Editorial

Research in Technology Education: What Are We Researching? A Response to Theodore Lewis

Fernando Cajas

Lewis (1999) analyzed the role of research in technology education. He suggested that: "We have to talk about research needs in a way that engenders ever more possibilities. Rather than boxing in the researchers, we must see ways to push the limits and explore new and different frontiers" (p. 52). Here I reflect on Lewis' recommendations. I concur with several ideas suggested by Lewis, and I propose that the discussion on research in technology education also needs to consider what students should actually learn after they complete their technology education programs.

Lewis stated that the most important questions for research in technology education "probably have to do with challenges encountered by students as they try to learn the *concepts and processes of the subject…*" (1999, pp. 42-43, italics added). I agree, but I would add that an equally important question for research in technology education is what specific concepts and processes of the subject we are talking about. In making my arguments I will focus on three of the eight areas of research suggested by Lewis: (1) technological literacy, (2) misconceptions, and (3) integration.

Technological Literacy

I completely agree with Lewis (1999, p. 43) who suggested that from the perspective of the general public, there is some degree of consciousness on the need for technological literacy. I would add that this should not be the concern of the general public alone, but rather technological literacy should be the main concern of the field of technology education.

According to Lewis, one approach to clarifying the meaning of technological literacy is to study how the term is used. Lewis cites Gagel (1995) who "employed phenomenological strategy, primarily heremeneutics (text analysis), to explore meanings that are ascribed to the notion of technological literacy…" (p. 44). Another approach mentioned by Lewis is to study how adults deal with technological decisions. Lewis cites Welty (1992) who conducted one study of adult behavior, attitudes, and knowledge about technological issues. Although

---

Fernando Cajas (fcajas@aaas.org) is a Research Associate at Project 2061, American Association for the Advancement of Science, Washington, D.C.

such studies could help us to inform our notions of technological literacy, I see two potential problems with them.

First, it will be very difficult to use this information to create technology education programs for *all*, because people will bring different knowledge to any one technology issue. Second, people may not be aware of their use of technology or how to control it. Moreover, people do not often think about technology nor make informed decisions about it. If they were doing so, we would not need a technological literacy movement. More important, the problem of technology literacy is not as much about what people are doing *today*, as it is about what kind of technological knowledge and skills students should have and will need in the *future*. Empirical work may shed some light, but it does not solve the problem. One still needs to imagine the future.

A second approach to technological literacy is to define it. This is not just to speculate about the future, but rather to identify key technological concepts that every body should know. One example of such effort is the work of the International Technology Education Association (ITEA) that has been clarifying the technological knowledge and skills that are needed by all K-12 graduates (ITEA, 1996; 1998). In reading the draft versions of the ITEA standards, one can see that there is a movement toward transforming technology education from craft (practical technology) to more scientific technologies (physical, chemical, biological, and informational technologies). The ITEA standards for technological literacy reflect the problem of how different technology communities are pushing for a place in general education by asking that their knowledge and skills be included in the standards. The authors of the ITEA standards have been generous by including so many areas of technology. But because of this, I think their work lacks focus and coherence. One may ask if research can have a place in formulating the basic knowledge that all students should know to be literate in technology.

First I would say that research might play a role in clarifying what knowledge all students should learn to be technologically literate. However, it is important to note that the basic task here is selecting key ideas of technology that are essential for *all* people in today’s and tomorrow’s world. One way of doing so is by working with expert scientists, technologists, and teachers. The American Association for the Advancement of the Science (AAAS) initiated a process like this through Project 2061. Starting in 1985 and advised by scientists, engineers, technologists, and teachers, the project identified a set of key ideas for technology education (Johnson 1989). These ideas, including a general framework on the nature of technology, were presented in *Science for All Americans* (SFAA), particularly in chapters three and eight (AAAS, 1989). SFAA presents more than a simple aggregate of technological facts. It is a coherent vision of what technology literacy for *all* would mean.

The careful selection of technological knowledge and skills presented in SFAA was a product of several years of discussions. Although it was not the product of empirical research, one can assume that consultants brought research findings to their discussions. Educational research, particularly cognitive research, had a more relevant role in the creation of *Benchmarks for Science Literacy*, known as “Benchmarks” (AAAS, 1993) where the ideas of SFAA were expanded and translated into specific learning goals. Although *Benchmarks* reported that "There is a very small body of research on students learning about what technology is…" (p. 334), it does offer some examples of useful research findings:

- Students can use the engineering model before they can use the scientific model (Schauble, Klopfer, & Raghavan, 1991), and
- Students believe that science affects society in more positive ways than does technology (Fleming, 1987).

One may argue that SFAA and *Benchmarks* have the problem of the "expert" view on technology literacy. However, *Benchmarks* includes several key notions about technology education that are emerging as part of a common ground in many technology literacy movements around the world (ITEA, 1986, 1998; Black & Atkin, 1998; Black, 1998). Some of these ideas are: the relationship between science, technology and society; the notion of design, control mechanisms, materials, manufacturing, sources and uses of energy, information, and systems. These ideas are consistent with recent research in the philosophy of technology and technology education as evidenced in Bunge (1985), Mitcham (1994), Vicenti (1990), Bucciarelli (1994), and Layton (1991).

There are research problems related to technology literacy as proposed by Project 2061 (AAAS, 1989; 1993; 1998). Although SFAA and *Benchmarks* topics have been carefully studied and selected, there is not enough research on how these ideas can be learned and taught. This is research on effective teaching and learning that should illuminate to what extent learning goals on technology education can be achieved. At this point I agree with Lewis on his statement that the most important questions of the field are to study challenges encountered by students as they learn those particular *concepts and processes of the subject*. But to be able to answer these questions, first we ought to clarify these concepts and processes. Take the example of design.

According to Project 2061, all students (adults) after grade 12 should have an understanding of what kind of thought goes into design, particularly the idea that design requires taking constraints into account (AAAS, 1989). There are important questions in working toward this goal. I suggest the following two, in order of their importance. What does it mean that somebody understands that design requires taking constraints into account? How do children learn these ideas and what is the best way to teach them?

What is the notion of design in terms of literacy? From the perspective of literacy, the ability to actually design is not the only important outcome—though designing things can be an important way to learn about design. Some members of society need the ability to design things (e.g., architects, engineers, economists, teachers, etc.), but every individual does not. Literacy involves having all citizens achieve a common core of knowledge and skills beneficial for all of us.

Conceptions or Misconceptions Held by Students

Lewis suggests several examples of the kind of conceptions or misconceptions that can be interesting to study. He proposes, for example, to study what students think about, such as “what happens in an electric circuit when a switch is turned on” (p. 45). Although there has been a lot of research in science education about how students explain electric circuits, particularly with regard to the popular instructional unit “Batteries and Bulbs” (Fredette & Lochhead, 1980; McDermott & Shaffer, 1992), there is not much research about electric circuits in the context of technology education. In implementing technology in elementary education, curriculum developers have found that even teachers who have widely used this unit in science education have problems in interpreting the very idea of switch (G. Benenson, personal communication, March 17, 1999). So the research suggested by Lewis is important, but I would argue that it is not in the study of electric circuits by themselves.

It is difficult to justify knowledge about electric circuits for literacy purposes. If one weighs the time required for successful instruction, as suggested by research, against what can be gained, then electric circuits do not have much to offer to literacy (AAAS, 1999a). Few people will need this knowledge for their lives, since most of the electrical work (e.g., wiring a house) is done by certified technicians, and the use of electric artifacts (e.g., a computer) does not demand this knowledge anyway. However, behind the notion of an electric switch are important technological ideas about *control systems* that are fundamental for literacy. It is important to know about control systems because they influence the behavior of people and things. In its recommendations about control systems, *Benchmarks* suggested that: “An idea to be developed in the middle grades is that complex systems require control mechanisms. The common thermostat for controlling room temperature is known to most students and can serve as a model for all control mechanisms” (AAAS, 1993, p. 50). However, the idea of complex systems is extended beyond physical systems: “Students should explore how controls work in various kinds of systems—machines, athletic contests, politics, the human body, learning, etc.” (ibid., p. 50). In short, an electric switch can be seen as one context for learning more important technological ideas, particularly ideas about *control systems*.

After having suggested a rationale to include electric circuits as a context of key technological ideas (complex systems), it is important to note that there is almost no research on how children learn how control systems work, and there is even less research on how teachers can teach these ideas. In fact, when students are working with their electric circuits, such as the Batteries and Bulb unit, one can sadly say that they are not being taught what is most important, that is, how complex systems work.

The second example presented by Lewis has to do with students’ conceptions regarding “how standard metal bars and rods get their shapes” (Lewis, 1999, p. 45). Again, it is important to clarify that learning about the specific properties of specific metals is not very important for literacy purposes since only certain members of society need this specialized knowledge (technicians who have to deal with metals, some kinds of engineers, some kind of artists, etc.). However, there are general ideas about materials that everyone should know (AAAS, 1989; Amato, 1998). For example, a K-2 benchmark states that: “Some kinds of materials are better than others for making any particular thing. Materials that are better in some ways (such as stronger or cheaper) may be worse in other ways (heavier or harder to cut)." (AAAS, 1993, p. 188). The justification of why this is an important idea for technology literacy requires recognizing where it comes from and where it leads students. In order to illustrate this point, consider a section of the Project 2061 map called Design Constraints (Figure 1). The map lays out conceptual strands (e.g., physical constraints) that develop over time with increasing sophistication and connections across topics.

Before students can learn that some *materials* are better than others, it is important to work with them in distinguishing between objects and the properties of the *materials* of which they are made. In Figure 1 this is the connection presented before the learning goal that states that "Some kinds of materials are better than others…" (K-2 level).

In my own current work with schools, I find that children (and teachers) have problems distinguishing the properties of the objects (e.g., this sheet of paper has a rectangular shape) from the proprieties of the material that made the objects (e.g., the flexibility of the paper). In fact, research has shown that "The tasks of classifying objects according to what they are made of and of comparing properties of materials can be challenging for early elementary-school children. In addition, elementary children may have limited knowledge or hold misconceptions about the origins and transformations of materials" (AAAS, 1993, p. 349, Russel, Longden, & McGuigan, 1991).

Since the work of Piaget, science educators have explored how children describe materials in terms of their physical properties. Because science education has different goals than technology education, research in science education has focused on how children describe physical properties. From the science education perspective, descriptions of physical properties of objects are the basis for understanding later important idea s such as conservation of matter, states of matter, and chemical reactions. What are the important technological ideas we want students to learn with their understanding that some materials are better than others? How relevant is this science education research for technology education? We cannot discuss the relevance of this research if we do not know what we want students to learn at the end of their K-12 technology education.

What do students need to know in order to understand ideas related to materials, particularly that some materials are better than others (K-2 level)? Research in science education on how children learn about materials and their properties may serve as a starting point. However, this research has not explored "functional" properties of materials (i.e., properties of materials based on their use such as those suggested by *Benchmarks*: strength, stiffness, hardness, and flexibility). There is almost no research on how students learn these ideas. In the context of the map, ideas about materials in grades K-2 are the basis for learning about design at higher levels. Students should understand that design requires taking constraints into account, some of which have to do with the properties of the material to be used (AAAS, 1993, p. 51, see Figure 1, box 3B#1 at 6-8 level). Although there are some high school curriculum guides that have

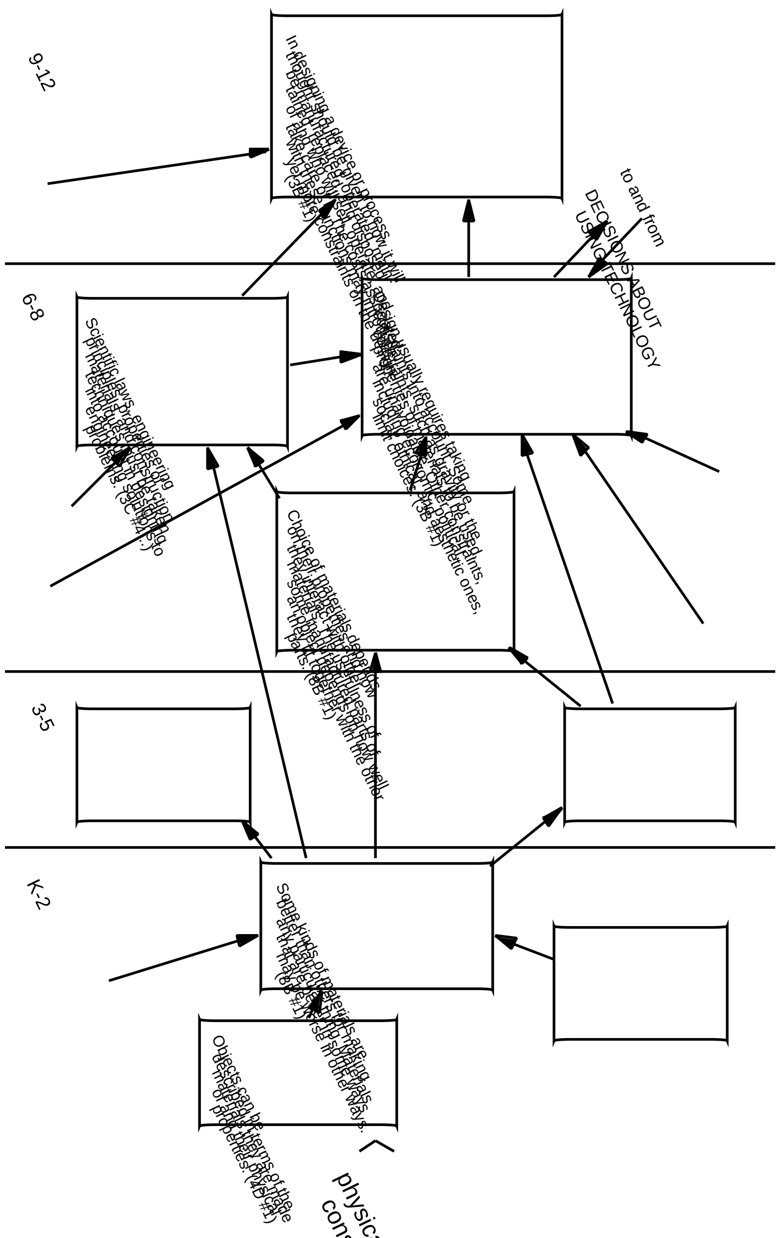

Figure 1. Map of Design Constraints from AAAS – Project 2061 (draft)

introduced ideas about materials (e.g., Hsu, Walhof, & Turner, 1996), there is no work on the introduction of these ideas over a K-12 plan for technology education. There is almost no research on how children learn these ideas and how teachers could teach them.

Integration

Integration is a word that produces sympathy in educational circles. However, as Lewis said, the field of technology education has to understand integration better (p. 49). Lewis developed a rationale to study how integration can help improve technology education. He suggested important research questions such as whether integration of technology with other subjects may help improve students' learning of technological concepts and processes. Another question is related to the models of integration that bear the most promise (p. 49). Although I think that these are valid questions, I believe that the problem of integration is not a problem of research alone. First, integration is a political decision. Second, we cannot be clear about integration if we do not know *what* we are going to integrate.

Let us take the example of the integration of science with technology. There has been some research, mostly from the science education perspective, on how to integrate science with technology. For example, in the 60's Renners studied how students understand the relationship between science and technology (1963). In the 90's, to mention one example, Roth has widely reported his work on how children learn science via technology (e.g., 1998, 1997, 1996a, b. See also Kamen, Roth, Flick, Shapiro, Barden, Kean, Marble, & Lemke, 1997; Schauble et al., 1991; Carey, Evans, Honda, Jay, & Unger 1989; *Benchmarks*, Chapter 15). Recent reports have acknowledged the difficulties that science teachers are having with such integration, i.e., connecting science with technology education (Hepburm & Gaskell, 1998; Bark & Pearlam-Avnion, 1999).

The basic problem I see with this "integration" is that it focuses mostly on science and only incidentally on technology. Technology is addressed only as a means to teach and learn science. It is true that technology can provide contexts to learn science as well as other subjects, but from the perspective of technology education the fundamental aim is to secure a permanent place in general education. What is urgent to understand is that there are important technological ideas that all should know. It does not immediately matter how we want students learn them, whether it be through integration or not. Integration, although important, should not be our priority now. The importance of technology in general education should not be dependent upon its integration into science, mathematics, or other subjects.

Concluding comments

Let us now step back and review my proposal. I have discussed Lewis' assumptions more than any specific suggestions he offered for research in technology education. This is because I think there is an essential prior question to be answered: What knowledge and skills should everybody know? Why is this an important question? Because contemporary society, as well as the society of the next century, depends heavily on technology. It is our responsibility to present a common argument to bring technology to the classroom. Such an argument demands that we clarify what we are trying to achieve. That is, what ideas and skills all people need to understand about technology to be able to participate in a technological world in a thoughtful and informed manner. This common ground should drive the need for and direction of research in the movement toward providing technology education for all. Without such a consensus, research in technology education and the efforts to bring technology into the school curriculum will remain an incoherent, fragmented, and ultimately ineffective endeavor.

Note: The map included in Figure 1 is closely connected to another map titled "Designed System," which is not included herein. The included map has been simplified from the original to more clearly support the argument made. It is suggested that the reader review the complete maps once they are published (AAAS, 2000b).

References

AAAS. (1989). *Science for all Americans*. NY: Oxford University Press.

AAAS. (1993). *Benchmarks for science literacy*. NY: Oxford University Press.

AAAS. (2000a). *Design for science literacy.* NY: Oxford University Press.

AAAS. (2000b). *Atlas for science literacy*. (forthcoming)

Amato, I. (1997). *Stuff: The materials the world is made of*. NY: Avon Books.

Barak, M., & Pearlman-Avnion, S. (1999). Who will teach an integrated program for science and technology in Israeli junior high school? A case study. *Journal of Research in Science Teaching, 36*(2), 239-253.

Black, P. (1998). An international overview of curricular approaches and models in technology education. *The Journal of Technology Studies, 24*(1), 24-30.

Black, P., & Atkin, M. (1996). *Changing the subject* London: Routledge.

Buciarelli, L. (1996). *Designing engineers*. MA: MIT.

Bunge, M. (1985). *Treatise on basic philosophy*. Volume 7. Epistemology and Methodology III. Boston: Reidel.

Carey, S., Evans, R., Honda, M., Jay, M., & Unger, C. (1989). An experiment is when you try it and see if it works: A study of grade 7 students' understanding of the construction of scientific knowledge. *International Journal of Science Education, 11*, 514-529.

Fleming, R. (1987). High school graduates' beliefs about science-technology-society II. The interaction among science, technology, society. *Science Education, 71*, 163-186.

Fredette, N., & Lochhead, J. (1980). Students conceptions of simple circuits. *Physics Teacher, 18*(3), 194-98.

Hepburn, G., & Gaskell, J. (1998). Teaching a new science and technology course: A sociocultural perspective. *Journal of Research in Science Teaching, 35*(7), 777-789.

Hsu, M., Walhof, L., & Turner, K. (1996). Composites. Materials World Modules. IL: Northwestern University.
International Technology Education Association. (1996). *Technology for all Americans*. Reston, VA: Author
International Technology Education Association. (1996). *Standards for technological literacy: Content for the study of technology*. Third Draft. Reston, VA: Author
Johnson, J. (1989). *Technology*. Report of Project 2061 Phase I. AAAS: Washington, D. C.
Kamen, M., Roth, W.-M., Flick, L., Shapiro, B., Barden, L., Kean, E., Marble, S., & Lemke, J. (1997). A multiple perspective analysis of the role of language in inquiry science learning: To build a tower. *Electronic Journal of Science Education*, *2*(1). [http://unr.edu/homepage/jcannon/ejse/kamen_etal.html]
Layton, D. (1993). *Technology's challenge to science education*. London: Open University.
Lewis, T. (1999). Research in technology education- some areas of need. *Journal of technology Education, 10*(2), 41-56.
McDermott, L., & Shaffer, P. (1992). Research as guide for curriculum development: An example from introductory electricity. Part I: Investigation of students understanding. *American Journal of Physics, 60*(11), 994-1003.
Mitcham, C. (1994). *Thinking through Technology: The Path between Engineering and Philosophy*. Chicago: University of Chicago Press.
Renner, J. (1963). Science, engineering, and technology as the junior high students understand them. *Journal of Research in Science Teaching, 1*, 89-94
Roth, W.-M. (1998). *Designing communities*. Dordrecht, Netherlands: Kluwer Academic Publishing.
Roth, W.-M (1997). Interactions structures during a grade 4-5 open-design engineering unit. *Journal of Research in Science Teaching, 34*(3), 273-302.
Roth, W.-M. (1996a). Art and artifact of children's designing: A situated cognition perspective. *The Journal of the Learning of Sciences, 5*, 129-166.
Roth, W.-M. (1996b). Learning to talk engineering design: Results from an interpretative study in grade 4/5 classroom. *International Journal of Technology and Design Education*, *6*(2), 107-135.
Russell, T., Longden, K., & McGuigan. (1991). *Materials primary space project research report.* Liverpool, UK: Liverpool University Press.
Schauble, L., Klopfer, L., & Raghavan, K. (1991). Student's transitions from engineering model to a science model of experimentation. *Journal of Research in Science Teaching, 28*(9), 859-882.
Vicenti, W. (1990). *What engineers know and how they know it*. Baltimore: The Johns Hopkins University Press.