

The structure of matter

Like science, teaching should be the result of independent ideas converging.

Harry J. Lipkin

The twentieth century began with the consensus that matter is not continuous but is made up of atoms and molecules. It ended with the confirmation that matter is made of even tinier objects called quarks. But how are such realities established? And how can the process be explained in a plausible way to a non-scientist? I was surprised to find the answer in a book, *The Schools We Need and Why We Don't Have Them* (Doubleday, New York, 1996), by E. D. Hirsch Jr, a professor of English at the University of Virginia.

I read this book because of my concern about the large numbers of functionally illiterate children in both Israel and the United States unnecessarily condemned to the lowest levels of a democratic society. Professionals in the field of reading education are still obsessed with fighting wars between outdated 'ideologically and politically correct' party lines called phonics and whole language, rather than using new knowledge obtained from research and classroom experience to teach children to read. How to use this knowledge to provide effective education is well documented in extensive research sponsored by the US National Institutes of Health.

Twenty years of experience in Israel have shown how all this knowledge and information can be combined to produce a system that can teach 95% of a heterogeneous class of as many as 40 six-year-old pupils to read, to understand written texts, and to become independent learners with a single teacher and no help from parents. Not only does Hirsch's book provide the theoretical background supporting the empirical success of this system, he also gives an excellent description of how the scientific community reaches conclusions.

He writes: "The pattern of independent convergence (a kind of intellectual triangulation) is, along with accurate prediction, one of the most powerful confidence-building patterns in scientific research. There are few or no examples in the history of science (none that I know of) when the same result, reached by three or more truly independent means, has been overturned."

He quotes Abraham Pais's biography of Einstein for an example of this convergence: "The debate on molecular reality ... was settled once and for all because of the extraordinary agreement in the values of *N* (Avogadro's number) obtained by many different methods. Matters were clinched

not by a determination of *N* but by an overdetermination of *N*. From subjects as diverse as radioactivity, Brownian motion, and the blue in the sky, it was possible to state, by 1909, that a dozen independent ways of measuring *N* yielded results which lay between 6×10^{23} and 9×10^{23} ."

In 1966, Richard Dalitz and I were both already convinced that matter was made of quarks when we led the discussion on this topic at the annual international conference on high-energy physics. We could not understand why this conclusion was not generally accepted until well into the 1970s. I now realize that we were experiencing Hirsch's independent convergence. Unexplained regularities in the spectrum of particles created in high-energy accelerators; simple relations between collisions among different kinds of particles; that the annihilation of a proton and an antiproton

at rest nearly always produced three mesons; relations between the electromagnetic properties of mesons and baryons; and the 3/2 ratio of the magnetic moments of the neutron and proton all converged on the same conclusion: mesons and baryons are built from the same elementary building blocks. Hirsch applies this concept to pedagogy: "The independent convergence on the fundamentals of effective pedagogy that exists today is less mathematical but nonetheless compelling."

I find Hirsch's demonstration of how the scientific community reaches conclusions and of how the results of research on reading can be interpreted very exciting. I have always disliked the explanations of the 'scientific method' presented by social scientists in which scientists are said to do experiments to 'test hypotheses'. The description of the acceptance of new ideas as a result of independent convergence fits the reality that I know.

The gap between natural and social scientists is much too large and deserves serious attention. Perhaps these ideas can stimulate new lines of communication to overcome this gap. Perhaps they can also direct us to using new knowledge in finding better ways to teach children to read. ■

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School's in: 95% of six-year-old Israelis can read, understand and learn independently.