The course clearly shows its STSE pedigree. The module on 'Food Matters', for example, treats familiar topics such as the nitrogen cycle and the human digestive processes, but it also examines the environmental impact of various farming practices, the state-regulation of food safety, debates over the precautionary principle, and the role of obesity as a risk-factor in Type 2 diabetes. Other components are designed to show science and scientists at work. Student activity is organized around reports, data collection and analysis, and research on student-chosen case studies of contemporary science-related issues. Students are allowed to choose an additional science elective, one presenting more traditional, content- and concept-oriented material, and another focusing on contemporary technological applications from the standpoint of individuals pursuing vocations in fields like health care, agriculture, communications technologies, and chemicals.[6]

The U.K. experiment has not been free of controversy. Developers have had to cope with charges that the courses represent a 'dumbing down' of school science, objections to the focus on contemporary, controversial issues, and the fears of parents that the curriculum will not adequately prepare students for the intensity of A-level science courses. Nevertheless, the experiment has enjoyed considerable success in its short history. In national assessment exercises, students express increased levels of interest in science in general and in school science in particular. That outcome indicates that the Twenty First Century Science experiment is effectively dealing with the problem that it was created to solve: the disengagement of students from science and science study at the upper-middle-school level.

ENGAGING THE ENGAGEMENT PROBLEM HERE

We do not argue that Twenty First Century Science offers a roadmap to Canadian educational planners; the national contexts are much too different. But we have argued that our national debate over the strengths and weaknesses of school science is too obsessed with comparative rankings and economic competitiveness while ignoring the more pressing challenge of student engagement. As Canadian educators and planners, we need to be aware of the international debates on the topic and learn from them; think more boldly about the purposes of school science and what science we want to teach; and beware of learning theories that do not adequately address the engagement problem. STSE-oriented curricula like that of Twenty First Century Science may not be the best or the only solution for Canadian schools. But any solution to our present problems must be one that restores to school science the awe and grandeur of science's vision of the world and that can convince young people that science is central to their personal lives and to their future as citizens.

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Notes

1 This article grew out of an unpublished keynote address presented by the first author to the *CRYSTAL Atlantique* annual colloquium in Fredericton, May 20-21, 2008. See www.crystalatlantique.ca/ docs/keynote_why_we_teach_school_science.pdf. We are grateful to our colleagues in *CRYSTAL Atlantique*, and especially to Director Karen Sullenger, for assistance and stimulating input.

2 Jonathan Osborne, and Justin Dillon, *Science Education in Europe: Critical Reflections*. A Report to the Nuffield Foundation (January, 2008).

3 Maurice Di Giuseppe, ed., *Science Education: A Summary of Research, Theories, and Practice. A Canadian Perspective* (Toronto: Thomson/Nelson, 2006), 25.

4 Robin Millar, "Toward a Science Curriculum for Public Understanding," *School Science Review 77* (1996), 7-18; Robin Millar and Jonathan Osborne, J. (eds.) *Beyond 2000: Science Education for the Future*. The Report of a Seminar Series funded by the Nuffield Foundation (London: King's College London School of Education, 1998); P. J. Fensham, "Time to Change Drivers for Scientific Literacy," *Canadian Journal of Science, Mathematics and Technology Education 2*, no. 1 (2002), 9-24.

5 Karen Sullenger, "How Do You Know Science is Going On?" *Science & Children 36*, no. 7 (1999), 22-26; Steven Turner, "School Science and Its Controversies; Or, Whatever Happened to Scientific Literacy?" *Public Understanding of Science* 17, no. 1 (2008), 55-72; William Brewer, "In What Sense Can the Child be Considered to be a 'Little Scientist'?" in Duschl and Grandy (eds.), *Teaching Scientific Inquiry. Recommendations for Research and Implementation* (Rotterdam: Sense Publishers, 2008), 38-49.

6 Detailed information on the Twenty First Century Science program is available on-line at http://www.21stcenturyscience.org/