Bell, R. (2001). Implicit instruction in technology integration and the nature of science: There's no such thing as a free lunch. *Contemporary Issues in Technology and Teacher Education* [Online serial], *1*(4) 465-471.

Implicit Instruction in Technology Integration and the Nature of Science: There's No Such Thing as a Free Lunch

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Although at first glance introducing technology and introducing the nature of science into classroom instruction may appear to be very different issues, several parallels between the two topics can be drawn. Both topics are recommended by current science education reform documents. Both are innovations in that they require commitments and actions differing from teachers' typical practice. And, in the case of both topics, educators have adhered to seemingly logical pedagogical assumptions that have proven inadequate to change students' deep-rooted beliefs. It is on this last point that my commentary on the article by Germann, Young-Soo, and Patton (2001) will focus.

Germann et al. reported the reactions of preservice teachers in their secondary science methods class to electronic journaling and electronic concept mapping. In this writing intensive course, students explored a variety of issues, including inquiry learning, classroom management, and curriculum design. The focus of the electronic journaling and concept mapping treatments, however, was to enhance the preservice teachers' understandings of the nature of science.

By 'nature of science,' I refer to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). Nature of science is a complex and abstract construct that involves reflecting on the scientific enterprise in ways not encouraged by typical textbook-based science curricular experiences. While there is disagreement regarding specific aspects of the nature of science, there exists an acceptable level of generality regarding the nature of science upon which the majority of experts agree and which is relevant and accessible to K-12 students (Lederman, Abd-El-Khalick, Bell, Schwartz, & Akerson, 2001; Smith, Lederman, Bell, McComas, & Clough, 1998). For instance, the concepts that scientific knowledge is tentative (subject to change), empirically based (based on observations of the natural world), and partly the product of human inference, imagination, and creativity are consistent with current philosophical views of science and useful for combating students' absolute views of scientific knowledge. Furthermore, these tenets of the nature of science are supported by current science education reform documents (American Association for the Advancement of Science, 1989; 1993; National Research Council, 1996) and have provided a conceptual framework for a number of investigations (Abd-El-Khalick, Bell, & Lederman, 1998; Bell, Lederman, & Abd-El-Khalick, F., 2000; Lederman & O'Malley, 1990; Lederman, Schwartz, Abd-El-Khalick, & Bell, 2001; Matkins & Bell, 2001).

It is unclear from their article how Germann et al. defined nature of science, what targeted conceptions of the nature of science they hoped to change, and what instructional approaches they used to elicit this change. From what they did not say, however, it can be inferred that they used an implicit approach to nature of science instruction. Implicit teaching is perhaps best defined by its basic premise that students will learn about a construct (such as the nature of science) simply through participating in activities consistent with the construct. For instance, in the historical approach, students might read about important episodes from the history of science or perhaps repeat historically significant investigations. In the process-centered approach, students might be taught process skills and participate in inquiry-based activities. In the discussion approach, students would participate in open-ended discussion (in class or online) about their beliefs in and experiences with science. Note that in all of these approaches, students may be engaged in pedagogically sound instructional activities. What makes the instruction implicit is the lack of direct attention to particular aspects of the nature of science. In other words, the focus of the lesson is history, process skills, or science content, with students left to pick up conceptions of the nature of science as a by-product.

In the class described by Germann et al., students were encouraged to reflect upon and discuss their own views of the scientific enterprise. The authors provided no evidence that these discussions were purposeful or directed at changing students' conceptions. As the authors put it,

> It was hoped that the use of electronic journaling and concept mapping would promote sustained reflection....On the surface, we were disappointed. Most students had never even thought about the nature of science before (despite having spent countless hours in lecture halls and laboratories) and 16 weeks was simply not long enough for them to articulate and then refine or change their initial propositions. Reflection as measured by change in propositions did not happen.

Given Germann et al.'s implicit approach, I believe that their lack of success in eliciting conceptual change in the preservice teachers' understandings of the nature of science was predictable. This belief is based upon my experiences as a teacher, in my nature of science research, and in my review of the relevant nature of science literature, all of which point to the necessity of explicit nature of science instruction.

Underlying the explicit approach to nature of science instruction (not to be confused with direct instruction) is the philosophy that teaching is a deliberate act, and that to maximize learning, instruction must be purposive and goal driven. Explicit instruction addresses the nature of science (or other constructs) head-on and rests on the premise that students are likely to learn what we want them to learn only when they are purposively taught. This is not to say that students do not learn implicitly; however, lessons learned implicitly may well be contrary to the teacher's intentions. Effective teachers do not leave to chance their students' development of accurate understandings of science content. Rather, they purposively plan and execute instruction designed to facilitate students' construction of scientifically valid understandings. Lessons on the nature of science should be no exception.

Explicit instruction may involve students in similar activities to those mentioned previously, but as part of the lesson the teacher guides students into thinking explicitly about specific aspects of the nature of science. As Russell (1981) noted, 'If we wish to use the history of science to influence students' understanding of science, we must...treat this material in ways which illuminate particular characteristics in science' (p. 56). Thus, at the conclusion of a lesson on the history of the development of the atomic model, the teacher might encourage students to consider the sources and implications of the tentative nature of science. A skillful teacher could challenge students' absolute views of scientific laws by demonstrating through historical vignettes that many scientific laws have changed over time. Likewise, teachers may teach students the processes of observation and inference through demonstrations and hands-on activities.

The lesson becomes explicit in regard to the nature of science when the teacher encourages students to think about how observation and inference apply to the construction of scientific concepts and what implications this has for scientific knowledge in general. It should be noted that the same instructional activities may be used in implicit and explicit approaches. The difference, therefore, is not so much a difference in kind as it is in emphasis. Implicit approaches assume students will enhance their conceptions of the nature of science indirectly through doing science or studying historical episodes. Explicit approaches address the nature of science as something to be 'planned for instead of being anticipated as a side effect or secondary product' (Akindehin, 1988, p. 73).

It is unfortunate but true for most students coming into our preservice science education programs that, as Germann et al. noted, they have 'never even thought about the nature of science before (despite having spent countless hours in lecture halls and laboratories)' (p. 8). Students' misconceptions are the result of years of science instruction focusing on the products of science, with little attention to the values and assumptions inherent to the development of scientific knowledge. Furthermore, there is increasing evidence that students construct a 'common sense' epistemology as part of their cognitive development, in which they see knowledge in general as arising directly from observation and view bodies of knowledge as collections of (absolutely) true beliefs (Kitchener & King, 1981; Kuhn, Amsel, & O'Loughlin, 1988). To further exacerbate the problem, they are exposed to textbooks and other curricular materials rife with misconceptions about the nature of the scientific enterprise ' such as the so-called 'scientific method' and the spurious hierarchical relationship between scientific theories and laws (see McComas, 1996, for a discussion of these and other common nature of science misconceptions).

Thus, through a combination of years of both implicit and explicit instruction, the majority of our students come to class with deeply ingrained misconceptions about the nature of science. Many science educators, as well as the scientists who teach college level science courses, believe that students will pick up current conceptions of the nature of science by osmosis'by listening to lectures about science, engaging in discussions about science, or by 'doing' science, including hands-on, inquiry-based activities. Yet the nature of science is a complex topic, and students' misconceptions about the nature of science have proven as resistant to change as their misconceptions about other science content.

Abd-El-Khalick and Lederman (2000) reviewed empirical studies on improving science teachers' understandings of the nature of science. They concluded that of the three general approaches reported in the literature (historical, implicit, and explicit), the explicit approach consistently effected the most significant conceptual change. The extensive literature on conceptual change adds further support, indicating that explicit, purposive instruction is necessary to address the misconceptions students develop both implicitly and explicitly (Butts, Hoffman, & Anderson, 1993; Joshua & Dupin, 1987; Strike & Posner, 1992).

In the explicit approach, instruction is geared toward specific aspects of the nature of science, sometimes utilizing elements from the history and philosophy of science. Activities specifically developed to target nature of science concepts serve as object lessons that can enhance classroom discussions (Lederman, Abd-El-Khalick, & Bell, 2001; McComas, 1998; National Academy of

Sciences, 1998). And contrary to the results of Germann et al.'s experience with implicit instruction, a number of investigations have reported substantial gains in preservice teachers' understandings of the nature of science in a single semester of explicit instruction (Abd-El-Khalick et al., 1998; Akindehin, 1988; Bell et al., 2000; Carey & Stauss, 1968; Lederman et al., 2001; Matkins & Bell, 2001; Olstad, 1969; Shapiro, 1996).

As Germann et al. pointed out, concept mapping and journaling have the potential to facilitate students' abilities to pose effective questions, challenge assumptions and confront points of confusion. It is worth reminding ourselves, however, that such tools can support, but not substitute for effective instruction. Experience has made it clear that it is inherently unproductive to assume that students will implicitly develop desired knowledge and skills through the introduction of tools (whether technological or pedagogical). This being the case, methods courses should strive to help preservice teachers develop the skills, knowledge, and attitudes they need to turn potentially useful tools into sound instructional practice.

As indicated at the beginning of this commentary, the issue of what our students learn and do not learn implicitly has direct application in regard to the topic of technology, as well as the nature of science. Teacher preparation courses all too often focus on implicit approaches to improving technology integration in science instruction. How often have we heard the call for greater access to computers and other technologies, with little attention to the professional development necessary to assist teachers in using these tools? Or how about the approach that teacher educators simply need to help preservice teachers become comfortable with using technology, and they will automatically use it to teach more effectively? If the goal is for teachers to reform their practice (a process that involves conceptual change), then explicit instruction is required. Just as the introduction of concept mapping and electronic journaling alone failed to produce changes in the nature of science conceptions of Germann et al.'s students, the introduction of technology alone will fail to produce changes in teachers' conceptions of science instruction.

What is true in life, in general, is also true in teacher preparation'there's no such thing as a free lunch. Technology access and skills are necessary but insufficient steps toward using technology effectively in science instruction. Rather, science educators should explicitly instruct preservice teachers on ways to integrate technology into their instructional practice. Such instruction will require science educators to provide conceptual frameworks for technology integration, model lessons involving appropriate uses of technology, and opportunities for preservice teachers to develop and practice teaching lessons that appropriately integrate technology. Like most worthwhile goals, such explicit instruction is inherently more difficult to achieve, but much more likely to produce desired results.

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