Comprensive, Technology-Based Clinical Education: The "Virtual Practicum"

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ABSTRACT

This paper discusses the application of technology to promote more comprehensive clinical education in the biopsychosocial aspects of primary care. Comprehensive refers to the inclusion, in addition to scientific and technical knowledge, of knowledge that is less easily characterized, quantified, and taught: empathy, intuition, the demonstration of artistry. Clinical education will be increasingly facilitated by the proliferation of computers capable of displaying combinations of text, graphics, video, and sound; broadband networks capable of delivering these multiple media to the home or office; and new methods for using these technologies for education and training. However, current models for technology-based learning are limiting, lagging behind the rapid technological evolution driving our entry into the Information Age. Some recent educational models (Schön's reflection-in-action and reflective practicums, Boisot's E-space, Kolb's learning cycle) provide for a more comprehensive and complete view of health professional education. This paper describes these models in depth and proposes a new model for technology-based clinical training, the "Virtual Practicum," based on them. The Virtual Practicum is illustrated with a new interactive CD-ROM program, dealing with primary care of patients with HIV/AIDS. The concepts presented here are generally useful in thinking about clinical education, regardless of the means used.

KEY WORDS: Education, Medical; Computer-Assisted Instruction; Computer Communication Networks; Clinical Competence; Simulation; Internet; World Wide Web; Instructional Technology.

> There is no discipline in the world so severe as the discipline of experience subjected to the tests of intelligent development and direction.
>
> John Dewey *Experience and Education* [1]

> It will be clear that we need to balance the hope for certainty and clarity in theory with the impossibility of avoiding uncertainty and ambiguity in practice.
>
> Stephen Toulmin *Cosmopolis* [2]

> But the machine is the servant of man, and to pattern one's function on the machine provides no measure for dignity.
>
> Jerome Bruner *The Conditions of Creativity* [3]

INTRODUCTION

This paper considers the role of technology in the clinical training of health care providers, particularly in areas of practice in which the highly variable nature of human behavior and situations plays a significant role. In such areas success is likely to depend-in addition to scientific and technical knowledge-on knowledge that is less easily characterized, quantified, and "taught:" empathy, intuition, and the demonstration of artistry. Management of depressive disorders is such an area. While there is increasingly firm scientific understanding of depression and technical methods for its management, the diagnosis and treatment of patients with depression involves knowledge and skills that, as Donald Schön says, "lie beyond the cannons" of technical rationality [4]. In order to be comprehensive, professional education should take into account these indeterminate zones of practice.1

This is a somewhat unusual topic in at least two ways. Post-Flexnerian medical education has sought academic respectability by embracing technical rationality as its dominant theme [5]; knowledge lying outside the boundaries of research-based theory and fact is either ignored, or viewed as comprised of qualities that a practitioner somehow possesses or develops-or does not. Perhaps stranger is the notion that "information technologies," for some an embodiment of the rational and technical, might be used somehow to help someone develop this kind of imprecise, ill-defined, and perhaps unteachable knowledge in any kind of meaningful way.

There is some reason for skepticism in this last notion, given current models for technology-based medical education. Delivered via the Internet and its superimposed World Wide Web (the Web) or interactive CD-ROMs, these informatics-oriented models are, with few exceptions, firmly grounded in technical rationality. They place greatest emphasis on the learning of facts and use formats largely derived from traditional, scientific-technical publishing: research papers; practice-oriented textbooks, reviews, and guidelines; and case reports. The predominant method for using these resources is "information access" via Web "browsers" [6] such as Microsoft(r) Internet Explorer(tm) and Netscape(r) Navigator(tm). Their use provides for very rapid access to vast resources, a process that can seem to many users both comprehensive and complete. However, access can be flawed by inadequacies in the search and retrieval process, the frequent uncertainty about the pedigree of the information retrieved (and its accuracy and relevance), and the likelihood that this "ready-reference" approach-while admittedly rapid and convenient-provides educational models that may be no more educationally useful than providing access to a real library [7], and perhaps less so [8]. The browsing model has been championed by educationalists intrigued with "hypertext"-cum-"constructivism" as a technology-based learning model [9,10], but the educational experience is primarily driven by the preferences-or whims-of the end-user; that is, there is rarely an attempt to provide a cohesive, coherent set of experiences that can be construed as usefully educational in the ways in which a Dewey or Schön might prescribe (see below).2

Contrasted with Web browsing, more traditional forms of computer-assisted instruction are sometimes provided via the Web, ranging from drill-and-practice (e.g., multiple-choice tests of factual knowledge) to simulations attempting to employ problem-based learning strategies. With few exceptions, these efforts are static, text and images, using formats that are essentially the same as paper-based case reports and "programmed learning" methods of the behaviorist tradition3 [11]. One reason for these restricted formats is the limited network bandwidth currently available between server (centralized computer providing the educational service) and client (computer receiving it); broadband networks, capable of delivering video of adequate quality, are imminent and these will expand options for designers of educational software. Educationally richer alternatives do exist, demonstrated by numerous computer-based training programs delivered first on floppy disk, then Laserdisc, then CD-ROM.4 These non-networked programs employ a variety of designs, ranging from more pedestrian drill-and-practice and

browsing/reference models to high-fidelity simulations depicted with high-quality motion video/audio. It is fair to say, however, that the general state of computer-based professional education and training is one of unrealized potential. The great majority of programs manifest a dominance of technical rationality in double doses (health care and computing), neglecting artistry in both their content and in their design.

Other trends are likely to have great impact on education, as sociological phenomena in a post-modern world. New forms of social interaction, notably in Multi-User Domains (MUDs), provide for contextualized, real time interactions via keyboard; these can not only promote the sharing of information and ideas, but can achieve surprising levels of experiential intensity and emotion [12]. The increasing impact of simulation in our lives-from TV and movies to computers with their "desktops" and interactive games to Disneyworld re-creations of alligators and Main Streets-prepare us to participate in a world that is part real and part virtual, with increasing willingness, even eagerness, to enter into experiences that are largely manufactured [13]. As with any experiences, we learn from them, and if done effectively the learning can be more powerful than real life provides. Simulation, in this broad sense, is likely to play an increasing role in education and training; whether this will be for good or ill depends on the care with which we craft these experiences, our respect for the power of these approaches, our understanding of how to employ them, and our motives. Simulation, in this same broad sense, is a main topic of this paper.

Technology unequivocally exerts pervasive, systemic effects on individuals and society, and technologies intentionally applied to learning can be very big guns indeed. An example of this is the practice of quantifying learning via examinations, in itself a relatively recent educational development [14]. Over the past few decades, this has been accompanied-perhaps driven-by the development of methods and automated technologies for constructing and grading tests in large populations. This requires questions and responses that can be expressed and/or judged in categorical/quantifiable terms that are expressible as text, i.e., highly codeable. Not only text, but text sufficiently succinct and discrete to be conveyed in a booklet containing hundreds of questions reducible to a machine-gradable form. Expertise, de facto, becomes defined in terms of an ability to retain and recite facts (at least long enough to pass an examination), analyze question structures and response combinations, and solve problems that have short and usually precise solutions. Such examinations are, of course, used to select among candidates for medical school and to examine physicians seeking board certification. They have certainly shaped the ways in which we conduct medical education, and many would agree that its current form does not serve our students, our profession, or our patients particularly well [15]. As we introduce new technologies designed more overtly to "teach," we would do well carefully to consider what we want to accomplish, and how best to do so. A primary goal of this paper is to help stimulate that consideration.

A THEORETICAL FRAMEWORK

This section provides a conceptual framework for consideration of a new model for technology-based clinical education, the "Virtual Practicum." To make this paper more self-contained, we will provide a detailed review of the work of two theorists, Donald Schön and Max Boisot. Schön provides a "top down,"5 philosophical view of professional education. He argues that we must adopt a more complete view of professional knowledge than a traditional one based mainly on technical rationality, a view that incorporates artistry, captured in a concept he terms "reflection-in-action." He advocates the use of "reflective practicums" as a means for conveying this more comprehensive body of knowledge. Boisot provides a "bottom up," more systematic and precise approach to similar conclusions. Boisot's work is outlined with links to Schön and clinical education. The two approaches meet with discussion of Kolb's theory of experiential learning and his learning cycle.

Schön's Reflective Practicum

Schön describes "artistry" as a kind of intelligence that is inherently different from, but essential to the exercise of, standard professional knowledge.

> In the terrain of professional practice, applied science and research-based technique occupy a critically important though limited territory, bounded on several sides by artistry. There are an art of problem framing, an art of implementation, and an art of improvisation - all necessary to mediate the use in practice of applied science and technique ... [16]

Schön raises and addresses these deeper educational questions: Can any curriculum adequately deal with the "complex, unstable, uncertain, and conflictual worlds of practice?" Can anyone, having studied and described it, teach "artistry" by any means?

Several educational theorists from Dewey to Schön have emphasized the importance of reflective thinking in education. Dewey [17] describes reflective thinking as "the kind of thinking that consists in turning a subject over in the mind and giving it serious and consecutive consideration."

> ... reflective thinking, in distinction from other operations to which we apply the name of thought, involves (1) a state of doubt, hesitation, perplexity, mental difficulty, in which thinking originates, and (2) an act of searching, hunting, inquiring, to find material that will resolve the doubt, settle and dispose of the perplexity [18].

Reflective thinking, in other words, is the best approach to indeterminate, "swampy" situations often encountered in the real practice world.

Extending this idea, Schön develops his concept of reflection-in-action, which is distinct from another concept, knowing-in-action. Knowing-in-action applies our existing knowledge to expected situations. Reflection-in-action comes into play when a situation that develops falls outside the boundaries of what we have learned to consider normal. That is, we are extending our expertise into unfamiliar or unexpected domains. Encountering the unexpected leads to reflective thinking as Dewey has outlined; we embark on a process of critical examination of the situation, framing of the problem, on-the-spot information gathering to explore the new phenomena. The process may work, yielding expected results, or it may lead to new surprises that incite additional cycles of reflection-in-action. Schön acknowledges that this is idealized and simplified; however, he feels that here lies a phenomenon that captures the essence of what he means by "artistry." Reflective practitioners exercise reflection-in-action to deal effectively with problems in the "indeterminate zones of the swamp."

Schön proposes that reflective practice can be learned through exercising reflection-in-action, and that professional education can and should provide opportunities for doing so. To achieve this goal, he advocates the use of "reflective practicums:"

> . . . a setting designed for the task of learning a practice. In a context that approximates a practice world, students learn by doing, although their doing usually falls short of real-world work. They learn by undertaking projects that simulate and simplify practice ... The practicum is a virtual world, relatively free of the pressures, distractions, and risks of the real one, to which, nevertheless, it refers ... It is also a collective world in its own right, with its own mix of materials, tools, languages, and appreciations. It embodies particular ways of seeing, thinking, and doing that tend, over time ... to assert themselves with increasing

authority...

> Students practice in a double sense. In simulated, partial, or protected form, they engage in the practice they wish to learn. But they also practice, as one practices the piano, the analogues in their fields of the pianist's scales and arpeggios. They do these things under the guidance of a senior practitioner... From time to time, these individuals may teach in the conventional sense, communicating information, advocating theories, describing examples of practice. Mainly, however, they function as coaches whose main activities are demonstrating, advising, questioning, and criticizing [19].

Schön [20] lists three types of practicum (he does not number them as done here): Type I practicums see professional knowledge in terms of "facts, rules, and procedures applied nonproblematically to instrumental problems" and are equivalent to technical training. In such cases, students learn by taking in the necessary facts and rules and apply them; coaches observe student performance, detect errors, and correct behaviors.

Type II practicums see professional knowledge in terms of "thinking like a doctor." They still emphasize facts and rules, but also focus on "the forms of inquiry by which competent practitioners reason their way, in problematic instances, to clear connections between general knowledge and particular cases." Depending on their view of what "thinking like a doctor" means, coaches may stress the facts and rules or the "reflection-in-action by which, on occasion, students must develop new rules and methods of their own." The clinical experiences of medical students and house staff are examples of this kind of learning. However, learning requires feedback that is timely and relatively unambiguous [21]. These are much less likely in the typical, uncontrolled world of clinical practice, given the variability-or unavailability-of coaches, practical experiences in the form of appropriate patients, and the differences between the pace of the education and the pace of disease evolution. This is a key justification for the use of constructed practice worlds such as the reflective practicum and the Virtual Practicum.

Type III practicums focus on reflection-in-action. They assume neither that every problem has applicable rules nor a right answer. Students will have "to learn a kind of reflection-in-action that goes beyond statable rules ... by constructing and testing new categories of understanding, strategies of action, and ways of framing problems." Coaches emphasize the "indeterminate nature of practice and reflective conversation with the materials of the situation."

Schön notes that there can be value in all three types of practicum, and that there is a natural hierarchy to them:

> Perhaps we learn to reflect-in-action by learning first to recognize and apply standard rules, facts, and operations; then to reason from general rules to problematic cases, in ways characteristic of the profession; and only then to develop and test new forms of understanding and action where familiar categories and ways of thinking fail [22].

The practicum strategy adopted in developing a technology-based learning program will depend on the needs of the student and what must be taught. For example, a program teaching primary care physicians how to manage major trauma might adopt the Type I or Type II strategy. Here the physician inexperienced in trauma management is given a basic understanding to get him or her (and the patient) through the occasional event. It must be a concentrated and relatively brief experience, since time available for learning is limited by the constraints of everyday practice. It might not move much beyond facts, rules, and procedures, possibly using those already developed for the Advanced Trauma Life Support (ATLS) course by the American College of Surgeons. Such a program has been developed for

the U. S. Navy [23]. The program realistically simulates trauma management in a combat environment using motion video and allows the student to exercise ATLS principles by making choices using a menu-based interface. The program incorporates a mentor who outlines objectives and the ATLS approach, and provides feedback on performance. On the other hand, though it appears to emphasize the application of well-defined rules, there may be distinct elements of the swamp in it. Most learners using the program experience much of the emotional impact of trauma management, with the stresses of time, confusion, and uncertainties surrounding diagnosis, treatment, and outcome. It is one thing to make a decision on paper or in a room with an instructor and a patient scenario that is clearly contrived; it is another to feel as though one is actually in a combat hospital, with a patient who is realistically depicted as deteriorating rapidly, and the clock is ticking. If this kind of simulation helps one develop an ability to make momentous decisions under pressure, then reflection-in-action is occurring, and elements of a Type III practicum are present.

The Virtual Practicum model proposed in this paper uses predominantly a Type II strategy, including facts and rules, but with emphasis on "think like an expert" kinds of learning. On the other hand, there are the occasional forays into unfamiliar, "swampy" areas of indeterminacy, where even experts are not sure of the answer, so we see use of Type III strategies as well.

Boisot's E-Space and Kolb's Learning Cycle

Schön inspires us to consider critical areas of practice that are difficult to codify and classify and usually remain tacit during learning and in practice. He provides the beginnings of a language for making them explicit. However, Schön's approach is mainly descriptive and philosophical. He provides no clear path to more systematic consideration of this domain and provides few methods for educational implementation.

The work of the economist and organizational theorist, Max Boisot, is more helpful in this regard. Boisot collates and systematizes an extremely broad body of research and thinking, linking scientific and philosophical theory to learning [24]. Though he does not directly consider Schön's ideas, professional education, or learning technology, he provides a conceptual framework-the epistemology space, or E-space, and its underlying constructs-that allows a deeper consideration of what constitutes comprehensive clinical education and how it may be facilitated using technology [25]. Boisot begins his derivation of the E-space with a connectionist view of memory and learning [26], incorporates some of Bruner's concepts regarding perception and generalization [27], and then ties the E-space directly to learning methodologies via superimposition of Kolb's learning cycle.

Since the 1980s, connectionism has emerged as a major movement in cognitive psychology, neurobiology, and research into artificial intelligence [28]. A connectionist model developed by Edelman, the Theory of Neuronal Group Selection (TNGS), assumes the brain to be made up of populations of neuronal groupings, individually variant networks-defined by interneuronal connections-whose structure and function are selected by a Darwinian-like process during development and behavior. NGS involves establishing patterns of interneuronal connection strengths, excitatory and inhibitory, that result in patterns of input-output activation that are appropriate to different circumstances. In the end, effective perception and complex, sophisticated representations of events and environments occur through competition among neuronal groups, resulting in a selection of "repertoires" that deal most successfully with the circumstances of the moment. Repertoire selection forms a basis for recognition, the mind/brain's coding of perceptual stimuli, assigning them into representational categories.

Perception and categorization are thought to result from a process of "settling" into a solution rather than calculating it. The brain moves from less probable to more probable hypotheses, through a process of 'voting' interactions among neuronal groups. The number of cycles-and hence the learning strategies

employed-can range from one ("single shot") to many ("relaxation" to a solution over several iterations). Situations that are simple or familiar, that the individual has already learned, can be handled using strategies toward the "single shot" end of the scale; complex, unfamiliar situations require "relaxation" strategies that can take much longer. Some complexes of stimuli have achieved semantic or symbolic status, in the form of spoken or written surrogates. This is mainly a question of having consensus on how things should be named and understood, i.e., that there exists an a priori coding scheme that applies, allowing divestment from the sensory data that accompanies that object or event. As a result of learning and applying this coding scheme, rather than dealing with a multitude of perceptual stimuli, we mainly apprehend and process the symbolic representation of that complexion of data. Symbolic encoding is one means for chunking of sensory data and the greater likelihood of single shot processing of "facts," which, in turn, provides for the application of rules to manipulate those facts and draw conclusions. This parallels Schön's knowing-in-action. Progressing from relaxation strategies, which consider numerous, sometimes conflicting or ambiguous stimuli, to single shot strategies which can consider facts and rules, is a process of learning to deal with what is initially unfamiliar, and is analogous to Schön's reflection-in-action. A central issue is whether one can learn to move from relaxation strategies toward single shot more efficiently, a goal of Schön's reflective practicums.

From sequences of sensory input we identify those things which are recognized as in some ways stable and reproducible, as opposed to ephemeral. Having selected, we then work to categorize as a routine, nearly unconscious activity, matching perceived characteristics to existing schemata and, where necessary, modifying them or creating new ones. To provide adaptive advantage, however, categorization must involve generalization, or abstraction, in which the individual, based on a small number of stimuli, recognizes and responds to a much larger, more varied set of stimuli, to move, as Bruner has said, "beyond the information given:"

> William James wrote picturesquely of this process, remarking that cognitive life begins when one is able to exclaim, "Hello! Thingumbob again." The adaptive significance of this capacity for equivalence grouping is, of course, enormous. If we were to respond to each event as unique and to learn anew what to do about it or even what to call it, we would soon be swamped by the complexity of our environment [29].

Edelman notes an important difference between perceptual and conceptual categorizations. Perceptual categorizations originate in local stimuli involving the five senses and conceptual categorization depends mainly on non-local stimuli originating in memory and experience. These categories provide quite different methods of dealing with the world. However, they interact constantly, with concepts shaping and filtering the perceived world. Bruner and co-workers have drawn a relationship between the number of hypothetical concepts, H, possible after the first positive occurrence of an event, and A, the number of attributes in an array, as $H = f(A)$ [30]. For example, if 3 attributes can be grouped under 7 possible categories, then 4 may be grouped under 15, 5 under 31, and 6 attributes under 63 categories). The formula allows us to specify two strategies for reducing complexity [31]:

1. Reduce the number of attributes that must be perceived. This is a function of perceptual categorization of attributes, or coding, which economizes on the amount of data to be processed.
2. Reduce the number of categories that will be used in processing sense data. This is a function of conceptual categorization, or abstraction. Creation of a reduced set of suitable, generalizable concepts economizes on the number of concepts through which data must be processed; it also reduces cognitive load by focusing perception, filtering the number of attributes that must be processed.

Note that reducing the objects of experience to symbolic representations achieves both types of data processing economies; by naming something ("thrush," "regret"), we reduce the number of attributes and

the number of categories we consider. These economies can increase the effectiveness and efficiency of thought and action. It can also increase our ability to communicate and learn, by focusing on key, salient features and disregarding stimuli that are considered to be "noise." However, there are costs associated with such reduction. For one thing, the coding structures that evolve frame the texture of new experiences, rendering some features salient and others insensible, and some features neglected as "noise" may, in fact, be crucial. For another, coding is not completely efficient; it necessarily involves loss of information. Moving on a scale of less coding to a higher degree of coding means that data have been set aside. But codes depend on their context, i.e., the codes further down the coding scale; one cannot recover context in moving back down the scale, it cannot be specified from the code itself, and information is inevitably lost. This returns to a main topic of this paper: what if the information set aside is important to success? Most formal medical education involves the transmission of highly coded and abstract information in the form of facts and rules. Even more practical laboratory experiences, e.g., in anatomy and microbiology, anchor a physical world of cadavers and growth media to abstract facts and theories. More efficient? Yes. More effective? It depends on one's definition of expertise. If defined in terms of passing multiple-choice board certification examinations, the answer is probably yes. If defined in terms of an ability to deal with complex, biopsychosocial aspects of clinical care, then what?

Note also that there is an alternative strategy to coding via "chunking." When the goal is to arrive quickly at a decision, as is increasingly the case in today's health care, then economy in "processing" time and energy will usually lead to use of chunking strategies. On the other hand, to operate for a time at a lower level of coding, and experience increased complexity, can provide broader experience of the world, preserving context, and allowing for multichannnel communication of sense data and ideas. This scanning method of sensory processing will ultimately result in selection and categorization, but these occur at a more contemplative pace. Scanning is an element of relaxation learning strategies and is likely a key component of Schön's reflection-in-action. Boisot notes a danger in scanning strategies in that uncoded "signals" are often ambiguous and idiosyncratic, and difficult to separate from "noise" [32]. On the other hand, if we prematurely "thin out" the input from our environment, and especially our patients, we may be missing the message. Noted physician and humanist Robert Coles talks about his experiences as a psychiatrist-in-training and his mentor, poet and physician William Carlos Williams:

> As a house officer I had to report in detail a given medical or psychiatric reality, and do so in a manner my colleagues could accept and comprehend. I had no time or sanction for embellishments, nor for narrative that didn't draw diagnostic conclusions ... At worst [Coles argued at the time] it was a form of shorthand; certainly many were eager and quick to respond to it. Theory was a means of getting to the core of things, focusing precisely on what connects this patient, right here, sitting before me, with others all over the world who belong to a category. I can say, "The patient is phobic"-not a callous or coldhearted or impersonal attitude, but a brief, pointed piece of information shared with another busy professional. Yes; but Dr. Williams had this amplification: "Who's against shorthand? No body I know. Who wants to be shortchanged? No body I know."
>
> He's been dead a quarter of a century, yet I still hear him speaking those words, a poem of sorts to someone having trouble seeing the obvious [33].

Coding and abstraction share many strategies, are highly interdependent, and they are easily confused. However, they have different roles. Boisot makes the distinction between coding (and its externalized form, codification) and abstraction:

> [Coding] saves on data by giving a better definition to form, removing its fuzzy edges and allowing a sharper discrimination and focus. Abstraction saves on data by correlating features of the forms so defined on the basis of shared attributes, thus avoiding the need for

> independent description or treatment. Simplifying somewhat, we might say that codification reduces the complexity of forms whereas abstraction reduces the complexity of content. The first proceeds by differentiation, and allows us to enumerate finite sets of discrete elements; the second aims for integration, and brings elements so created into some limited and specifiable relationship with each other [34].

Coding and abstraction generally go on more or less unconsciously, a routine parsing of events and associated stimuli based on previously learned routines of percepts and concepts. However, when an appropriate repertoire is not available, then innovation is required, and it is here that learning occurs. Theorists of the PDP tradition speak of "bottom-up" learning when innovation is data-driven (coding) and "top down" when it is theory-driven (abstraction). In the long term, theory creation has far greater impact. For example, a beginner's first view through a microscope will at first be confusing, as Patricia Churchland notes:

> [I]t may be difficult to know what is artefact and what is part of the cell ('That's endoplasmic reticulum ...??'). Theory informs observation and after a short while it becomes hard not to see, say, the end bulb ... To apply the term 'end bulb' is not a sheer naked observation: it implies an indefinite number of generalizations applicable to the object. This cascade of indefinitely many applications is a general feature of the observational application of any descriptive term, whether it is 'coyote,' 'red,' or 'synaptic vesicle' [35].

Theories form in individuals as a result of experience and reflection, or they are received from others. However, there are no guarantees that the personal knowledge6 gained will be valid or comprehensive. A major thesis of this paper is that education should provide, in addition to the articulate, scientifically validated theories of technical rationality, experiences that stimulate the individual's development of valid personal theories. The latter includes basic beliefs, and values that manifest themselves in such "skills" as empathy, compassion, and an ability to communicate. Boisot's epistemological space (E-space) facilitates consideration of this more complete view of knowledge.

The E-space (Figure 1) summarizes the preceding discussion in a simple, schematic way.

> The two dimensions of coding and abstraction allow us to visualize graphically in what form an individual processes and stores the data available to him. It can be used to give us a snapshot of how the knowledge held by an individual is distributed at a given instant... or it can allow us to trace the evolution of a particular item of knowledge by following its trajectory in the space ... The way that the knowledge held by an individual is configured in the E-space is affected by the way he learns and by more general personality factors [36].

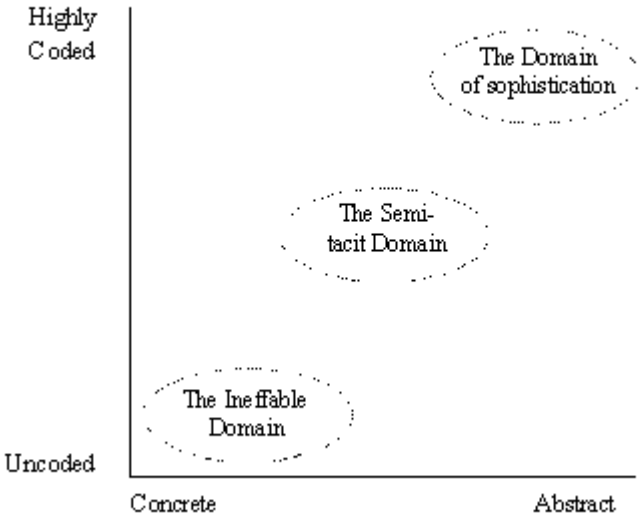

Figure 1. Modes of Knowing in the E-Space (modified after Boisot)

As a first instance of using the E-space, one can roughly consider different modes of deriving personal knowledge, which Boisot develops following Polanyi [37,38]. In the far southwest region of the E-space lies the ineffable domain. Here lies knowledge that cannot be put into coded form. In the practice world, it is the region of knowledge most subject to errors of interpretation, since one's experiences are so completely subjective. The tacit domain requires little or no investment in learning codes or mastering concepts, so it is potentially available to all. Since this domain deals with concrete experiences, these can generally be shared only with those who are there for the same events, and this has previously limited the sharing of such experiences to those who are physically co-located.7 It is the purest form of what Polanyi calls "personal knowledge."

Around the center of the E-space lies what Boisot calls the semi-tacit domain. Here we can experience discourse that uses non-specialized symbols and concepts that are widely shared, ones resulting from a process of general socialization. There is still room for errors of interpretation, but this is reduced through the introduction of frames of reference provided by coding and categorization on which there is general agreement. Data are lost when coding into words or by abstracting from concrete situations, but multichannel communication, via tone of voice, facial expressions and gestures, can compensate for that loss. Because specialized knowledge is not required, knowledge in this domain may be widely accessible by anyone who has general knowledge of social discourse and situations. Though Boisot does not stress this point, it is possible to share this knowledge at a distance, and even add emphasis, via film or television and, if digitized, via computer networks. Context is, to a large extent, retained.

In the northeast region of the E-space lies the domain of sophistication. Here we encounter only symbols that represent highly coded and abstract kinds of knowledge. The formal processes of scientific rigor and review can decrease errors of subjectivity. Data embedded in richer complexions of attributes and categories are disregarded. Language shapes thought, liberating concepts from the myriad data that encumber it; for example, f=ma communicates a great deal of general knowledge about the nature of accelerating objects and can lead to unfettered manipulations of symbols, resulting in new insights. Communication of specific meanings may be enhanced and these are more readily shared via text-based

media (journals, textbooks, the Web). On the other hand, because context has been nearly entirely shed, communication may be lacking sufficient detail and therefore may lose relevance to the indeterminate circumstances of the practice world, Schön's "swamp." This domain requires significant investment in developing repertoires of codes and concepts (e.g., learning algebra and physics to understand the relation, f=ma).

Another way of viewing the E-space is in terms of the knowledge artifacts one encounters in its different regions (Figure 2). In the upper regions of the E-space we find knowledge that derives from technical rationality. The northeast region contains highly coded, logically formulated, more systematically studied and reviewed, scientific knowledge. As already noted, we find this type of information in journals and textbooks, expressed almost exclusively as symbols, words, formulas, and tables, with figures and occasional images such as x-rays and photomicrographs that themselves require highly coded, abstract knowledge to interpret. This is the region of rational thought and action, isolated to a great extent from the variability and idiosyncrasies of the real world. That which is difficult to quantify tends to get ignored.

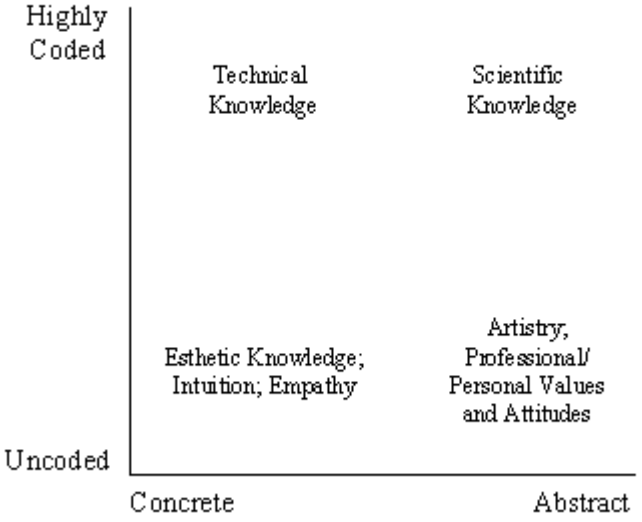

Figure 2. Types of Knowledge in the E-space (modified after Boisot)

The northwest region has technical knowledge, which provides for direct applicability of abstract scientific knowledge to concrete situations. This knowledge is often manifested in physical devices, such as an ultrasound machine, IV delivery set, or medication.

Though Boisot does not so state, it is in the lower regions of the E-space that we find the knowledge essential to Schön's artistry. The southwest region contains what Boisot calls esthetic knowledge, which can be interpreted as an ability to sense and understand at a non-verbal level, to grasp meaning in a situation without necessarily being able to account for the process used. The ability rapidly and accurately to determine which features of a complex set of stimuli are salient is a mark of the expert practitioner, learned through a process of 'enskilment' that comes not from mechanistically internalizing a stock of knowledge, but from being actively engaged with a practice environment [39].

Knowledge that lodges in the southeast region of the E-space contains uncoded abstractions which, while they cannot be handled with precision, may nevertheless contain the most powerful influences on behavior. It is here that core beliefs and values lie, influencing our thinking and behavior in fundamental ways, often at an unconscious level. Some argue, Boisot notes, that one cannot abstract without coding, but he distinguishes between codes that one merely names (e.g., "professional ethics," "compassion," or "truth"-or empathy and artistry, for that matter) and having an uncoded, personal knowledge of what they mean. That philosophers and ethicists debate the meaning of these sorts of abstract concepts attests to their instability as quantifiable, codeable knowledge. One can find language to discuss such concepts in abstract ways, but it is mainly through the richer contexts of concrete experience that one learns about and practices them.

To clarify with an example, consider the kinds of knowledge that might be brought to bear when dealing with a patient with HIV infection, one who is unexpectedly undergoing sudden disease progression, with rapid fall in CD4 T-cell count and increased viral burden, and who is not currently taking antiretrovirals. Figure 3 shows a very limited view of an E-space that might apply here. A great deal of scientific information bears on management of this patient's situation. In the northeast region lies knowledge of the HIV life cycle, viral mutation, and development of drug resistance (and basic science supporting that knowledge, e.g., genetics, biochemistry, pharmacology) and, perhaps, data about compliance among different patient populations. The northwest region contains a set of objects that manifest our scientific and technical knowledge: medications in the form of pills that interrupt the life cycle, perhaps a brochure or videotape on why and how to take the drugs.8

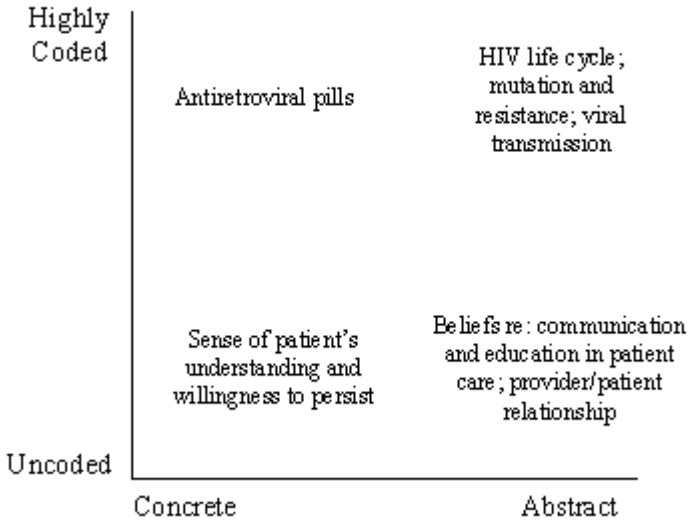

Figure 3. An Example from HIV Care

If the northern regions of the E-space contain the more biological aspects of management, to the south are the more psychosocial aspects. Having applied scientific knowledge and elected a technical method of treatment, success now depends entirely on our patient's persistence in following a difficult drug regimen very long term. Our ability to understand her emotional and intellectual state, to explain and motivate, to have appropriate models of patient-provider interaction and to exercise them, in short to participate effectively in the transactional aspects of patient care, will be important determinants of

success.9 In the southwest region lies particular knowledge of this patient and her qualities, of her gestures and facial expressions, recognizing patterns that are combinations of coded and uncoded cues and responding to the concrete circumstances she presents us with. To the southeast lie broad, unarticulated knowledge of communication, especially non-verbal; values about the importance of communication and education; beliefs about patient-provider interaction (a provider-centered, rational agent model? Patient-centered? Shared decision?); and attitudes about patients with HIV and the various life styles that can accompany that condition. Again, these can be named, but they are developed, incorporated, and applied at a more uncoded, contextually rich level.

The E-space is highly dynamic with, as already noted, a great deal of interaction between coding and abstraction. In particular, representational categories shape perception and the unfamiliar becomes hard to perceive and remember correctly. This can manifest as habits of thinking that can cause important aspects of the practice world to be seen as inconsequential, or to be invisible. We return to the issue raised by Schön and this paper: how do we provide learning experiences that encourage development of E-spaces that are sufficiently comprehensive when dealing with the familiar (knowing-in-action), and how do we do so in ways that promote effective innovation and problem solving in unfamiliar situations (reflection-in-action)? This leads us to a final aspect of Boisot's work to be considered here,10 generative movement in the E-space, or learning.

To make a direct connection with adaptive learning, Boisot modifies Kolb's learning cycle [40] and maps it onto the E-space, as shown in Figure 4. In Kolb's experiential learning model, experiences are translated into concepts, in turn channeling new experiences. There are four stages: 1) immediate, concrete experience is seen as forming a basis for 2) observation and reflection; this, in turn, leads to 3) a process of abstraction and assimilation into models and theories; in a fourth stage, these models are applied as actions in new situations. The cycle can then repeat itself indefinitely, with "successful" iterations persisting as knowledge in the learner's E-space.

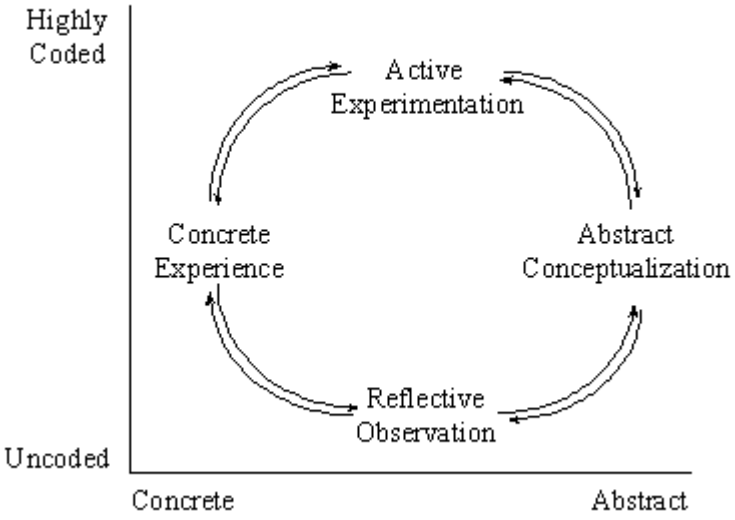

Figure 4. Kolb's Learning Cycle (modified by Boisot) in the E-space

In its original form, the arrows of Kolb's cycle moved only counter-clockwise. Further, Kolb viewed concrete experience and active experimentation as dealing only with the concrete world and its events. Boisot argues that Kolb's distinctions between "real," external activities and internal, concept-building activities are limiting. The cycle can be strengthened

> if we think of active experimentation as the deliberate and conscious manipulation of well-coded data complexions-whether this is carried out in one's head, on things, or in documents-and we think of reflective observation as a detached, non-committal search for patterns, operating either internally or externally, at a lower level of coding. The first takes place in the world of the given, of things with hard edges that can be moved about without dissolving; the second takes place in the world of the possible, one in which things shade into one another to yield new configurations [41].

This modification maps the learning cycle into the E-space. Further, since the active experimentation stage becomes a source of analytic activities, then the cycle, still starting from concrete experience, can run in both directions.

Kolb and Boisot agree that different individuals, through combinations of natural makeup, life experiences, and the demands of their environments, have different abilities within the learning cycle. This results in different learning styles, which correlate with relative strengths in handling the different stages of the learning cycle:

> Some people develop minds that excel at assimilating disparate facts into coherent theories, yet these same people are incapable of, or uninterested in, deducing hypotheses from the theory. Others are logical geniuses but find it impossible to involve and surrender themselves to an experience. And so on. A mathematician may come to place great emphasis on abstract concepts, while a poet may value concrete experience more highly. A manager may be primarily concerned with the active application of ideas, while a naturalist may develop his/her observational skills highly. Each of us in a unique way develops a learning style that has some weak and some strong points [42].

Kolb derives four statistically definable learning styles, which can be viewed as the "quadrant" of the E-space for which an individual learner has a predilection. However, to become fully mature, Kolb argues, there is a strong need for the individual to integrate the four styles. From an educational viewpoint, this necessarily involves providing learning experiences that promote such integration. Experiences that concentrate attention only on one area of the E-space, in the end, limit growth. What Boisot does not point out is that the learning cycle under different conditions of learning may not cover the E-space as completely, as Figure 4 indicates. In most formal clinical education, the cycle is shifted to the northeast, occupying mainly those areas of the E-space that are more highly coded and abstract. And opportunities for learning-and growth-are restricted, not by the limitations of the learner, but by the design of the learning experience. Comprehensive clinical education as proposed in this paper, fills the E-space more completely, and provides learning experiences that promote professional and personal growth.

As we contemplate the use of technology in learning we have an opportunity, and a mandate, more carefully to consider the design of the learning experiences we provide. This section has provided a framework and rationale for doing so.

RESULTS

The Virtual Practicum Model

As we have noted, current thinking about technology-based learning for clinical education, with few exceptions, adopts an informatics model. Medical knowledge is seen as reducible to that which can be expressed in highly coded form; education and information access are viewed as equivalent; and computers connected via networks are mainly there to provide appropriate facts and rules in support of clinical decision making. The informatics model is completely consistent with, and reinforces, a technical-rational approach to clinical practice and clinical education lying in the upper reaches of the E-space. This approach obtains efficiency by reducing complexity, and allows communication via a single, symbolic channel. Discourse can be limited to text-based or verbal case presentations, scientific papers, and lectures that use Coles' "shorthand." But, as Dr. Williams noted, we can be "shortchanged" when the single channel and its codes are insufficient. In gaining efficiency, we risk losing effectiveness:

> Messages are then efficiently transmitted but are not necessarily understood, or, if understood, do not lead to the desired behavior. We discover, sometimes rather late, that communicative efficiency and communicative effectiveness make uncomfortable bedfellows ... The first is concerned with economizing on means, the second with achieving ends [43].

This observation is particularly apt when applied to the psychosocial and transactional aspects of clinical practice. As we have argued, they are often difficult or impossible to convey in coded form. The informatics model is insufficient when considering them.

The Virtual Practicum model seeks more fully to exploit the E-space and to achieve, simultaneously, increased educational efficiency and effectiveness. It incorporates all elements of Schön's reflective practicum model, all in an automated, electronic, replicable, and disseminable form. A key to both the reflective and virtual practicums is simulation of the practice world with sufficient complexity and realism. Multichannel communication can help achieve these qualities by greatly expanding the repertoire of stimuli that can be conveyed to a learner. As Boisot notes, "Multichannel communication is communication in a natural mode, it is the deployment of coordinated gesture, speech, tone, clothes, movement, in the service of messages whose complexity would overwhelm the single channel" [44]. However, Boisot appears not to recognize completely the role of technology in supporting multichannel communication at a distance. On the contrary, while we cannot be complete in depicting all features of clinical practice, we can with video and sound convey the less coded, essential features of that environment. In fact, key features may be dramatically emphasized, as our common experience of television and film bears out.11 Digital multimedia technologies, including motion video, can be delivered today via CD-ROM and tomorrow via a broadband Internet; these technologies can be used to provide for multichannel communication, to deliver complex, intellectually and emotionally rich sets of learning experiences to a global audience.

The following shows the derivation of the Virtual Practicum model and describes its elements in detail. We then present an example: a Virtual Practicum dealing with HIV and AIDS.

Exploiting the E-space: the Reflective Practicum and the Learning Cycle

Schön's reflective practicum can be used to define the elements of the Virtual Practicum. Kolb's learning cycle can be used to consider the deployment of these objects more fully to exploit the E-space.

As described previously, Schön's reflective practicum has the following elements:

- Provides a setting that approximates the practice world
- Students learn by doing work that simulates (but simplifies) practice
- Provides a virtual world, free of pressures, distractions, risks of the real one [and, we add, that it focuses perception, facilitates understanding, and is intrinsically satisfying to use]
- Is a collective world in its own right, with its own mix of materials, tools, languages, and appreciations
- Embodies particular ways of seeing, thinking, and doing that assert themselves with increasing authority
- Activities range from more basic exercises ("scales and arpeggios") to actual practice (e.g., simulated patient care)
- All these are done under the guidance of a senior practitioner who may
- teach in a conventional sense, communicating information, advocating theories, describing practice examples
- function as a coach, demonstrating, advising, questioning, and criticizing

Using this list as a nearly exact template, we specify the elements of the Virtual Practicum:

- It provides a technology-based "Virtual Clinic" or "Virtual Mini-fellowship" that approximates the world of clinical practice, represented as media elements (graphics, video, sound, text) within which the learner can move, work, and learn
- Students learn mainly through simulation of clinical practice; a key ingredient is simulated teaching cases which compress time and space, giving the experience of evaluating, managing, and counseling a patient over a virtual time span ranging from days to years; in addition, there are documentary-style "interviews" with genuine patients, providing narrative impetus and context for considering health and illness from the patient's perspective
- Provides a virtual world that is sufficiently immersive and intrinsically enjoyable to allow even busy professionals to ignore, for a time, the pressures and distractions of the real world; the Virtual Practicum may reduce the risks to real patients as students develop and apply new knowledge and skills, since these are done in a technology-generated environment before applying them in the real world
- It is a collective world in its own right, providing an inviting, strong sense of place that one can visit repeatedly to learn; it contains language, materials, and tools most of which have analogs in the real world of practice, some of which borrow from the esthetics of best-practices in computer game design; a key feature is use of narrative and case-based reasoning to increase engagement, enhance reflection, and improve learning.
- It embodies particular ways of seeing, thinking, and doing via cycles of experience, reflection, abstraction, and experimentation in the tradition of Dewey, Schön, and Kolb (see Figure 5 and discussion, below); narrative used in the case presentations provides an underlying structure and context for discussions and reflection that, after Schön, "assert themselves with increasing authority" and intensity.
- Activities include clinically realistic patient encounters, documentary-style interviews with real patients and practitioners, and computer-generated exercises that allow for heuristic learning of facts and rules.
- All this is done under the guidance of senior practitioner (in the best case a master teacher and master clinician) who may
    - teach in a conventional sense, "communicating information, advocating theories, describing practice examples" via mini-lectures and case discussions
    - function as a coach, "demonstrating, advising, questioning, and criticizing" via case discussions and guided (with feedback) reflection and experimentation.

As shown in Fig. 5, the Virtual Practicum ties Schön's ideas directly to Boisot's E-space. The Virtual

Practicum elements are associated with different stages of Kolb's learning cycle; the underlying E-space is omitted for clarity and it is understood that the learning cycle fully occupies the E-space as in Fig. 4. The figure does not show the interplay among the various elements nor the fact that each element plays some role in all of the learning strategies; these interdependencies are brought out the following discussion.

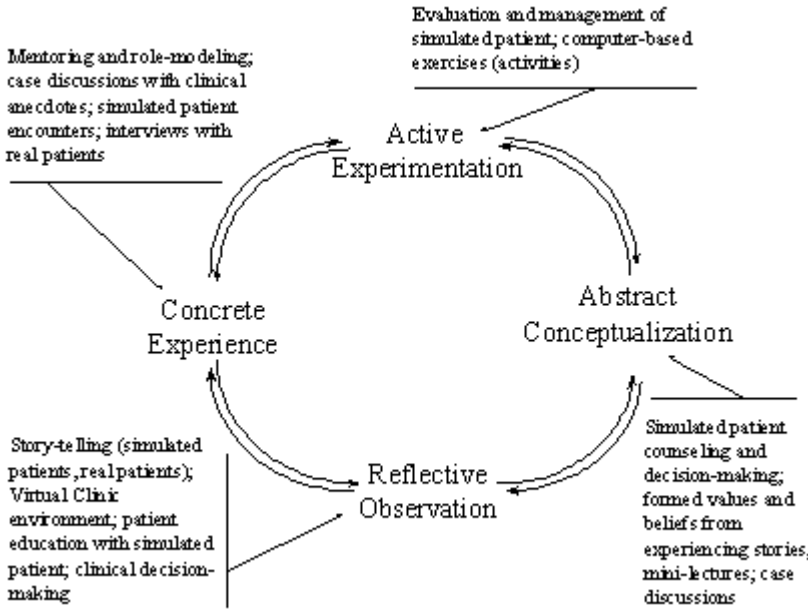

Figure 5. Virtual Practicum elements within Kolb's learning cycle

Concrete Experience

Concrete experience is provided by simulated cases; mentoring and role modeling by an expert practitioner and teacher, including "pearls" of wisdom stemming from years of clinical experience; computer-based activities; and interviews with actual patients (or care providers).

Simulated cases: a patient, played by an actor, depicts the biological and psychosocial evolution of a disease process in a series of simulated clinical encounters. Each encounter follows a typical clinical format: history taking, physical examination, ordering (and later interpreting) studies, patient education and counseling. Storytelling and case-based reasoning are used to enhance learning, as discussed under Reflective Observation, below. Dramatic devices typical of video/cinematic narrative are provided to add impetus and impact during and between encounters. Production quality is sufficient to meet the expectations of an audience accustomed to the standards of television and, increasingly, computer games.12 The simulation must be sufficiently developed, realistic and detailed to feel authentic.

Mentoring and role-modeling: this is, in the best case, provided by a master clinician and master teacher with an international reputation in his or her field. The mentor serves as a personal guide during the practicum, welcoming and orienting the learner to its use, providing suggestions about the sequence of learning experiences. The mentor also provides oral case discussions, contextualized to the simulated cases that the student has completed; the case studies present facts and theories but also, and perhaps more important, "pearls" of wisdom and anecdotes stemming from years of clinical experience, the sort of knowledge that is not usually found in the more formal discourse typical of lectures and articles. As

with all oral discourse, there is much uncoded information conveyed in the presentation: facility and organization in presenting ideas (indicating mastery of content and teaching skills), excitement and passion about the topic, and compassion for the patient being discussed. The mentor establishes a collegial and supportive tone in a cordial, polite, and no-nonsense way. Several lines of evidence and educational theory, in addition to Schön, support the use of mentors as role models and guides in this way [45].

Computer-based "activities:" these are equivalent to Schön's "scales and arpeggios." As musical exercises provide a repertoire of techniques that can be applied generally to playing musical compositions, these activities provide an opportunity to learn actively and heuristically about generally applicable facts and rules for a given clinical domain. These exercises do not emulate the practice world in any substantive way; that is left to the simulated patient encounters. Activities use text and graphics to present a series of puzzles to solve, and presenting immediate, polite feedback in the form of graphical changes and text messages. For example, activities related to the life cycle of the human immunodeficiency virus might include naming the virus' key structures, unscrambling a jumbled list of the life cycle steps or, given a diagram showing the complete life cycle, match a life cycle step to a possible intervention (e.g., an integrase inhibitor would act at the step where the viral DNA is integrated into the cell genome).

Interviews with actual patients (or care providers): these intend to provide insights into health and illness from the patient's perspective. Motion video and documentary interviewing techniques are used to capture extemporaneous narratives that communicate at several levels, verbal and non-verbal, coded and uncoded. This can provide a perspective on clinical practice that is too often neglected in the business of clinical care: the perspectives of articulate patients, describing and reflecting on their personal experiences. Interviews with other care providers can also provide insights, particularly when given by providers from other professions (clinical psychology, nursing, nutrition, etc.).

Reflective Observation

Reflective observation is stimulated by the use of storytelling; the overall appearance and impact of the program, in its whole and in its parts; and question-answer interactions (patient education, clinical decision-making).

Use of storytelling: this is one of the most important aspects of the Virtual Practicum model. Narratives are used at several levels: in the overall environment (Virtual Clinic as stage with its sets), in the simulated patient (with her physical and emotional challenges and life issues), in the stories of real patients (with deeply moving, insightful, and sometimes surprising twists), and even in the mini-lectures, with narratives in the academic tradition. Storytelling can greatly enhance the learning cycle. Schank, for example, argues that case-based reasoning involves learning from narratives. Cases are richer in features than rules, more richly indexed in memory, easier to modify and adapt to new situations, and thus easier from which to learn.

> It would seem, then, that the cliche "Experience is the best teacher" is quite true. We learn from experience, or to put this more strongly, what we learn are experiences. The educational point that follows from this is that we must teach cases and the adaptation of cases by telling stories, not teach rules and the use of rules by citing rules. We may never find ourselves in a situation where the rules we were taught apply exactly. Ordinarily, we find answers for ourselves. Lots of stories and cases help, but methods of applying these stories and cases, especially in places where they weren't originally supposed to apply, help more [46].

Note Schank's resonance, in his last sentence, with Schön's reflection-in-action.

Overall appearance and impact: The program strives to provide a learning environment that is conducive to having an optimal experience, as described by Csikszentmihalyi in his work on the flow state [47]. According to this theory, when there are clear goals and expectations, timely and clear feedback, and an excellent match between the difficulty of tasks and the abilities of the learner, a flow state can occur which can be completely engaging, to the point where one's consciousness is absorbed with the tasks at hand. This experience, Csikszentmihalyi says, can be extremely enjoyable, and leads to superior performance in problem-solving and increased learning. Flow is likely to have strong effects on reflective observation, in that attention is more fully engaged in processing the multiple, complex stimuli of the immediate environment.

In addition, the Virtual Clinic incorporates an esthetic that is pleasant and inviting, providing a respectful and safe environment for learning. We presume that, by encouraging novel thought and experimentation without undue fear of failure, the environment facilitates reflection.

"Counseling" interactions: Reflection is stimulated via question/response interactions. Every simulated patient encounter involves patient education and counseling, during which the patient asks questions of the learner. After the patient asks a question (on video), the learner selects from among three choices that delineate key issues related to facts and counseling style. Learner may elect to get feedback on selections and to learn what resident experts think are key issues related to the patient's question. Again, the aim is to provoke reflection, and not to be prescriptive regarding counseling.

Clinical decision-making provides guided reflection about the management of the simulated patient. During each encounter, the mentor (or other expert) frames a series of questions addressing different aspects of the problems noted. Format is 1) short summary of relevant findings, 2) question; 3) select from among four choices; 5) immediate feedback on selection; 6) select new answer and/or 7) repeat cycle with new question. Simulated situations and questions are designed to avoid cut-and-dried application of facts and rules. They verge on, and sometimes enter, swampy territory.

Abstract conceptualization

Abstract conceptualization: there is overlap here with the Virtual Clinic elements that generate reflective observation, in particular the simulated patient and patient interviews. Additional elements include the presentation of facts in more traditional formats: lecture presentations and case discussions..

Simulated patient and patient interviews: the patient education and clinical decision-making elements link concrete experience to general principles. That is, when responding to questions regarding the management of this particular (simulated) patient, the learner receives feedback from the mentor that links to general principles of counseling and management. Further, the experience of managing the simulated patient and experiencing the real patient interviews is intended to stimulate and support the development of attitudes and values regarding patients and their care. These may not be articulatable in simple question/response or lecture formats, but occur nevertheless though the events and emotional force of their stories, and their general relevance to the human condition.

Mini-lectures follow a traditional format for passive learning of more highly coded and abstract information (theories, facts, rules). However, the lectures have more in common with educational television programs, such as Nova, than the typical classroom lecture. They are given by experts; are carefully scripted and produced; and use video, graphics, and animations to show clinical findings and to illustrate and clarify complex points.

Case discussions are more extemporaneous lectures, placed in the context of concrete simulated patient encounters. The mentor generalizes from the specific issues raised by each encounter to broader theories and principles of practice. These may be scientifically validated or they may be based on the personal experiences of the practitioner. This process is intended to guide the learner in moving from concrete, personal experience (during his or her management of the simulated patient), to generalized knowledge in such a way that the learner "owns" it.

Active experimentation

Active experimentation occurs during patient simulation interactions and activities. Active experimentation is a key aspect of Schön's reflection-in-action but it cannot be viewed in isolation. Rather, it is the learner-initiated step of what may become many learning cycles, both rapid and protracted, nested one with another. We can have learning cycles within learning cycles, generated by a blending of stimuli that play out at different rates. This choreography of stimuli, responses, and feedbacks can be difficult to construct and optimize but, when successful, can result in powerfully engaging and effective learning experiences.

Patient simulations: the learner experiments in several ways, ranging from data-gathering decisions (what history, physical exam, lab or x-ray studies to perform) to counseling and management decisions. The learner's experiments can result in immediate feedback from the mentor and/or the feedback may be seen during subsequent encounters-through changes in clinical findings and patient behaviors-as management strategies play out over time. Further feedback is obtained during the mentor's case discussions, as he or she takes up questions with which the learner has wrestled, but now seen from the perspective of the expert practitioner.

Activities: as described previously, text and graphic elements combine to provide stimulus-response-feedback loops that are nearly all short-loop. However, the activities should complement the active experimentation occurring during patient simulations. For example, an activity leading to better understanding of the HIV life cycle might lead to better understanding of antiretroviral therapy which might, in turn, lead to better management of the simulated patient when she requires antiretrovirals. Or the process might be reversed. Again, cycles within cycles, choreography of ideas and experiences that can, to great extend, be tailored to the needs and desires of the learner.

Example: A Virtual Practicum on HIV/AIDS

It will help to clarify the Virtual Practicum by providing an example of its application. The first technology-based learning program to use the model is now available on CD-ROM [48].13 It deals with primary care of patients with HIV/AIDS and is intended for physicians, nurse practitioners, and physician assistants. The program makes extensive use of multichannel communication via motion video, still and animated computer graphics, audio, and text. The Virtual Practicum is presented to the learner as a "Virtual Mini-fellowship" which one can attend by visiting a "Virtual HIV Clinic." The following describes this realization of the Virtual Practicum and its various elements.

Overall appearance and impact of the program

The Clinic is a highly detailed, computer-generated environment that is intuitive and easy to use. As with many computer games, interaction is done by mouse-clicking on graphic elements or text. Fig. 6 shows the master navigational screen, an interactive graphic depicting the Clinic in overview. Different kinds of learning are keyed to locations within the Clinic. To the left are two examining rooms: Room A on the left leads to more basic encounters with the simulated patient, Laurie Matthews, beginning with

screening and counseling for HIV infection; Room B leads to more advanced encounters with the patient, several years later, when she has begun to develop clinical manifestations of HIV infection. (See below for a detailed description of the patient simulations.) To the right of the examining rooms is the Conference Room where one can meet with the host/mentor for case discussions. At the right end of the Clinic hallway is the Learning Resources room. There one finds patient interviews, activities, and mini-lectures.

Figure 6. Overview navigational screen of the Virtual HIV Clinic: Examining Rooms A and B are to the left, Conference Room is to the right of them, and the Learning Resources Room is at the end of the hall.

While one can travel in the Clinic by mouse-clicking on the master screen, most learners navigate by traveling "in" the Clinic. Figure 7 shows one view of the main hall with Room B just visible to the left, along with the Conference Room; the Learning Resources room is seen at the far end of the hall. (The open door on the right leads to an office whose only active ingredient is a book listing those who participated in development of the program.) Fig. 8 shows the view seen on entering the Learning Resources room. To the left are mini-lectures and activities; to the right are Patient Interviews.

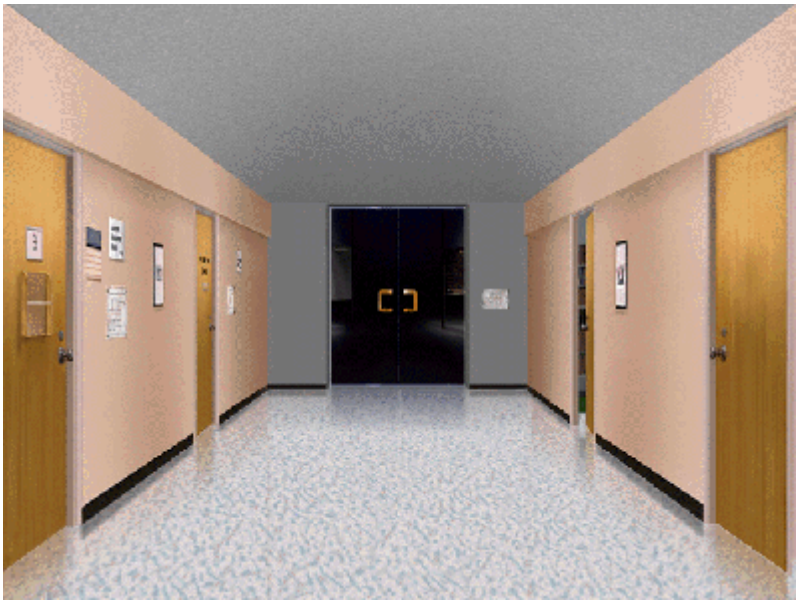

Figure 7. Navigating in the Virtual HIV Clinic: main hallway with examining rooms and conference room to the left; entrance to Learning Resources Room is at the far end.

Figure 8. Navigating the Virtual Clinic: the Learning Resources Room. Mini-lectures and Activities are to the left, Patient Interviews are to the right.

Great attention has been paid to production quality, and the esthetic seeks broadcast-level standards, from the moment that the program begins (music with credit roll that invokes a familiar broadcast "feel") to the moment we first meet our host, to the moment he says goodbye and invites us to return "any time." There is a sense of place that can be visited repeatedly to learn, with a sense of, as Dewey puts it, a "career," that the reality has a past, a present, and is going somewhere.

Perhaps most important, the environment strives to provide an optimal learning environment, one that is

conducive to the flow state as outlined by Csikszentmihalyi. While there are clear goals and structure to the experience, the learner adjusts the learning experiences and their sequence to his or her abilities and tastes. Feedback about how one is performing is clear and timely. Though not formally studied, it has been our experience that many people using the program exhibit signs of having entered a flow state: there is intense concentration, self-consciousness decreases, and time sense is altered (learners lose track of time).

Mentoring and Role-Modeling

The host and mentor for the program is John G. Bartlett, MD. Dr. Bartlett is Chief, Division of Infectious Disease at Johns Hopkins University School of Medicine and Johns Hopkins University Hospital. He is widely regarded by his peers and students as a pioneer in HIV care, a master clinician, and a master teacher. Dr. Bartlett is also an extremely active researcher and has written over 500 papers and nine books in 24 editions.

Dr. Bartlett is a continuing presence in the program, acting as a guide in its use, providing suggestions about the sequence of learning experiences when required. He introduces each encounter with the simulated patient and afterwards offers to discuss key points raised by the encounter. This dialogue was scripted and videotaped using a TelePrompTer.

The case discussions, on the other hand, were recorded extemporaneously. Each encounter with the simulated patient was presented to Dr. Bartlett as it would be during a house-staff conference. Dr. Bartlett then discussed each case as he would with his own residents and fellows. A minimum of editing was used to remove some redundancies and to tighten the timing of the discussions. See further discussion of case presentations, below.

Simulated cases

There are a total of five encounters with the simulated patient, Laurie Matthews. In the first encounter (Room A) we conduct pretest screening and counseling. We learn that she is a 20 year old college student. She desires a "test for AIDS' after getting a letter from a man recently diagnosed with Pneumocystis carinii pneumonia (PCP), and with whom she had had a single sexual encounter. In the second visit we must tell her she is HIV positive (different methods of disclosure result in different reactions), conduct a complete baseline evaluation, conduct patient education and counseling, and make initial treatment decisions. Among several other obvious psychosocial issues attending newly-diagnosed HIV infection, we also learn that Ms. Matthews is engaged to a man who does not yet know her history.

Encounter 3 takes place in Room B, 3-4 years after initial diagnosis. We learn that her disease has suddenly, and unexpectedly, entered a phase of rapid progression, with constitutional symptoms, thrush, declining CD4 count and markedly elevated viral burden. We also learn that she has married her fiancé and wishes to become pregnant. We must conduct an evaluation, make decisions regarding her clinical management, and provide counseling to help her deal with several complex psychosocial issues (coping with advancing disease, initiating multi-drug regimens, compliance, beginning to deal with pregnancy counseling, etc.). The fourth encounter occurs about 7 seven weeks later. We receive a telephone call asking that we see her on an emergent basis, and she presents with (somewhat atypical) PCP (she has been non-compliant regarding her prophylaxis). After we decide to admit her for treatment, she tells us that she is two months pregnant. There are several significant treatment decisions and counseling issues to deal with. The fifth encounter occurs 2 weeks after she gives birth to a daughter; the encounter is taken up with her questions about neonatal transmission, testing, and treatment.

Laurie Matthews is played by a young actress who, given specific points to cover, extemporized most of her lines on camera. The performance has been judged by experts and students alike to feel authentic, and there is an emotional depth to her character that is extraordinary. Her story plays out in installments that give great dramatic impetus to the learning experience. As important, the character introduces the often subtle, semi-tacit elements that are so important when gaining experience with the behavioral/transactional aspects of clinical care.

"Counseling" Interactions

These have been described previously. Reviews by experts and students verify that much can be accomplished using this format, that care in writing text responses and feedbacks can successfully provide guided reflection on complex and subtle issues.

Clinical Decision-Making

This may be the weakest aspect of the program. While the multiple choice format is acceptable and familiar from board examinations, it forces simplification and emphasizes the application of facts and rules at the expense of reflective thinking. The approach is expeditious, but ultimately less-than-satisfying. Other approaches to this were considered and discarded, including free text entry of diagnoses and management steps, and selection from a menu of choices regarding differential, diagnosis, and treatment.

Interviews with Actual Patients

Four individuals are moving and articulate as they tell their stories. Peter Canavan is gay and is a nurse working on an AIDS unit. Billy and Mary Corwin married after meeting in a 12-step program; Mary has a 12 year old daughter who is HIV negative. And Doris Butler is a black woman who learned she was HIV positive when her then-18 month old son was diagnosed with AIDS.

They reveal complex and deep experience with HIV and its psychosocial impact, and the different ways in which individuals cope with illness and loss. Learners select from a menu of topics, then see video segments lasting from 1-3 minutes each.

Finally, there is a special "mini-documentary" that the learner must view before starting the fourth Laurie Matthews encounter. This is introduced by Dr. Bartlett, who excuses himself for interrupting. He delivers a short homily on "adversity, diversity, and reality," emphasizing the transactional nature of HIV care with the comment:

> And then there's reality ... The things we learn in the abstract - as theories and practice guidelines - only go so far. When you add in people - all the wonderful, rich, unpredictable, and sad things they do - then the world, and our ability to influence it, becomes much more uncertain. That's not news to most of us who practice health care. But it helps to be reminded.

This is followed by 8 minutes of absorbing storytelling in which we learn about gay sexuality and courageous humor in the face of devastating illness; about the stresses placed by newly diagnosed HIV disease on family dynamics and sobriety; about the responsibilities of motherhood and their effect on self-care, about the callousness of social service bureaucracies, and about the impact of the death of a child.

Use of Storytelling

As described previously, this permeates the program, in the unfolding of events in the simulated patient and in the four stories of the actual patients. In addition, as with most good lectures, the mini-lectures and case presentations have strong elements of storytelling to them (see below).

Mini-Lectures

These lectures (and the computer based activities) cover a broad range of topics, ranging from U.S. and global epidemiology to basic science to clinical practice. Lectures are given by two practitioners, a physician (Jay Dobkin, MD, Columbia-Presbyterian Medical Center) and a nurse (Joyce Anastasi, RN, PhD, Columbia University School of Nursing) who have specialized in HIV care. Using video, computer animations, and audio with bulleted text, mini-lectures can be viewed in their entirety or by subtopic. This format improves in several aspects on the typical classroom lecture in that the lectures are carefully produced and include graphics and animations that help make complex topics clear. For example, in the lecture on the HIV life cycle the segment on binding, an animation shows how viral membrane glycoproteins interact with the CD4 molecule on T-cells, resulting in macromolecular conformational changes and tethering of the HIV to the white cell. Difficult to understand via words. Easily understood, dramatic and memorable when seen.

Computer-Based Activities

Several different designs were used, including categorization of challenge statements, unscrambling jumbled lists, labeling diagrams, matching challenge statements to images (e.g., of skin and oral findings), an interactive map of the global epidemic, an interactive HIV infection classification table (CDC). These are, in essence, puzzles to be solved and, as with most puzzles, are generally enjoyable and popular. They range from easy to moderately difficult. There is generally good balance between difficulty and learner ability, there is immediate feedback, the goals and rules are clear; hence, conditions are conducive to the learner maintaining a flow state while engaged in these activities.

Case Discussions

As discussed previously, each discussion has been contextualized by the respective encounters with Laurie Matthews. Having worked through a case, it is as though the learner is presenting it for consideration and discussion by Dr. Bartlett. From the learner's point of view, these experiences approximate those of the handful of residents and fellows who may have an opportunity to work personally with this master practitioner. The discussions are to the point, clear, and insightful. His discussions include presentation of research findings, providing practical advice and rules-of-thumb, and storytelling (clinical anecdotes).

A remarkable feature of the discussions is the compassion that Dr. Bartlett exhibits as he discusses our "patient." He ranges from more academic discussions of research findings to worrying about her (later stage) deterioration. He exhibits the inconsistencies of the ideal weighed against reality when, for example, he discusses the dilemma of choosing between antiretroviral therapy that's appropriate for a pregnant woman (and that may harm the fetus she carries) and therapy established as safe for the fetus (but is inadequate for the mother). Having said that we must lay out options and then let the patient chose, he reverses himself: "But we can't just say, 'Let the patient chose.' If your patients are anything like mine, they say, 'What would you do?' And with this patient, I'd probably be aggressive. That decline in CD4 count is shocking ... and if she's got thrush, she's got big-league immunosuppression that's rampant." Teaching at several levels, contextualized by a complex clinical story made clearer by

insightful experience.

This master practitioner brings clarity and realism to such swampy issues in a manner that is unpretentious, incisive, passionate, and compassionate. He is, in sum, an excellent teacher and role model, and the Virtual Practicum provides an opportunity to bring his wisdom and persona to a much larger audience than previously possible.

DISCUSSION

Peter Senge laments the "dilemma of learning through experience" in the complex, real world of practice [49]. Learning by doing, he says, only works when feedback on our decisions is rapid and unambiguous. In the complex, real world, experiencing the consequences of our actions is often removed in time and space. "How, then, can we learn?" Reminiscent of Schön's reflective practicum, he advocates use of computer-generated "microworlds" that recreate essential characteristics of a practice environment and "compress time and space so that it becomes possible to experiment and to learn when the consequences of our decisions are in the future and in distant parts of the organization." The argument applies to clinical education. A comprehensive educational experience is achievable in real life: synchronicity prevails and that master practitioner, that great patient, and the motivated student actually come together. More often than not, however, the conditions for optimal learning do not occur. Typically, clinical experiences are hit-or-miss; teaching is relegated to providers who are neither good educators nor master practitioners; and feedback on decisions made is delayed (or non-existent) and ambiguous.14 A result is wasted time and lost opportunities for learning. Virtual Practicums can be viewed as microworlds providing the necessary conditions for efficient and effective learning. Add to that an increased awareness of a need to encompass more of Boisot's E-space and we have created the conditions for very comprehensive learning. Virtual Practicums, if executed well, can at least supplement, and perhaps greatly improve on, real life clinical education.

However, there are dangers. Virtual Practicums are difficult and costly to design and produce and there is, so far, no community of educational technology practitioners to develop them. Even when extremely well done, their novelty may delay their adoption, since it is difficult to convey the quality of the experiences they provide when "marketing" them. There is also a danger that we will, like Pygmalions, become too deeply enraptured with our Virtual Galateas, blinding us to the fact that the realities created are fabricated, with limitations that may be more significant than we realize and, at best, miseducative.

That all said, we have raised issues that are of general importance to the education of care providers, independent of whether technology is used. Dewey's observation that there is no discipline so severe as the "discipline of experience subjected to the tests of intelligent development and direction" is just as applicable to everyday training in the clinical trenches. But technology allows us in some way to step out of the rushing stream of everyday practice. As educators, we can take time to re-examine our assumptions, to consider more carefully what and how we will teach, to take time really to do it well. As students we can enter a learning environment that can focus our attention, engaging us in experiences that expand not only our factual and theoretical knowledge, but the beliefs, attitudes and habits of thinking that filter and shape our perceptions of the practice world.

Toulmin argues that the approaching millenium and the new Information Age give us occasion to pause and consider the usefulness of Modernism and its models of knowing, that we need to expand our definitions of knowledge to "balance the hope for certainty and clarity in theory with the impossibility of avoiding uncertainty and ambiguity in practice." This amounts to fully utilizing Boisot's E-space, providing opportunities for learning in all its regions. The Virtual Practicum model presented here provides one means for doing so.

Finally, it is clear that technology permeates nearly every aspect of our lives, and the effects are, as Marshall McLuhan has noted, so pervasive as to be insensible. Traditional, data processing views of computing and informatics models of technology-based learning will serve further to embed an unbalanced, overly technical view of clinical practice. Drs. Coles and Williams deplore the gulf that we impose as clinicians-in attitude, demeanor, and language-between us and those who would benefit from our care. There is a danger that computer-based technologies will further distance provider from patient, rendering their transactions even less communicative, less personal, and less effective. As Bruner notes, to pattern one's function on such technologies provides "no measure for dignity," for our patients or for our selves.

Alternative views exist, as we have noted at length. It may be a matter of reframing technology-based learning, viewing it mainly as a means to enhance communication among people rather than among data bases. The philosopher, Richard Rorty, argues that eventually we must come to see others-especially those marginalized by their heredity or behavior-as like ourselves, and to see ourselves as more like them. This used to be, he says, the work of philosophers and clergymen; today it is it is the domain of novelists and film makers [50]. And even, perhaps, those who develop technology-based education.

> What patients say tells us what to think about what hurts them; and what we say tells us what is happening to us-what we are thinking and what may be wrong with us ... Their story, yours, mine-it's what we all carry with us on this trip we take, and we owe it to each other to respect our stories and learn from them.
>
> William Carlos Williams, MD [51]

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FOOTNOTES

1. This reasoning applies to any domain of clinical practice that is transaction-oriented (contrasted with more procedure-oriented practice) and thus highly dependent on the behaviors of patient and provider. It is in these areas of interpersonal communication with a goal of behavioral change that we hope to encounter the well-developed qualities of empathy, intuition, and artistry that mark the master clinician (or master teacher).
2. Browsers, e.g. from Microsoft and Netscape, have so far been distributed at little or no cost to the end-user, even though they have been developed at great cost. This is done largely to promote the development of enormous new markets and lucrative models for Internet-based commerce. Despite its educational limitations, the increasing commercialization of the Internet guarantees the persistence of this model, given its clear alignment with "on demand" advertising, targetable toward buyers whose identities and tastes can be individually identified.
3. One of the better examples of an early effort at providing a simulated patient encounter via the Web can be found at http:// medicus.marshall.edu/medicus.htm. A patient is presented via text

messages and still images and, in the case of chest auscultation, downloaded audio. Learners may take a history using free-text entry, with parsing of entered text that is moderately successful. Exam, studies, diagnosis and treatment are accessed via point and click interaction with menus and images. The sole departure from the paper-based, behaviorist model is the use of audio and limited free-text entry. In all, this is an interesting demonstration of potential, but of marginal substance educationally.

4. Various catalogues of health-related computer-assisted instruction programs are listed on the WWW. One comprehensive source, providing links to other compendia, can be found at http://www.ncl.ac.uk/~nccc/Faculty/med-cal/index.html.
5. This usage borrows from Patricia Churchland's [see ref. 26:3] approach to understanding the mind-brain. "Top down" thinking begins with general principles, is more descriptive and philosophical in nature, and works from there to increasing levels of detail. "Bottom up" thinking starts at as fine a level a detail as is appropriate and starts integrating. Both approaches, she argues, are required when striving to understand how we think and learn. Having said that, this paper does not dwell on Churchland's work and instead focuses on work more appropriate to professional education.
6. Internal, individual knowledge, contrasted with cultural knowledge, including scientific, that has been externalized. Personal knowledge includes that which can be expressed only with difficulty or not at all. See Polanyi [37] and subsequent discussion here.
7. On the other hand, does a musical performance fit into this domain, one that can be distributed via recordings or broadcast? Clearly, as one becomes more sophisticated regarding musical structures, instrumentation, or with individual pieces, one's experience changes, but music can be appreciated without this knowledge. More generally, as artificial realities become more fully realized, involving the senses more and more, this uncoded type of experience may become more easily disseminated.
8. This brings up the possibility that technology-based learning might be used for patient education in the same ways as we are advocating for professional education, i.e., that it provides information that lies in other areas of the E-space than the scientific and technical. Qualitative information that can help the patient understand her values and cope with what will be a major life-style change (taking multiple drugs with likelihood of significant side effects), may assist patient decision-making and improve compliance.
9. And the costs of failure could well be felt beyond our patient if she is non-compliant. With enough such patients we can lose generations of drugs through development and transmission of resistant strains.
10. The E-space is just one aspect of Boisot's view of information, and he uses it in other ways not considered in this paper, e.g., learning in organizations and cultures.
11. As, in fact, can well-written prose, a point emphasized by Robert Coles [33]. But this is not typically the stuff of clinical education, geared to a more scientific mindset.
12. This refers to a genre of immersive, interactive-story games the first of which, arguably, was Myst. More recent examples include Riven (Myst's sequel), A.M.B..E.R., and Titanic: A Journey Into Time. While all of these face the limitations of a form (and underlying technologies) in evolution, they are good examples of the potential for interactive story telling in entertainment and education. See discussion under Reflective Practicum, below.
13. In its next edition the program will provide links to the Internet/Web. It has been designed so that it can be delivered via broadband networks (no CD-ROM required) when these are commonly available.
14. Particularly in ambulatory care, where conditions are less controlled than with hospitalized patients.

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