CHAPTER 18

MICHAEL P. CLOUGH

TEACHING ABOUT THE NATURE OF TECHNOLOGY

Issues and Pedagogical Practices

INTRODUCTION

That technology, without our awareness, changes the way we think and act is not at all obvious. When that idea is raised, people almost always consider it only in superficial ways, and focus exclusively on how they think technology has positively changed their lives – how they now spend more time on the internet, playing games, listening to music, talking on the phone, and texting friends. Rarely do their responses reflect awareness that technology also changes the way we think, that it can change our behavior in harmful ways, and that it can take us down paths we would not willingly have chosen. Perhaps the most significant and insidious bias of technology is how it promotes a forward looking mentality (full of wonderful possibilities) that suppresses a more balanced and accurate examination and reflection of its current and historical impact. The ubiquitous phrase "technological *progress*" without a parallel phrase conveying how technology may also set back individuals, culture and society reflects that bias.

MY PERSONAL JOURNEY COMING TO UNDERSTAND THE NATURE OF TECHNOLOGY

How our thinking and actions are unknowingly altered by technology is difficult to grasp. My own understanding of this idea came about slowly. While browsing at a bookstore in the late 1990s, I happened upon a book by Neil Postman (1995) with the provocative title *The End of Education*. The main thesis of this book, reflected in the title's play on words, is that without a "transcendent and honorable purpose" (p. xi) for schooling (i.e. the ends of education), that social institution is finished (i.e. the end of education). Postman argues why former compelling metaphysical purposes for schooling have lost their appeal, and he puts forward five possible transcendental narratives that might provide compelling purpose for schooling. Not until the last five pages of the book's final chapter, at the end of addressing his fifth narrative regarding how human beings shape themselves and the world with the

Michael P. Clough, Joanne K. Olson and Dale S. Niederhauser (Eds.), The Nature of Technology: Implications for Learning and Teaching, 373–390.

symbols we create, does Postman raise the nature of technology as an example. I found those five pages thought-provoking and meaningful, but not convincing. In time I moved on to Postman's *Amusing Ourselves to Death* (1985) and *The Disappearance of Childhood* (1982). My understanding of his ideas regarding the nature of technology grew, but I maintained that they were exaggerated.

That began to change with an experience I had one summer evening two years later when I was heading out on a bicycle ride and thought, "I don't have my cell phone." I was in a hurry to begin riding, resented the delay to find my phone, but did not want to leave without it. As I dismounted my bike, I thought, "Why do I need the phone?" For years prior to the availability of cell phones, I had ridden often and far from home with never a worry about being in phone contact with others. Why was I now bothered by not having my phone with me? I thought about that while riding that evening and the idea that technology changes the way we think and act. Incidentally, my reaction at that time to being out of communication is not unique. A biology colleague takes students to a wilderness area on the United States/Canada border where no cell phone towers exist for miles. Students, he says, are very unsettled when they find their cell phones don't work and that they will be out of contact for the duration of the trip, despite being told this would be the case.

That fall, I had another experience that resulted in further pondering about how technology impacts thinking and action. A graduate student with whom I was having lunch noted that I was eating oatmeal. I said that at my last physical exam, my blood cholesterol had been above recommended levels and that after changing my diet, losing weight, and exercising more, I had dropped my number well into the normal range. I was surprised when my graduate student replied, "I just take my cholesterol lowering medicine and eat whatever I want." I thought about how the unintended consequence of such drugs (a technology) is to diminish in many individuals their personal responsibility for adopting healthier habits. That impact extends beyond individual responsibility to societal health care costs that, to a large extent, reflect the eschewing of prudent health decisions in favor of relying on current and possible future medical technology.

The following winter, while my young son and I shoveled deep snow from my driveway and sidewalk, I noticed that no other children were outside even though school was cancelled due to the snowstorm. This was in stark contrast to my childhood when neighborhood children always woke early to first shovel their own driveways and sidewalks and then head out to earn money shoveling snow for others. After that was a day full of playing outside. That is far different than what is generally now the case. For the past several years I have seen adults using snow blowers to clear snow, but rarely signs of children assisting in any way. Nor do I often see them emerge later in the day to play in the snow. Even on lovely spring, summer and fall days, neighborhood children largely stay inside. When I would tell my son he had to play outdoors, he protested, saying that he would have no one with whom to play. The varieties of entertainment technologies not only promote sedentary lifestyles that have led to a childhood obesity epidemic, they also create a culture that ostracizes those who do not or are not permitted to adopt that lifestyle.

Efforts such as Partnership for Play Every Day (http://www.playeveryday.org/) and NFL Rush Play 60 (http://www.nflrush.com/play60/?icampaign=rush_nav_play60) that now exist to encourage *children* to play sixty minutes each day reflect the way technology has changed childhood thinking and behavior. But here again, that impact goes beyond individuals to culture and society. As Richard Louv (2008) in *Last Child in the Woods* warns, the unforeseen impact of children shunning the outdoors is that, in not loving the natural world, they will not value and work to preserve it.

Many have noted how the internet, Twitter, texting and other electronic communication technologies have diminished many individuals' ability to follow extended logical arguments. Reflecting that, not too long ago, an article a colleague and I published in an electronic journal was piecemealed by the editors who said that on-line formatting requires shorter paragraphs. Echoing the tale of Emperor Joseph II's complaint to Mozart that one of his compositions contained too many notes, a graduate student in our program was recently told by a technology education faculty member that her written sentences were too long. These and many other experiences working with both undergraduate and graduate students have illustrated the unanticipated and unintended consequence of popular electronic communication technologies on writing and the ability of those who extensively utilize such communication technologies to follow lengthy arguments.

I now more easily see all around me the unacknowledged influence technology has on human thinking and behavior. For instance, school administrators and even science teachers increasingly see virtual labs and other technology replacing concrete science experiences with the natural world and with materials in a laboratory setting. Technology certainly can and should play a role in exploring and making more comprehensible phenomena too dangerous to directly explore (radioactivity for instance) or with theoretical entities like atoms and their behavior. However, in making possible this kind of engagement, the technology influences decisions regarding all science experiences. Full of good intentions, yet smitten with the technology, some make the claim that virtual labs are the new trend in teaching science. Ignoring what is well known about how children learn science and effective science teaching, hands-on science experiences are being marginalized in favor of virtual experience. Uncritically embracing technology, advocates of virtual labs see only positive future possibilities (including laboratory classroom and equipment cost savings) and neglect what will be lost.

As another example, many people are now tethered to their jobs even when not being paid. Had this been imposed upon us in an Orewellian sense (Orwell, 1949), workers would have risen up and demanded more fair working conditions and/or compensation. But in a Huxlean (Huxley, 1932) and Bradburean (Bradbury, 1951) sense, the nature of communication technologies and our unexamined adoption of them have resulted in our personal and work lives being inseparable. Communication technologies interfere with our personal lives in another way. Although they do make easier keeping in touch with those outside our immediate range, they are an assault on interaction with those in our immediate space. For example, while at an amusement

park with my wife and son, I noticed a child begging for attention from his parents and grandparents who were all busy with their smartphones. That is why I found ironic the message in a recently aired television commercial showing individuals patiently glued to their evidently slow and outdated smartphones, ignoring those around them (http://www.youtube.com/watch?v=l9evyGr57hs). The answer to this dilemma was not to put down our phones and pay attention to those around us, but instead to purchase a faster smartphone.

The way technology development is directed at assisting humans with their interpersonal relationships, yet often has a chilling dehumanizing impact is illustrated in Turkle's (2011) book *Alone Together: Why We Expect More from Technology and Less from Each Other*. Even before reading her book, I had become irritated with electronic gadgets that say "Hello", "Welcome", "Good-bye" and other statements that ought to communicate sincere human feelings for those with whom we interact. A machine, like a person who says such things in a perfunctory way, has no such feelings. That we program our technology to appear to care debases the earnest remarks made by truly caring individuals. Turkle's book goes well beyond these concerns and reports on the advancements made in robotics and their advocates' hopes that future robots will serve as companions to the lonely and be of assistance to the infirm. Critically examining these developments, Turkle warns how such developments focus our thoughts squarely on the desired assistance for raising children, assisting the elderly and the infirm, and meeting our need for companionship. Whether we also consider our values and what *caring for someone* actually means, as opposed to a machine acting out its programmed actions, remains to be seen. How we answer such questions will impact the extent that futuristic assisting robots reduce our personal motives to reach out in loving ways to actually care for those we know as well as those we don't.

Of course, that most technologies have positive outcomes goes without saying, but this must be explicitly stated for two reasons. First, anyone who critically examines technology faces the simpleton response that he or she must be a Luddite. I have a son with Type 1 insulin-dependent diabetes and I am thankful for the medical technologies that his life and long-term health depend upon. So I am emphatically not anti-technology! The second and more important reason that the positive outcomes of technologies must be emphasized is because they are what influence us to not examine and thus miss the downside of those same technologies. Each of the technologies I have noted above were created or are being developed for a reason and that is what we employ them for and judge them on. That narrowing of our analysis creates a pervasive bias that causes us to ignore how those same technologies impact us in ways for which they were not developed. Thus, when not critically examined, technologies will have unanticipated and often undesirable consequences that are not recognized. For instance, as much as I value insulin pumps, without critical examination and restraint, they promote a mentality and behavior of eating high levels of carbohydrates which is an unhealthy practice for diabetics. The artificial pancreas project is directed at developing technologies that will more tightly control blood glucose levels, but if left unexamined, the downside of that positive future

possibility is the downplaying or suppression of diabetics' responsibility to carefully monitor their diet. Future robotics development will assist us in many important ways, but if left unexamined, the downside is our own dehumanization. Thus, returning to the introduction of this chapter, the most significant and insidious bias of technology is how it promotes human thinking that sees in current and future technologies only positive possibilities, while silencing fair and more accurate assessments of its impact on thinking and action.

WHY ACCURATELY TEACH THE NATURE OF TECHNOLOGY?

The response to the question "Why teach the nature of technology?" is embedded in a larger issue regarding the purposes of schooling. Compelling reasons ought to exist for schooling children, for what is taught in schools, and for how we teach because, as Davson-Galle (2008) notes, compulsory schooling detains individuals, often against their will, for sustained periods of time. Moreover, schooling, when wisely considered and effectively accomplished, has an enormous positive influence on personal and societal well-being. I am purposely using the word *schooling* in place of *education* because while schooling *could* be directed at education, little of what goes on in schools actually resembles education. Instead, schooling as commonly enacted is primarily directed at *training* students to recall information and perform particular skills. If schooling was truly directed at educating children, then policies, curricula, teaching practices and assessments that promote and reflect the goals appearing in Table 1 would be far more pervasive.

Table 1. Commonly Suggested Education Goals for Students (adapted from Clough, Berg & Olson, 2009)

Students will:
1. Demonstrate deep and robust conceptual understanding of fundamentally important ideas.
2. Use critical thinking skills.
3. Convey an accurate understanding of the nature of disciplines being studied.
4. Effectively identify and solve problems.
5. Appropriately and effectively use communication and cooperative skills.
6. Actively participate in working towards solutions to local, national, and global problems.
7. Be creative and curious.
8. Set goals, make decisions, and accurately self-evaluate.
9. Convey a positive attitude about learning and wisdom.
10. Access, retrieve, and use existing knowledge in the process of inquiry.
11. Convey self-confidence and a positive self-image.
12. Demonstrate an awareness of the importance of what is being learned for personal and societal well-being.

Unfortunately, schooling is largely not about education. For example, despite extensive rhetoric about the rapid pace of technological change and the need to prepare individuals for a society and working world that will also swiftly change, policymakers, business leaders and technology enthusiasts foolishly promote technology training instead of technology education that would go much further and also prepare individuals to assess and appropriately respond to technology development. Technology instruction in schools is, with rare exceptions, directed solely at training students to operate technology and employ it for what it was designed to do while ignoring the goal of educating them about how to critically examine technology. Technology *education*, as opposed to a narrow technology training, would also assist learners in understanding what technology is, how and why technology is developed, the unanticipated impacts of technology, what is gained and lost by adopting any technology, and how society directs, reacts to, and is sometimes unwittingly changed by technology. Meaningfully addressing these and other important aspects of technology would promote habits of thought and action that ensure citizens are prepared to analyze technology so that they wisely use it rather than unknowingly permitting it to use them.

EDUCATING STUDENTS ABOUT THE NATURE OF TECHNOLOGY

We All Teach the Nature of Technology

Ironically, teachers do teach about the nature of technology whether or not that is their intent. Because the character of any subject matter is conveyed by the way it is taught, students develop ideas about a discipline even if the teacher does not purposely intend to convey those features. Consider for example the broad subject area of science taught in schools. School science instruction, generally speaking, consists of linear and factual-laden lectures, selected readings that report the end products of science research while ignoring how that knowledge was actually developed, cookbook laboratory activities and other activities where students primarily follow directions (Schmidt, McKnight, Cogan, Jakwerth & Houang, 1999; Weiss, 1993; Weiss, Pasley, Smith, Banilower & Heck; 2003). Those experiences along with the way teachers and instructional materials speak about science coalesce to convey mistaken ideas about the nature of science (Clough, 2006). Similarly, the very way technology is incorporated in lessons, the language teachers use when speaking about technology, the curricular materials employed, and what is left unexamined and unstated about technology coalesce to convey important messages about what technology is, how and why it is developed, and whether it is merely a tool we use for our desired ends or something more that ends up using us in the sense that it changes our thinking, actions and values. Thus, the issue is not whether teachers will teach about the nature of technology, only how accurate is the image that they portray.

What About the Nature of Technology Should A Robust Technology Education Address?

In deciding what to teach students about the nature of technology, we must keep in mind that the outcome of this effort will be a form of technology in the sense that a list is being developed to assist in accomplishing a task. This illustrates that technology is a much broader concept than is commonly envisioned (AAAS, 2007; NAE, 2009). The way technology can and does influence later action is illustrated by how learning objectives, when written as outcome statements, influence practice. For instance, learning objectives (what students should know or understand) influence teachers to focus primarily, if not solely, on the end product of instruction rather than the process of learning and teaching. Not surprisingly, a transmission and regurgitation process often ensues (Eisner, 2002).

Thus, the nature of a discipline should be seen as something to explore with students, not merely as a set of ideas students should learn. Writing about nature of science instruction, Eflin, Glennan, & Reisch (1999, p. 112) cautioned, "Just as science educators stress that science is more than a collection of facts, we emphasize that a philosophical position about the nature of science is more than a list of tenets." In the same way, students should come to deeply understand and apply nature of technology ideas, not simply know of them. Accurately analyzing technology and making appropriate decisions about it demands exploring questions like those proposed by Postman (1995) appearing in Table 2. These kinds of questions encourage both teachers and students to more deeply think about the nature of technology, its contextual nature, and promote thinking that takes into account context and complexity. If meaningful attention was given to these kinds of questions in schooling, then children would be well educated regarding the nature of technology and be far more likely to wisely use technology.

Table 2. Some nature of technology questions worth exploring (Postman, 1995)

• For every advantage of technology, what might be the corresponding disadvantage?
• How are the advantages and disadvantages of particular technologies distributed unevenly?
• How have particular technologies changed the way humans think and act?
• How might particular technologies now under development change the way humans think and act?
• What intellectual, emotional, sensory and social biases are inherent in particular technologies?
• What goals are promoted, ignored and dismissed by a particular technology?
• How does technology change the ways humans view learning, teaching and schooling?
• How does technology change for better and worse our interactions with one another?
• How does the technology promote and inhibit thinking and learning?
• How may technology change what humans value?

Teaching the Nature of Technology

While teachers do convey the nature of technology via the manner they teach when incorporating or referring to technology, once students have developed and codified ideas regarding the nature of technology, much concerted effort is required to alter those original ideas. This is because an important difference exists between initial conceptual development and later efforts to alter those concepts (Clough, 2006). Learners develop ideas to make sense of their everyday experiences. Even though children may not have been purposely and explicitly taught the nature of technology, they have developed many incorrect ideas to account for their many in and out-of-school experiences regarding technology. Those initial ideas regarding technology are initially tentative, but can and often do become well established and tightly held because they appear to accurately account for a wider array of experience. Over time, these ideas connect with other ideas and may form a tightly linked framework that is then used for seeing and interpreting their everyday world. For instance, from an early age children are bombarded by messages touting the purpose of various technologies and how they will solve some problem and make life better. While not overtly taught to see all future technological development as positive, that particular nature of technology misconception develops quite naturally. Tied to this is another misconception that technologies are mere tools, possessing no biases and certainly not influencing thinking and values. Students' use of technology is ubiquitous, and the ideas they have developed regarding the nature of technology are tacit, but become tightly held for both cognitive and emotional reasons.

What this means is that while students' initial conceptual frameworks are in part formed and reinforced by their implicit in and out-of-school experiences, once developed and strengthened, they are highly resistant to change (Posner, Strike, Hewson, & Gertzog, 1982). This is particularly the case regarding students' understanding of the nature of disciplines. The longer students have been immersed in a particular subject matter, the more developed and entangled are their notions regarding the nature of that discipline. Thus, students don't see their misconceptions as such, and employ them in making sense of new experiences. This is why accurately and effectively teaching the nature of technology demands that teachers overtly consider what nature of technology ideas should be explored with students, and how those ideas should be taught and assessed.

Deep and meaningful learning demands assiduous mental engagement. Learners must do more than simply attend to information; they must also overtly connect and compare that information to their prior knowledge. However, as previously noted, even when that kind of mental engagement occurs, learners often interpret and sometimes modify information so that it conforms to what they already think. Conceptual learning often demands not simply adding new information to what learners already think, but altering the way they think about their prior experiences and ideas (Driver, 1997). These and other reasons are why conceptual change and the teaching that promotes conceptual change are both far more complex and difficult

than is commonly thought (Appleton, 1993 & 1997; Clough, 2006; Duschl & Hamilton, 1998; Limon & Mason, 2002; Pintrich, Marx & Boyle, 1993; Posner *et al*., 1982; Strike & Posner, 1983 & 1992; Tyson, Venville, Harrison, & Treagust, 1997). Thus, moving students to a more honest understanding of the nature of technology is not merely a matter of presenting more accurate information or creating more accurate implicit experiences. Rather, teachers must overtly draw students' attention to nature of technology ideas, and in a way that has students think deeply about those ideas. Moreover, this must be done in a variety of contexts to convince students that their prior ideas regarding technology are mistaken.

Overtly drawing students' attention to the nature of technology does not mean teachers should simply lecture to students about it. Instead, teachers should ask questions like those appearing in Table 3. These kinds of questions overtly raise important nature of technology ideas, and they mentally engage students in thinking about those ideas. Teachers who understand the nature of technology and are proficient at asking questions like those found in Table 3 can teach about the nature of technology in most any lesson. Moreover, while teachers should at times purposely plan for instruction regarding the nature of technology, opportunities for raising nature of technology ideas often arise unexpectedly during classroom instruction. In both cases, teachers who can skillfully ask nature of technology questions are positioned to raise specific nature of technology ideas in a manner that engages students and scaffolds them to a deeper understanding of technology.

Nature of technology instruction can take place in a variety of instructional contexts. For instance, in chapter 19 of this book, Kruse (2013) notes the importance of introducing nature of technology ideas using technologies with which students have no close ties. Such technologies can be categorized as distal to students' emotional state. Lessons using these kinds of technologies isolate and emphasize nature of technology ideas in concrete ways, but do so using technologies that avert a thoughtless emotional rejection of the nature of technology idea being introduced. These kinds of lessons are important because they isolate and emphasize nature of technology ideas in concrete and plausible ways that students can begin to understand. However, such lessons may generate interest, but will unlikely impact students' deeply held nature of technology misconceptions. These lessons are, nonetheless, important because they make intelligible complex nature of technology ideas that previously have been invisible to students, and in doing so, a foundation is created for exploring these same issues with technologies that students obsessively employ and develop emotional attachments to, but have never judiciously examined. In addition to preparing students to benefit from further nature of technology instruction, such activities also raise students' interest in the nature of technology and communicate the importance that will be placed on it for the remainder of a course.

After introducing students to important nature of technology ideas in the manner described above, instruction should then make reference to technologies that students extensively and passionately employ (e.g. television, smart phones, video games, Facebook, the internet, tablets, modern medicine) and are thus more

Table 3. Example questions that draw students' attention to and encourage thinking about particular nature of technology ideas.

Nature of Technology Concepts	Example questions
Technology is a broad concept including both artifacts and the processes that created those artifacts. Examples of technology include, among other things, tools, machines, symbols, objects, and techniques.	• How is [insert tool, machine, symbol, object, technique, etc.] a form of technology? • How is democracy a social technology? • How is fire a technology?
Technology is developed for a particular purpose, but its impact may reach beyond its original purpose.	• For what purpose was [insert technology] developed? • For what other purposes is it being employed? • For what other purposes might it be applicable?
Biases are inherent in technology.	• How does the purpose and limitations of [insert technology] predispose you to employ it in particular ways, thus impacting decisions and other actions? • How does [insert technology] enhance creativity? • How does this same technology constrain creativity?
Technology is a Faustian bargain.	• What positive outcomes occur by employing this technology? (i.e. What is gained?) • What negative outcomes occur by employing this technology? (i.e. What is lost?)
Technology changes human behavior.	• How has [insert technology] changed human behavior in ways that were anticipated? • How has this same technology changed human behavior in ways that were not considered? (To ensure students understand how technology has changed their behavior, direct these same questions at students' behavior.)
Technology changes human thinking.	• How has [insert technology] changed the way humans think? • How has the development of certain medicines altered thinking regarding personal responsibility to make more prudent health care decisions? (To ensure students understand how technology has changed their thinking, direct these same questions at students' own thinking.)

(*Continued*)

Table 3. Continued

Nature of Technology Concepts	Example questions
Communication technologies impact privacy, personal space, and quiet time for reflection.	• How has [insert communication technology] changed where personal communication takes place? • How do communication and other technologies make difficult finding peaceful time for deep thinking and reflection? • What has been gained and what has been lost with communication technologies?
Technology promotes a positive forward looking mentality that suppresses a more balanced and accurate examination of its impact.	• How does the way we speak of technology bias us toward seeing it as primarily, perhaps only, in positive terms? • The phrase "technological progress" is commonly used. Why do we not have an equally common phrase for the downsides of technology?
The process by which technology is developed is linked, and thus constrained, by already existing technologies.	• How is this classroom interactive white board similar to chalk boards and white boards? Why do you think this is the case? • How is the development of new technologies linked to, and thus limited by, already existing technologies?
Technology influences human values.	• How have cell phones altered family values? • How has technology altered relationships? • How may the development of assistive robots erode human values of caring and compassion?

proximal to their emotional state. For example, assign students to analyze how much time passes on television before a new camera angle or scene appears. They will find that rarely does more than four seconds pass. Postman (1985) refers to this and other technology (foremost among these is the internet) that shortens our attention span as the "the Peek-a-boo world." Have students consider how this impacts attention span, the ability to focus and follow lengthy arguments, and meaningfully reflect on information. Draw students' attention to how texting and/or Twitter does the same while also assaulting formal writing that is necessary to convey complex thought in a logical, concise and clear manner. Countless other examples of how contemporary technology alters thinking and action can be purposely planned for as part of instruction — like those found in chapter 21 (Spencer, 2013) — or addressed when such opportunities arise in the course of everyday instruction. Asking questions similar to those appearing in Table 3 are again important for drawing students'

attention to ways that contemporary technology impacts thinking and action. Students will likely struggle to understand or outright balk at any suggestion that their cherished technologies impact the way they think and act. To make these ideas more plausible, draw students' attention to the distal technologies examined earlier. Ask scaffolding questions that assist students in understanding how the same nature of technology issues that were raised with distal technologies apply as well to their proximal technologies. For example, ask questions like:

- "What cues or biases existed in [insert previously examined distal technology]?
- "How did that [insert previously examined distal technology] impact your thinking and action?"
- "What cues or biases exist with your [insert proximal technology]?
- "So how do those cues or biases influence your thinking and action?

Even as students begin to accept that technology does influence thinking and action, they will unlikely grasp and appreciate the full significance of the nature of technology and the importance of understanding it. Historical examples illustrating how technology has changed social institutions and values as well as individual thinking and behavior provides further evidence for nature of technology ideas. For example, Postman (1982) argues how the invention of the printing press resulted in the need for universal schooling so that individuals could learn to read and write. As the years of compulsory education grew, the passage to adult life was delayed thus creating a new social phenomenon — an extended childhood. Postman goes further to show how a new technology — the internet — has attacked basic notions of what childhood entails, promoting rapid movement into adolescence. At the same time, the technology of post-secondary schooling has delayed entry into adulthood resulting in an extended period of adolescence never before seen in history. These and other historical examples of how technology impacts individuals, society and culture (see this book's recommended readings) provide compelling evidence regarding the often invisible nature of technology.

Features of the three above contexts for nature of technology appear in Table 4. Figure 1 illustrates the scaffolding between these three contexts that assists students in developing a deep and robust nature of technology understanding that will more likely be applied to out-of-school technology experiences.

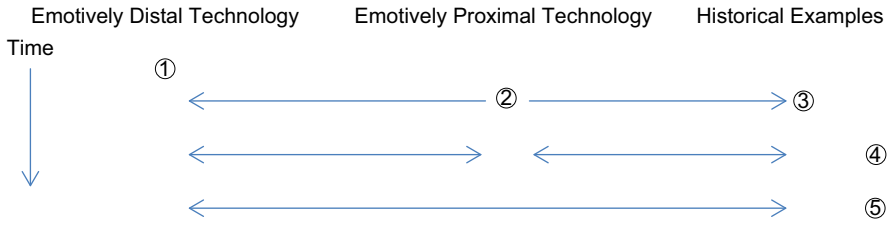
Assessing Students' NOS Understanding

While the above recommendations will ensure that the nature of technology is a consistent theme in a course, incorporating nature of technology questions as part of assessments throughout the school year is crucial. As Dall' Alba *et al*. (1993) and many others have stated, "assessment gives clear messages to students about what is important in the subject" (p. 633). To begin, teachers should determine

Table 4. Important contexts for nature of technology teaching and learning

	Emotively Distal Technology	**Emotively Proximal Technologies**	**Historical Examples**
Feature	Students have little emotional investment in the technology.	Students have high emotional investment in the technology.	Authentically documents and exemplifies how technology has impacted societal values and/or individual thinking and action.
Example	Ruler and marble used to illustrate nature of technology ideas (Kruse, 2013)	Mobile phones, Facebook, the internet, video games, etc. used to illustrate nature of technology ideas.	How the printing press brought forth the need for universal schooling thus influencing the length and concept of childhood (Postman, 1982).
Pros	Mitigates students' emotional response to and rejection of initially introduced nature of technology ideas.	Makes apparent how personal technologies alter students' everyday thinking and action.	Provides students with well documented evidence for nature of technology ideas making more difficult rejecting those ideas.
Cons	Nature of technology ideas will unlikely transfer to personal or societal technology contexts.	Nature of technology ideas will be emotionally rejected if technology examples are not carefully chosen or if scaffolds are not skillfully made to other contexts.	Students may not transfer such lessons to their own devices and personal thinking and action.

their students' prior ideas about the nature of technology early in the school year to enable more effective planning for such instruction. Once students' preconceptions regarding the nature of technology are identified, teachers should begin consistently incorporating instruction at appropriate times to create student dissatisfaction with their misconceptions and provide more accurate alternatives. The kinds of questions appearing in Table 3 can also serve as formative assessments that inform teachers of their students' developing NOS views. Thus, learning to ask these kinds of questions as a normal part of instruction is important for effectively



① Lesson addressing nature of technology using emotively distal technology. Teacher leads interactive presentation and discussion during lesson asking questions like those found in Table 3. Several of these kinds of lessons are advisable before moving on to nature of technology lessons addressing emotively proximal technology.

② Lesson addressing nature of technology ideas using emotively proximal technology. Teacher leads interactive presentation and discussion that includes questions that scaffold to ① and ③, thereby assisting in understanding and acceptance of ideas.

③ Lesson addressing historically accurate account of technology impacting societal values and/or individual thinking and action. Questions asked that have students compare nature of technology concepts in historical example to ①and ②.

④ Later lessons occurring in any of the three contexts should scaffold back and forth along all three contexts, making reference to previous nature of technology lessons.

⑤ Summative assessments may be embedded in any of the three contexts and seek links between contexts.

Figure 1. Teacher Scaffolding Across the Three Nature of Technology Contexts.

understanding students' nature of technology thinking, planning and incorporating instruction regarding the nature of technology, and assessing students' thinking as it develops.

Including nature of technology questions on summative assessments is important for making clear that understanding the nature of technology is an important part of students' education and must be taken seriously. However, because attention to teaching and learning about the nature of technology is relatively recent, formally developed assessments targeting the nature of technology are not readily available. Instruments assessing this important aspect of education are sorely needed for classroom implementation and research efforts. However, questions like those found in Table 3 can make for fine summative assessments. The downside to multiple-choice questions addressing the nature of technology is that context and important nuances are almost always lost. In whatever manner teachers summatively assess students' understanding of the nature of technology, students will realize that such understanding is important and will be assessed throughout the course.

EDUCATORS' RESPONSIBILITY TO ACCURATELY AND EFFECTIVELY TEACH ABOUT THE NATURE OF TECHNOLOGY

No doubt teachers already have extensive demands placed upon them. Adding yet another responsibility to their already overburdened workload may seem unfair. However, as noted earlier, all teachers teach the nature of technology by the very way they employ and talk about it in their classrooms. The issue is not whether teachers will teach about the nature of technology, only how accurately and effectively they will teach it.

Schools have largely welcomed the extensive infusion of technology for teaching children without examining the nature of technology and its Faustian bargain for teaching and learning. For instance, technology enthusiasts point to how technology enhances collaboration between students in class and with others well beyond the classroom walls. Enhanced communication that brings us closer together is, of course, what many technologies are designed to do. The unanticipated and often unexamined Faustian bargain has been that we increasingly form associations only with like-minded individuals and groups, more easily ignore and denigrate views we don't like, and substitute distant electronic communication for personal face-to-face interaction where we must acknowledge the whole person (Bauerlein, 2008). The extent of this can be seen everywhere if people would merely look up from their electronic gadgets long enough to see how alone they are while in the presence of others (Turkle, 2011).

Carefully examining technology is crucial for understanding what is gained and what is lost in blindly adopting particular technologies in and out of schools. This demands that educators first acknowledge and teach the most deceptive bias of technology — how it fosters an almost exclusive optimistic forward-looking mindset that suppresses a more fair and accurate examination of its historical, current and possible future impact. Any cursory review of the history of schooling makes clear that such optimism has always existed regarding how technology would improve both teaching and learning. But the results have been quite different. For instance, many current technologies have been seen as a way to motivate students, but the fallout from this entertainment approach to schooling has been a view that learning ought to be fun (or at least not demanding), and that important educational outcomes can be achieved on a wide scale without extensive teacher-student interaction, lengthy reading, or disciplined focus and reflection. Many educational technologies make easily accessible enormous amounts of information, and in doing so confuse information with learning and wisdom. The plethora of visual and auditory distractions, ease of point and click/touch, and the information overload that ensues promote short attention spans. The constant bombardment of stimuli from our nearly inescapable gadgets is an assault on the concerted time and attention that is required for reflection, deep learning and the development of wisdom.

What has been previously well-established regarding how people learn and the kind of teaching that promotes such deep thinking, reflection, and wisdom is not

changed by the presence or absence of technology. Humans matter and humanizing teachers interact extensively with students to understand them and their thinking. This requires effective questioning, use of wait time, supportive non-verbal behaviors, active listening, and responding to students in ways that further thinking and reflection. These *human* and *humane* interactions are not simply about engaging students in meaning-making, but to convey that the children we teach are far more than a cog in a schooling factory and future economic machine. To what extent we acknowledge that technology is not neutral, analyze it for its biases, and then wisely employ it in and outside schooling will say much about our humanity or lack of it. Left to its own devices, education technology often implies that teachers are superfluous to student learning. Paraphrasing Arthur C. Clarke, any teacher whose interaction with children can be replaced by technology ought to be replaced.

Technology's influence on schooling, teaching and learning is not limited to electronic tools. *No Child Left Behind* and other outcomes-based technologies emphasize "scientifically based" education research, testing, and academic accountability. Such technologies bias thinking and action regarding the purposes of schooling and how children are taught. The biases of these tools direct us toward particular solutions for reaching targeted ends while ignoring others. Not surprisingly, the technologies promoted in schools follow quite naturally from reform documents' biases toward testing and academic accountability. The Faustian bargain is that we unwittingly agreed to be silent on the moral aspects that have throughout history been an inseparable part of education. That silence is deafening to those who see teaching as the sacred activity it can and should be. Research-based teacher decisions and practices are crucial for promoting many important ends of schooling, but alone they marginalize the sacred nature of teaching that is directed at helping children grow to be ethical, caring, altruistic, responsible, and mentally and physically healthy individuals. Our infatuation with technology further blinds us to the philosophical and moral aspects of schooling. Thus, research-based teaching can become mechanical and detached from children. Without attention to the sacred nature of teaching, teaching becomes mechanical and merely a job.

I am not seeking to place blame, only to bring to the forefront what makes a meaningful education worth having, and the sacred nature of teaching that brings about that kind of education. Children are far more than entities to be taught so that they can become cogs in an economic machine, and the sacred nature of teaching is far more than putting into place research-based strategies. Neil Postman (1995) emphatically argued that economic productivity alone does not provide a compelling justification for education. Nor does it provide a compelling rationale for the commitment that is required for effective teaching. The philosophical and moral reasons for education, and the sacred nature of teaching, are what compel teachers to put in the enormous time and effort helping children grow to be all we want for them. Without that sacred perspective, little reason exists to learn and implement effective teaching practices — to engage children in truly meaningful educational experiences rather than simply convey information and skills to them.

I once had a high school principal tell me that I take teaching too seriously. I don't think that is possible. Each of us, with great effort, can make a significant positive difference in the lives of students that will then spread well beyond our classroom, school and local community. That attitude is what compels teachers against great odds to educate (in its most noble sense) children about the nature of technology and so many other important ends ignored by policymakers. For only through deliberate and careful analysis of technology with equal deliberation regarding our values can we ensure that we use technology rather than permitting it to use us.

REFERENCES

American Academy for the Advancement of Science (2007). Project 2061: *Science For All Americans – Chapter 3 The Nature of Technology*. http://www.project2061.org/publications/bsl/online/.

Appleton, K. (1993). Using Theory to Guide Practice: *Teaching Science from a Constructivist Perspective, School Science and Mathematics*, *93*(5), 269–274.

Appleton, K. (1997). Analysis and Description of Students' Learning During Science Classes Using a Constructivist-Based Model, *Journal of Research in Science Teaching*, *34*(3), 303–318.

Bauerlein, M. (2008). *The Dumbest Generation: How the Digital Age Stupefies Young Americans and Jeopardizes our Future*. Penguin Group, New York.

Bradbury, R. (1953). Fahrenheit 451. *Simon & Schuster*, New York.

Clough, M. P. (2006). Learners' Responses to the Demands of Conceptual Change: Considerations for Effective Nature of Science Instruction. *Science & Education*, *15*(5), 463–494.

Clough, M. P., Berg, C. A. & Olson, J. K. (2009). Promoting Effective Science Teacher Education and Science Teaching: A Framework for Teacher Decision-Making. *International Journal of Science and Mathematics Education*, *7*(4), 821–847.

Dall' Alba, G., Walsh, E., Bowden, J., Martin, E., Masters, G., Ramsden, P. & Stephanou, A. (1993). Textbook Treatments and Students' Understanding of Acceleration. *Journal of Research in Science Teaching*, *30*(7), 621–645.

Davson-Galle, P. (2008). Why Compulsory Science Education Should Not Include Philosophy of Science, *Science Education*, *17*, 677–716.

Driver, R. (1997). In Annenberg/CPB Minds of Our Own Videotape Program One: Can We Believe Our Eyes, *Math and Science Collection*, PO. Box 2345, South Burlington, VT 05407–2345.

Duschl, R. & Hamilton, R. (1998). Conceptual Change in Science and in the Learning of Science. In B. Fraser & K. Tobin (Eds) *International Handbook of Science Education*, pp 1047–1065. Kluwer, Dordrecht, The Netherlands.

Eflin, J.T., Glennan, S. & Reisch, G. (1999). The Nature of Science: A Perspective from the Philosophy of Science, *Journal of Research in Science Teaching*, *36*(1),107–117.

Eisner, E. W. (2002). *The Educational Imagination: On the Design and Evaluation of School Programs, 3rd Ed.* Pearson Education, Upper Saddle River, NJ.

Huxley, A. (1932). *Brave New World.* HarperCollins, New York.

Kruse, J. W. (2013). Promoting Middle School Students' Understanding of the Nature of Technology. Chapter 19 in M. P. Clough, J. K. Olson & D. S. Niederhauser (Eds.) *The Nature of Technology: Implications for Learning and Teaching, Sense Publishers*, Rotterdam, The Netherlands.

Limon, M. & Mason, L. (2002). *Reconsidering Conceptual Change: Issues in Theory and Practice*, Kluwer, Norwell MA.

Louv, R. (2008). *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder*. Algonquin Books, Chapel Hill, NC.

National Academy of Engineering (2009). *Technically Speaking*. http://www.nae.edu/nae/techlithome.nsf/ (Retrieved 1/14/2013)

Orwell, G. (1949). *Nineteen Eighty-Four*, Penguin Books, New York.

Pintrich, P.R., Marx, R.W. & Boyle, R.A. (1993). Beyond Cold Conceptual Change: The Role of Motivational Beliefs and Classroom Contextual Factors in the Process of Conceptual Change, *Review of Educational Research*, *63*(2), 167–199.

Posner, G.J., Strike, K.A., Hewson, P.W. & Gertzog, W.A. (1982). Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change, *Science Education*, *66*(2), 211–227.

Postman, N. (1982). *The Disappearance of Childhood.* Vintage, New York.

Postman, N. (1985). *Amusing Ourselves to Death: Public Discourse in the Age of Show Business.* Penguin, New York.

Postman, N. (1992). *Technopoly: The Surrender of Culture to Technology*. Vintage, New York.

Postman, N. (1995). *The End of Education: Redefining the Value of School*. Vintage, New York.

Schmidt, W., McKnight, C., Cogan, L., Jakwerth, P. & Houang, R. (1999). *Facing the Consequences: Using TIMSS for A Closer Look at US Mathematics and Science Education.* Kluwer: Dordrecht, The Netherlands.

Spencer, J. T. (2013). Technology Criticism in the Classroom. Chapter 21 in M. P. Clough, J. K. Olson & D. S. Niederhauser (Eds.) *The Nature of Technology: Implications for Learning and Teaching, Sense Publishers*, Rotterdam, The Netherlands.

Strike, K.A. & Posner, G.J. (1983). On Rationality and Learning: A Reply to West and Pines. *Science Education*, *67(*1), 41–43.

Strike, K.A. & Posner, G.J. (1992). A Revisionist Theory of Conceptual Change. In R. Duschl & R. Hamilton (Eds.), *Philosophy of Science*, *Cognitive Psychology, and Educational Theory and Practice*, pp. 147–176, SUNY, New York.

Turkle, S. (2011). *Alone Together*: *Why We Expect More from Technology and Less from Each Other*. Basic Books, New York.

Tyson, L.M., Venville, G.J., Harrison, A.G. & Treagust, D.F. (1997). A Multidimensional Framework for Interpreting Conceptual Change Events in the Classroom, *Science Education*, *81*(4), 387–404.

Weiss, I.R. (1993). Science teachers rely on the textbook. In R. E. Yager (Ed.) *What research says to the science teacher, volume seven: The science, technology, society movement.* Washington, D.C.: National Science Teachers Association.

Weiss, I.R., Pasley, J.D., Smith, P.S., Banilower, E.R. & Heck, D.J. (2003). *Looking inside the classroom: A study of K-12 mathematics and science education in the United States*. Chapel Hill, NC: Horizon Research, Inc.

Michael P. Clough
School of Education,
Iowa State University