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Of Tinkertoys, Technology, and the Educational Encounter

The only thing that's new about technology in education is the technology. Education has been going on for a long, long time. But what do we really know about what happens or should happen when teaching and learning occur? Only by trying to answer this question can we think about the ways technology affects the transaction we call learning.

How can technology affect learning? How should it? In trying to answer these questions, we had better first turn our attention to the nature of the learning process. We have to start by thinking about what I call the educational encounter, an event that takes place whenever there is a setting in which someone is trying to teach and someone is trying to learn. For the learner, the experience is an encounter because the other entity—either an animate one such as a teacher or a colleague, or an inanimate one such as a book or a video—can trigger a process that leads to the acquisition of information, the development of skills, the solving of a problem, or the creating of new knowledge.

The Educational Encounter

This encounter has several characteristics—some occurring sequentially, some simultaneously—but all of which are present at some time in all encounters that are truly educational. These characteristics are exposition, exploration, challenge, assessment, and motivation.

- **Exposition**. It takes the form of information conveyed by the teacher or a textbook to a student and often gets the encounter started. But such statements of information are effective only if they appear to students to be in the context of some question of theirs that requires an answer. Students rarely learn well or truly master new skills unless what is presented to them appears in the context of a question they have posed for themselves or had posed for them in a way to capture their attention. For this reason, the issue of exposition is intimately linked to the issue of motivation.

- **Exploration**. It is something we rarely permit our youngsters to do in the formal educational encounters that we have in schools. Exploration involves allowing students to roam the intellectual terrain finding connections for themselves. Aimless roaming can, of course, be counterproductive, and our overwhelming reaction to the fear of aimless roaming is not to permit it at all. But there is another way to cope with our fear.

We could provide guidance to our emerging roaming intellectuals by posing thoughtful challenges for them to bear in mind as they traverse the landscape of the discipline we are asking them to study.

- **Challenge**. It is intimately connected to exposition and exploration. Let me explain how they work together. Suppose you give children sets of Tinkertoys and tell them to build whatever they like. You show the various kinds of building blocks in the set and explain how they may be joined to one another. That's exposition. The children will explore the possibilities of the materials. Many of them will construct quite interesting things, but some will randomly poke dowels into hubs and end up with little more than dowels poked into hubs. Some people find free exploration frustrating and even frightening.

  It could be much more interesting to provide the children with a good set of challenges. Clearly, they can build a cube, which could be a model for a house, out of eight hubs and twelve sticks. But can they enclose a three-dimensional volume using fewer hubs and sticks? What is the smallest number of hubs and sticks that can be used to enclose a three-dimensional volume? Or, can they build a Tinkertoy bridge strong enough to support a 20-pound dictionary? What about a 60-pound classmate?

  Not all challenges are good. A challenge that doesn't permit students to judge for themselves whether they've succeeded in addressing it is, in my view, dumb. For example, if I challenge you to use a calculator to find the product of 37 and 563, that's pointless. On the other hand, if I tell you to build a Tinkertoy bridge that can hold a dictionary, you don't need me to tell you when you've succeeded. You can test your results right away. An intelligent challenge permits you to judge whether or not you've met it.

- **Assessment**. When you test your bridge by piling books on it, you are involved in assessment, a necessary and essential part of any educational encounter. Like Janus, assessment has two faces. Instructors need to know whether they are succeeding and whether and what their students are learning. This is the traditional and classic face of assessment. More important for a successful educational encounter, however, is getting students to ask of themselves, “How well am I learning this?” or “Do I really understand this?” In a deep sense, education has failed if these questions aren't asked. We all need to internalize the habit of asking, “How do I devise a test for myself to see if I can do this?"

- **Motivation**. It must be involved in any educational encounter. Students come to learning with a mixture of motives. Some of them, at least some of the time, may engage in education to satisfy a genuine personal need, a hunger for knowledge or competence. Many students, however, are motivated by a range of external pressures ranging from the need to get into college or to get a job, to an awareness of the emotional investment of some other person—most often a parent—in their achievement.

We need to be aware of these characteristics of educational encounters as we consider critically (and not necessarily negatively) educational innovations, both technological and other. Whenever we attempt to modify the educational encounter in some way, whether by the adoption of a new teaching technique or a new technology, we should ask ourselves, “How can and should this new element affect exposition, exploration, assessment, and motivation?” When we consider the potential effects of an educational innovation, we also must consider the idiosyncratic strengths and weaknesses of that innovation. When we think about the role of technology in education, therefore, we must both evaluate its effect on each characteristic of the educational encounter and remind ourselves of several issues that are specific to technology. We need to consider the subject matter being taught, what students and teachers bring to the encounter, and how the characteristics of different technologies can shape the encounter in various ways.

A Match Game

All technologies do not benefit all areas of inquiry equally well. Some subject areas have a natural affinity for certain technologies and little to gain from others. For example, the computer is a wonderful tool for math and science. And the study of music has gained immeasurably from the technology of sound recording and reproduction. I believe that print is still the technology of choice for the study of literature, although I am certain that students' understanding of *King Lear* is greatly enhanced when they can see several different interpretations on videocassette. Estimating the usefulness of a particular technology for a subject area involves the educational ideology of the researcher, teacher, or administrator. Most literary scholars would argue that computers are unlikely to provide them with genuine literary insight. Others seek illumination about an author's intention by ranking words in a text according to the number of uses. These people may legitimately claim that the computer is the essential ally of their literary analysis.

The point is, a sense of purpose has to underlie any decision about the use of technology. It makes about as much sense for a school to decide to use a poorly conceived instructional video series on math merely because it's available as it does to try to teach children to swim in a sandbox.

I will never forget the evening I heard the late historian, Barbara Tuchman, give a lecture entitled “How I Write My Books.” After greeting the audience, the very first sentence she uttered was, “First you have to have an idea.” The same admonition applies to the application of technology to education. It's foolishness to squeeze a subject area and a technology together in a Procrustean way.

Students And Teachers

Even when the technology and the subject matter are well suited to one another and there is a thoughtful approach to the match between the two, we must consider our students and our teachers.

Students come to learning from a great variety of backgrounds, with varying degrees of motivation and a great range of abilities. Some may respond quickly and well to the immediacy

of video presentation; some may learn readily from impersonal, nonjudgmental computer software. Others may require constant one-on-one contact and encouragement from a teacher; still others may learn best in small-group interactions with their fellow students. Teachers know their students well and have to use their considered judgment.
In addition, teachers may have many problems implementing even the best-designed technologies. Traditionally, the school setting has not made the use of technology very easy. The VCR is at the other end of the building on a cart with a broken wheel; the cable that attaches it to the TV monitor is missing, or there's no extension cord to be found anywhere. A computer freezes up or crashes, and no one in the building is trained to troubleshoot. Using technology effectively can be a substantial logistical undertaking, and such problems can ultimately defeat the most well-intentioned projects.

Technological Conversations

Even when the user has a well-developed idea about the purpose of using a technology for a particular subject matter, and when its suitability for students and teachers has been established, we still have to look at the specific characteristics of an educational encounter mediated by technology.

First, there is the nature of the conversation. In a two-way conversation, each party responds to the other, and each response triggers another. Each party continually grows or changes as a result of the ongoing interaction.

Even though it may not look like it—or it may not be the response we were hoping for—in an educational encounter, a student is always responding. Therefore, it's a mistake to talk about passive learning. As they read a book or watch a video, students continually make constructions and interpretations, but their constructions and interpretations have no effect on the expository sequence built into the work. Interactive videodiscs, on the other hand, permit us to see a limited form of interaction between student and medium. In response to input from the student, the sequence of images can be altered.

But interactive videodisc technology has its limits. Although there is a large number of distinct images on a videodisc—and thus a large number of possible sequences of images—the images themselves are frozen. Nothing the student does will cause the system to display an image that was not previously recorded on the videodisc.

The dominant use of computers in education occurs in a mode called Computer-Assisted Instruction (CAI). In most CAI, the computer software is in control. It establishes the terms of the encounter, limiting the learner's vocabulary and choices. It asks; the learner answers—and only in terms the computer accepts. Even when it is combined with an interactive videodisc, the software directs the interaction with the student.

Most of the time I abhor this use of technology. Granted, there are situations in which this kind of educational encounter is reasonable, but for me it's an issue of informed consent, of knowing what I'm getting into. I do not know how to touch-type, for example, and were I to actually want to learn to type properly, I admit that typing tutorial software can be very useful for practicing such a skill. But it's questionable whether such directed drill is really educational. It's certainly not creative.

Once we concede that a computer runs the encounter, we have to ask, “How structured is the conversation? How prestructured is it?”

No computer program is entirely open-ended, able to discuss variable mortgage rates with the viewer one moment, correct spelling or grammar the next, and then immediately go on to solve a problem in astrophysics. Every piece of computer software—every technology, in fact—operates in a specific and limited domain or environment. In that sense it is structured.

If the software runs a conversation that not only is structured but also is prestructured, it establishes a path that the learner must follow. Choices are often possible, but the consequences of each choice—the branch in the path—has been laid out in all details. Learners can never step off the path to explore the woods. And because the path has been laid out by someone else, they never experience discovery, or find or make what no one has found or made before.

Intellectual Mirror Environments

I suggest an alternative. Suppose you give a child a set of building blocks and say, “Using only these blocks, try to build a structure that is both big enough for you to sit inside of and strong enough for your cat to walk on.” If the child finds the challenge interesting, she can set to work in this open-ended, but nonetheless structured, environment. She can stack the blocks you have given her any way her imagination leads her. If the blocks have interesting shapes and colors, she will be enticed into exploration and experimentation. She and her playmates can decide for themselves when the challenge is met. The objects combined with interesting challenges constitute an environment that permits exploration and experimentation within a bounded, structured domain. It is possible to use the computer to do exactly the same thing with domains of subjects we teach in schools.

About a decade ago, a colleague and I began work on a computer software environment that similarly challenges students' creativity while they are working within the structured and bounded domain of Euclidean geometry. The GEOMETRIC SUPPOSER is what I call an intellectual mirror environment. It is a series of computer programs that deal with geometry and that allow—indeed invite—the user to explore and experiment. Just as the child's blocks do not by themselves pose problems, neither does the SUPPOSER. Just as the blocks, in conjunction with interesting challenges, provide an opportunity for invention, exploration, and problem posing and solving, so does the SUPPOSER.

Here is a standard problem situation. You are given a square, each side of which is marked in three equal segments. Some of these points are joined, and a new four-sided figure inside the square is formed. Geometry classes for hundreds of years have solved the problem of proving that the new figure is also a square and that the ratio of the area of the original four-sided figure—in this case a square—to that of the newly formed four-sided figure is nine to five.

But some 10th-grade students working with the SUPPOSER discovered something that had not hitherto appeared in any geometry book. The same ratio of areas pertains if one starts with a parallelogram or a kite or a trapezoid or indeed any four-sided figure, even one with no regularity or symmetry whatsoever. Allowed to wander intellectually with the SUPPOSER, our sophomore geometry students devised a new piece of mathematics.

In an intellectual mirror environment, students can pose questions, suppose, explore, and create. They are never directed to a “right” answer, or to any answer. Within the limited domain of geometry, they are free to wander at will. If we are wise enough to pose interesting challenges, they can go far and have the all too rare experience of making new knowledge.

Unless we learn to exploit technology to create such intellectual mirrors for use in schools, we will condemn schools to simply teaching what is already known. Teaching the already known is absolutely necessary, but teaching the already known is also absolutely insufficient. We need to educate our youngsters to pose and solve new problems, to cherish old knowledge, and to make new knowledge.

The Nature of Some Media

The technologies of recorded sound and image present an additional dimension to the educational encounter, that of the relationship of image to reality. Users must ask themselves, “What is the source of these images and sounds? Did I create them, or recall already existing ones from some recording and storage device?” Standard videotapes and discs capture and present previously existing images and sounds. A computer and synthesizer permit the user to generate them.

New technology, however, is blurring the line between recorded and generated images and sounds. Recently developed techniques for the processing of recorded sound and images make it possible to produce sounds and images that are curious blends of the recorded past and the created present. Thus, we can see pictures in the newspapers of meetings that never happened between people who were not there, and we can hear radio conversations that never took place. We have yet to explore and understand the potential of these techniques for society in general and for education in particular.

We must not omit consideration of printed text in this discussion. In almost all classrooms, the textbook is the physical artifact that structures the long-term interaction between the student and the subject matter. It's the clothesline on which all other curricular materials are, in fact, hung. Texts are a quintessentially linear medium, as the table of contents tells us. Is any reader now likely to read chapter nine before reading chapters one through eight?

What if we restructure printed texts to accompany non-linear technologies? Text has many advantages and disadvantages compared to electronic media, but we may have to free it from its linear confinement in order to make it work better with other media. People now are doing timid experiments with typeface, size, color, margins, and insets to break linearity. As long as most people still feel that they have to be given permission to jump ahead or skip back, however, I believe we must be bolder. Suppose, for instance, that texts came in loose-leaf binders. You might be given 23 chapters, named but not numbered, along with several different suggested maps of how to organize the material. You could organize it in any way that suited your purposes. If printed texts were loosened up, there could be a much more fluid interchange between print and other technologies.

The Next Step

Technology will enter the educational encounter as a major player only when it can permit users to ask questions of their own posing, when it can permit free exploration in response to good challenges, and when it provides users with the means of assessing how far and in what directions they have progressed. When we are able to provide students with a range of such intellectual mirror environments, I believe we will have taken a giant step in the direction of motivating our students.

It is reasonably obvious that the road to doing better does not lie in the direction of the pedagogy of the past. If we are going to make the kinds of changes in our educational system that the times and the evolving world economy demand, we must clearly aspire to more than simply having all our students learn the basics, as important as that might be. We must do better than that.

We must commit ourselves seriously to the intellectual and social diversity of our young people and give them schools that motivate them and that allow them to explore, to experiment, and to invent. Above all, though, we must give them schools that teach them to ask of themselves, “How well am I doing?” and “How do I really know?”