5736 words, including references and endnotes

Education in an Open Informational World

Schools have historically functioned in a relatively closed informational world. Textbooks and lecturers were often the sole source of academic subject matter. New information media, starting with radio, began gradually to change that, but the change was marginal until the advent of the World Wide Web. We now live in an open informational world in which there are essentially no boundaries constraining the information that may be brought to bear on any topic, question, or activity.[i] College lecturers are liable to find their statements challenged by information retrieved as they speak by students armed with web-enabled mobile devices. At the school level, however, old structures persist, and so information openness finds its place mainly in the traditional research paper or, as it is often called at the elementary level, "project." Such projects may allow students to explore topics of interest drawing on the vast information resources of the web, but they generally play a peripheral role in the main instructional program, which continues in its closed-world ways.

An emerging research trend finds learning scientists, information and media scientists, and management scientists looking more deeply into the implications of the opening up of the informational world, including implications for the design of education. Relevant strands of research have not yet come together into full-fledged interdisciplinary research programs, but connections are forming. The most conspicuous effects of new media arise from their enabling of widespread social interaction. Thus we have Massive Open Online Courses (MOOCs), which exploit the web's ability to deliver rich content to a selected (or self-selected) but widely dispersed audience, and a variety of social networking websites, which provide meeting places for widely dispersed people who wish to interact socially for whatever reason. Both of these are receiving considerable and well-deserved attention from behavioral scientists. With respect to openness of the informational world, arguably the outstanding web-based innovation is *Wikipedia* and the many other wikis inspired by it. Here we have a reference source of a size exceeding by an order of magnitude that of any printed encyclopedia. More remarkable than its size, however, is the fact that its content is user-generated. This has made reliability of information a major concern, and one frequently noted in the education literature (see, for instance, articles, links, and an on-going poll at edutopia.org). The reliability of information presented to students is a perennial problem brought into sharper relief by the new media, but the more important consequence of the opening up of the informational world is that students themselves must begin to exercise judgment about the information they process into knowledge. We will have more to say about this later, in the context of a general expansion in students' collective responsibility for knowledge advancement. Our immediate focus, however, is on issues that involve changes in the form and connectedness of information and that imply changes in the roles of both information providers and information users. The issues are *coherence, sustained work with ideas,* and *complexity.*

Coherent Knowledge: From Text to Hypertext to Subtext

A well-crafted textbook or lecture does not only deliver information. The pieces of information fit together. There is a line of thought, and if you follow it the topic will make sense as a whole and not merely as a collection of facts and ideas. What has been called "considerate text" is a discourse that makes connections between ideas explicit and easy to recognize. MOOCs, because of the extensive work that goes into preparing the lectures and instructional texts, sometimes set new standards of informational coherence. But the more pervasive way of presenting organized information on the web is well represented by *Wikipedia.* A topic that would normally occupy a whole book is introduced in an article that would print out to 20 pages or less but contains numerous links to other articles that cover subtopics or related topics; these also contain hyperlinks and so on. The result is a "hypertext," which if all the pieces were assembled would constitute a text of enormous size but which readers are expected to traverse in limited ways according to their own interests (Bromme & Stahl, 2005). This can lead to problems of distraction and losing the thread, but in any case the job of putting the pieces together into coherent knowledge is left to the reader. There is no overseeing author or integrator doing this for us, as is the case of the well-crafted book or course.

The ability to produce coherent knowledge out of fragmentary information now has a name: *transliteracy,* a term introduced by media analyst Alan Liu.[ii] An older term, *multiliteracy,* refers to ability to use a variety of media for obtaining and communicating information. Transliteracy assumes multiliteracy and adds the essential element of coherence making. Coherence making can be, and for most learners must be a group activity. One might suppose that the "social web" (Semple, 2012), with all its ways of bringing people together, would be a lush ecosystem of people working together to produce meaning, but the opposite is more nearly the case: pages of sentences and pictures held together by little more than the personality of the page owner. In our web browsing we have followed the discussions on a number of news sites where important issues are commented upon. There are occasional insightful or informative comments, but further comments seldom build on these. There may be collaborative belief reinforcement, but that is something quite different from collaborating to make sense of something in need of explanation —almost the polar opposite, in fact.

It is not that human beings are averse to collaborative explanation. After a headline-grabbing event, even strangers at a bus stop may enjoy a minute or two of collaborative theory building. School could be a place where collaborative explanation building enjoys a longer life span, but unfortunately that is not the norm in most classroom discourse. Students take turns expressing loosely related thoughts. Organized debate gives more structure to the discourse, but it tends to divide information along pro-con lines rather than integrating information into more coherent understanding. A recent trend that shows up in both curriculum materials and tests is having students draw conclusions from two or more contrasting documents. Although current efforts tend to be focused on deciding which source to trust rather than on reaching coherent conclusions, they at least represent a start on transliteracy, which we predict will come to be recognized as the most distinctly "21st century" of 21st century skills.[iii]

The *subtext* of a book or other communicative object is content that is not explicit but that may be inferred or intuited. The subtext may or may not be intended by the author, but in any case it is a mental construction by the perceiver. In the case of hypertext, where there may be many authors with diverse intentions, the subtext may be thought of as the main text. It is the fabric of meanings that holds the pieces together, and of course it varies from reader to reader, depending on each reader's intentions and path through the hypertext maze. In the case of conventionally authored literary works, explicating the subtext represents a secondary sort of literary creation, practiced by literary critics. It is presumably a learnable craft and one that can be extended beyond literary texts to informative and ideational texts. The coherence-making aspect of transliteracy could be defined as the process of constructing a subtext out of a hypertext.

Sustained Work with Ideas

Knowledge work is work with ideas. Sometimes the ideas are embodied in tools, artifacts, or material actions and so the work has an observable physical character, but insofar as it is knowledge work it has a conceptual layer where the things operated upon—generated, categorized, combined, transformed, and so on—are the immaterial entities collectively known as ideas. Ideas have started coming into their own in education. Curriculum standards and guidelines now call for explicit attention to "big ideas," whereas previously ideas were hidden behind specifications of topics and procedures. Ability to make difficult ideas accessible to students—by means of definitions, demonstrations, illuminating examples, and so forth—has been a long-recognized mark of good teaching, figuring prominently in student ratings of course instructors. With the opening up of the informational world, however, the teacher's task becomes less straightforward. A large body of research on students' misconceptions had already shown that "teaching for understanding" often failed. Now, with a diversity of information resources of varying accuracy and clarity, and with a diversity of ideas to be grasped rather than a limited set of ideas selected in part because of their teachability, teaching for understanding becomes even more problematic. More responsibility for such idea work as defining, identifying positive and negative instances, relating ideas to one another and to larger contexts, and producing explanations falls to the learners. Education needs to prepare students for this.

Striking the right balance between understanding and fact learning has always been a problem for curriculum designers. However, the greatly increased accessibility of factual information has led to technobabble about "just-in-time" knowledge and about teaching internet search skills instead of facts. This ignores the body of research from the 1970s showing the strong effects of prior knowledge on comprehension and learning (Schallert, 1982). While there may be "just-in-time" information, there is no such thing as "just-in-time" understanding.

Research on conceptual understanding has shown that success often depends on students' *trying* to understand (Vosniadou, 2003). The need for intentionality in understanding may seem self-evident, but in fact a large part of our understanding of the world is picked up effortlessly in the course of pursuing goals other than understanding. Understanding becomes problematic when what needs to be understood is complex. Given normal experience with countable quantities, young children will acquire a sufficient understanding of whole numbers, cardinality, and addition and subtraction. However, when it comes to algorithms for adding and subtracting multi-digit numbers, understanding is not a natural result of working with such quantities. Educators have tried to craft understanding by having children do computations using blocks of one, ten, and a hundred sections, so that they would need to trade a tens block for ten ones, or vice-versa, and so on. In an experiment where students worked the same problems, alternating between using blocks and using the numerical algorithms they were taught, Omanson and Resnick found that many children learned to carry out both kinds of operations but never saw the connection—never caught on that the block trading and the symbolic regrouping were the same mathematical operation. Some did grasp it, however, and when interviewed they revealed that they had recognized there ought to be a connection and tried to figure out what it was. The same phenomenon appeared in college physics. Provided with worked examples, students would apply the examples to solving textbook physics problems but most would not learn the physics the examples were intended to convey. Those who did grasp the physical principles engaged in what Chi and van Lehn called "self-explanation"—trying to explain why the worked examples worked. Along with research showing the pervasiveness of instruction-resistant misconceptions, these studies indicate that even in the relatively closed world of conventional curricula students need to do serious work with ideas and not merely receive them passively and carry out prescribed tasks in the least effortful manner possible. The opening up of the information world has heightened this imperative both by distributing the need for cognitive effort over a wider range of things to be understood, and by increasing the importance of understanding as compared to factual memory.

Complexity: Love it or Leave it

That tomorrow's citizens will have to deal with a heightened level of complexity is already a platitude. It draws approving nods but little action. Meanwhile, today's citizens are flocking to ideologies that offer them monumentally simplified representations of the world. For instance, the vast majority of Americans reject the idea of Darwinian evolution (they either reject species evolution altogether or else believe it has to have been intelligently guided). This suggests that the concept of natural selection is just too complex for many people to grasp. The truth is, however, that the world is too complex for any of us to deal with in the systematically rational way that we can deal with more constrained artificial problems such as sudoku puzzles. With some finality, Herbert Simon (1991) declared:

> Whatever their computational powers, present or future computers are no match for the complexity of the real world. They (and we) are forever condemned to carrying out our reasoning with highly simplified models of tiny parts of the entire reality that confronts us.

Two factors can cause complexity to get out of hand: combinatorial explosion (exponential increase in the number of possibilities as the train of decisions gets longer) and working memory limitations (the fact that humans can hold only a small number of items in mind to be acted upon coordinately). Computers are great at generating combinations but the number can quickly exceed the ability of either human or artificial agents to evaluate them. Computer search can go a long way toward making up for deficiencies in long-term memory, but when it comes to helping people make up for working memory limitations, available computer tools are not much improvement over a pencil and a sheet of paper. That may well change as computers keep getting smarter, but for the present we are stuck with using simplified models that are hopefully not so simplified that they miss the essence of the problem we are trying to deal with.

All things considered, most people do fairly well dealing with complexity at a practical level and some even thrive on it. However, if complexity is getting worse and more pervasive, as Homer-Dixon (2000) has persuasively argued, we need to find ways of doing better and helping more people cope successfully with it rather than joining a cult or a reactionary political movement. Complexity has its own body of theory, best known to educators as dynamic systems theory. One trend already beginning to appear in schools is explicit teaching of systems concepts or at least familiarizing students with them by means of simulations. A different though related kind of effort is teaching "systems thinking"—which unfortunately is about as ill-defined as a curriculum objective can possibly be. Skill objectives are now appearing that call for students being able to "use systems thinking," but often the only definite objective is using systems concepts to explain things. Every up-to-date school subject that has theoretical content will require this, and so treating it as a separate objective is questionable. The real challenge is using systems ideas in solving complex real-world problems. Here complexity science has scant offerings, but is clearly the direction to go in seeking what Homer-Dixon calls "ingenuity" and defines as "*ideas* applied to solve practical social and technical problems."

In order to give substance to the goal of promoting systems thinking, more research is needed on how successful thinkers actually deal with complex problems. A good start was research in the 1980s on mental models and analogies. As carried forward by Philip Johnson-Laird (1983, 2009) and others, the upshot is that human beings do not function like logic machines, even imperfect ones, but instead harness a variety of resources not routinely available to computers and which, though makeshift and imprecise, do manage to circumvent combinatorial explosion and working memory limitations. These resources include unconscious inference, imagery, affective responses, mental modeling, and analogy. For any complex situation, a virtually unlimited number of simplified decision or explanatory models could be generated. We of course do not simplify reality in such a crank-it-out way. Instead we say things like "The essence of this problem (or situation, concept, plan, et cetera) is…." A "sense of essence," as Douglas Hofstadter has said, is the essence of sense. It is what enables us to recognize good models and productive analogies from among the vast number of possibilities that equally fit formal (logical) requirements. It is an important edge we have over thinking machines and is one that education is still a long way from exploiting.

Beyond 21st Century Skills

The misfit that arises from trying to insert new ideas into predetermined frameworks is nowhere more evident than in the widely heralded "21st century skills" movement (Johnson, 2009). Terms like "knowledge creation," "knowledge society," and "innovation-driven" signal a new set of imperatives that education is expected to address in some fashion. The way education authorities around the world customarily address such challenges is by adding new elements to existing categories: new skills entered into the objectives list, new subjects into the subjects list, new tests into the assessments list, new teacher workshops into the professional services list. This is essentially the same approach that was taken in back-to-basics movements such as No Child Left Behind: define objectives, institute tests to drive schools to pursue those objectives, and then offer guidance in how to teach to them.

No Child Left Behind and similar approaches to educational improvement have had questionable results and have raised doubts about the whole notion of using tests to drive instruction (Ravitch, 2011). However, there is this much to be said for "back to basics": Unlike "21st century skills," basic literacy and numeracy are already well established as teachable and testable skills, there exists a body of "best practice," which, however imperfect, is demonstrably more effective than no teaching at all, and it is reasonable to expect that just by trying harder some gains can be achieved. Above all, it is reasonable to assume that gains in literacy and numeracy achieved within the school context will have value in modern life outside the school. None of this is true of most "21st century skills." They are a mixed bag. Computer skills are definable, testable, and teachable and so they can readily fit within existing curriculum frameworks, but there are questions of obsolescence and how much instruction is really necessary--questions that do not apply so obviously to the traditional academic skills. There are tests of critical thinking and creativity, and these have some predictive validity, but it is not clear whether these are skills at all, as distinct from psychological traits, mindsets, or habits. Training and other learning activities can produce gains in test scores, but there is little or no evidence that such gains have any value outside the immediate learning context. (For instance, a common form of creativity test calls for rapidly listing as many uses as possible for a familiar object such as a coat hanger. Thinking of novel uses may have real-world value, but in the real world the *number* of such ideas and the speed of producing them seldom count as measures of one's value to a project or organization. Problem solving is identified as a supposedly generic 21st century skill, but tests of it are limited to specific content areas, such as arithmetic problems, and the evidence indicates little or no transfer between acquired problem solving skill in one area and another. Then there are oral communication skills, which, being based on more general language skills, fit comfortably within existing curriculum frameworks; but there is nothing particularly 21st century about oral language skill and one could point to past times when it was probably more important than at present.

One of the most widely publicized projects to promote 21st Century Skills is "Assessment and Teaching of 21st Century Skills," funded by three major technology companies (ATC21S.org). The actual creative work of the project has concentrated on test development, with the teaching part left largely to affiliated groups. Thus its framework is essentially the familiar one of test-driven reform. However, in the initial formulation of objectives, a project team, comprising learning scientists and tasked with examining learning environments, proposed a complementary approach (Scardamalia, Bransford, Kozma, & Quellmalz, 2011). They identified the test-driven reform strategy as "working backward"—a term that has a positive connotation in the cognitive literature on problem solving. Start with objectives, work backward from them to assessments of success in attaining the objectives, and then work backward from the tests to develop learning activities that produce gains in the assessments. The learning scientists argued that, although working backward can be effective for already well-understood objectives, the dynamic nature of contemporary knowledge societies calls for an approach that is open to emergent objectives—objectives that arise out of systemic interactions between societal changes and human capabilities and that need to be *discovered* rather than determined in a top-down manner. Such discovery, in turn, depends on educational environments in which new competencies (or deficiencies) have an opportunity to appear. That would mean educational environments that approximate the conditions of the surrounding open, innovation-driven, knowledge society.

The emerging trend that will take education beyond test-driven curricula and such test-driven offshoots as the 21st century skills movement is grounded in recognition of self-organization and its ubiquity in learning and human development. Systemic evolutionary processes dominate education at all levels, with settling on local minima being a common phenomenon. Modern education administrators are well aware of this as an explanation of why, for instance, the "mile wide, inch deep curriculum" persists despite a dearth of advocates. "Systemic change" has been the watchword of school reform for a quarter century or more. The elementary school classroom is a self-organizing social unit in which the teacher plays an important but not all-powerful role. The classroom community may, for instance, self-organize around minimizing the cognitive and time demands of schoolwork in response to an excessively task-oriented teacher. At the individual level there are cognitive strategies such as "knowledge-telling" and "copy-delete" that are efficient for the performance of school tasks but defeat the educational purpose of the tasks (Brown & Day, 1983; Scardamalia, Bereiter, & Lamon, 1994). Students do not design these strategies, are not even aware of them, but they evolve through the interaction of task demands, internal constraints, and goal-directed behavior.

We cannot leave this topic without noting the currently hot topic of "brain fitness." Discussions of 21st century skills are sometimes muddied by confusion with brain fitness exercises, which are much in the news as well as being intensely commercialized. Brain exercises deal with basic cognitive functions such as short-term memory capacity, attentional control, and response speed. These are at a much more basic level than such favorites of the 21st century skills movement as critical thinking, problem solving, and creativity. Brain fitness is not about strategy learning and improving skills through practice, it is about improving brain chemistry and sprouting more dendrites in certain areas of the cerebral cortex. The important point as far as education is concerned is that whatever benefits research may attribute to brain exercises are irrelevant to decisions about 21st century skills, except perhaps in pointing to an *alternative* to thinking skills instruction.

The Classroom as a Knowledge Building Community

Sociocultural theory, inspired by Vygotsky and with a nod to Dewey, began to take hold in education in the 1980s and evolved into ideas such as "situated cognition" and "communities of practice." The result is that learning research has taken a decided turn toward treating learning as a group phenomenon while educational practice, under the influence of tests that always index individual performance, has moved increasingly toward focus on the individual learner. This anomaly is brought out dramatically in the case of collaboration, which is increasingly recognized in the world at large as essential for progress in any knowledge-based activity. Acknowledging this, PISA, the leading international achievement test, will reportedly contain a test of collaborative problem solving ability in its 2015 edition. However, true to the norms of achievement testing, scores are to be awarded on an individual basis and so examinees will not interact with real people but with computational avatars. Dating from two decades earlier, computer supported collaborative learning, abbreviated to "CSCL," has been a thriving research and development area within the learning sciences, and "collaborative learning" has become a byword right up there with "learner centered." Yet shifting classroom practice toward something more closely resembling real-world collaborative knowledge work remains more a vision than a reality. School-age students are capable of working together toward a common knowledge objective such as producing an explanation, a solution to a significant problem, a plan, or an invention, but learning activities often function as an obstruction rather than a means to that end.

The obvious solution is to focus collaborative schoolwork on the "big ideas" already gaining a favored place in the curriculum: producing explanations of those ideas, building them into larger conceptual structures (e.g., theories), finding uses for them, solving problems such as perceived inconsistencies or gaps. An approach that has this as its explicit focus is Knowledge Building, one of five foundational approaches recognized in the 2006 *Cambridge Handbook of the Learning Sciences,* and defined as "the production and continual improvement of ideas of value to a community" (Scardamalia & Bereiter, 2003). It is essentially the same idea as "knowledge creation," as that term is used in design sciences, knowledge-creating organizations, and knowledge management circles. A number of "constructivist" educational approaches engage students in creative knowledge work and problem solving but with less emphasis on what in Knowledge Building is the *sine qua non*: students taking collective responsibility for idea development and improvement. An important part of that collective responsibility is bringing relevant new information into the knowledge-building process, and this includes responsibility for information quality and reliability—both quality and reliability of the source and of the students' own rendition of the information as they contribute it to a knowledge-creating effort. We earlier noted educators' concern with information reliability. There is a growing body of research on students' ability to make such reliability judgments (Goldman & Scardamalia, 2013). However, like many other such concerns in education, it is not only a matter of students' ability but also a matter of their motivation to do the necessary intellectual work. Knowledge Building is designed to provide a context in which students have a reason to read and write carefully and critically. The classroom becomes a knowledge workshop, in which students collaborate to build something of value to themselves and thus have reason to care about the quality of the materials and the way they are used.

In order to change classrooms and other educational settings into knowledge building communities, systemic change is required not just at the level of curriculum standards and learning activities but at the level of knowledge building discourse. "Building Cultural Capacity for Innovation" (BCCI) http://ikit.org/bcci/ is an international initiative to introduce such systemic change in all kinds of educational contexts at all levels in more than 20 nations. BCCI aims at social and technological supports for sustained creative work with important ideas. It makes use of sophisticated assessment tools, but instead of using them to drive instruction it uses them to provide feedback that allows students to see their ideas in relation to disciplinary knowledge and empowers students in their knowledge-building efforts. Committed to open source, BCCI partners will develop and continually improve technology and pedagogical designs for education adapted to our innovation-driven open informational world.

Conclusion

Any speculation about emerging trends in the process of education must reckon with the still largely unknown effects of social media. Young people are demonstrating a massive shift away from television toward spending their leisure (and sometimes working) hours on the likes of Facebook and Twitter and internet games. This means more than a shift in form of entertainment. It means a shift from being spectators to being participants. One measured educational effect is a decline in achievement test scores associated with amount of time spent with social media (Kirschner & Karpinsi, 2010). The evidence being correlational, it must be considered only suggestive of a causal connection, but a causal connection is highly plausible. Watching television while doing homework may diminish attention to the latter, but dividing attention between homework and online social activity seems closer to being impossible. Effects on *how* students process information, on what gets attention and what gets filtered out, on students' worldviews, mindsets, and general orientations to knowledge—these could have profound educational implications, but so far little is known and speculations tend to be either airily optimistic or part of the usual moaning about the decline of civilization. When we were addressing one group of college educators with the concerns expressed here about coherence, one technology specialist responded that coherence is still being achieved but it is now taking shape in cyberspace. Concept maps and other types of visualization are ways of representing coherent knowledge, but the coherence is still in the mind of the observer and the visualizations are best viewed as aids to transliterate comprehension.

One documented change with implications for education in an open informational world is a shift from seeking authoritative information to seeking information from peers. There are now websites dedicated to such information exchange. It is easy to find examples on these sites of people exchanging ignorance rather than knowledge. However, much of the information people gather from peers is matters of judgment rather than fact. It seems important today more than ever to promote student engagement with what Joseph Schwab called "disciplined knowledge" and characterized as "a massive potential of capacities to do, to make, to alter, and to modify." A glance at Google appearances of this term suggests that the most common references to "disciplined knowledge" are disparaging. It is the dry stuff of textbooks, a prime source of boredom among students. But disciplined knowledge is, or ought to be, the home of big and growing ideas and a springboard to innovation. In its *21st Century Learning* manifesto, the Organization for Economic Co-operation and Development (2008) asserted: "Educated workers need a conceptual understanding of complex concepts, and the ability to work with them creatively to generate new ideas, new theories, new products, and new knowledge…. They need to learn integrated and usable knowledge, rather than the sets of compartmentalised and de-contextualised facts." In this view, innovativeness and disciplinary knowledge are partners, but getting these partners together in the same educational process is not common. If creative work with ideas enters the curriculum at all it tends to be through activities such as science fair projects, design challenges, and entrepreneurial ventures that are separate from the main curriculum and often authentically engaging for only a minority of students. The synthesis that Knowledge Building aims to achieve consists of making knowledge creation the principal way of engaging with disciplined knowledge--the way that produced that disciplined knowledge in the first place and continues to advance it.

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[i] Curtis Bonk (2009) has investigated the many aspects of what he terms the "open educational world," in which "Anyone can now learn anything from anyone at anytime" (p. 16). The opening up of the informational world may be seen as one aspect of this openness in education, but it is also a phenomenon affecting all areas of knowledge-based work.

[ii] Consistent with their focus on implications of new information media, transliteracy researchers have shown a distinct preference for non-print means of disseminating their work. Currently the best way to gain access is through the Transliteracies Project website at transliteracies.english.ucsb.edu.

[iii] As transliteracy has begun to gain recognition (more in library science than in education at present) most attention has been given to its multimedia aspects. This is unfortunate because these have already been receiving ample attention (including theoretical attention) for decades under the rubric of "multiliteracy" or "multimedia learning," whereas education apparently lacks a theory of how transliterate coherence building is even possible.