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Education as Social Construction:
Contributions to Theory, Research and Practice

Thalia Dragonas, Kenneth J. Gergen, Sheila McNamee, Eleftheria Tseliou
Editors

A Taos Institute Publication

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Kenneth J. Gergen
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Assessment and Pedagogy in the Era of Machine-Mediated Learning

Bill Cope and Mary Kalantzis

Technology is a social construction in the obvious sense that it is the product of human artifice. However, once we get the technology into our hands, we are often inclined to forget its invented-ness. Instead we experience the intrinsic 'object-ness' of technologies. We have things that we use, need and perhaps come to like. These things come to transform our lives. They seem to have a determining life of their own. In this way we reify technologies as if it is the things themselves that change our lives—which of course, in an obvious sense, they do. In our lives with technology, however, there is more scope for human agency than the immediate impressions of thing-ness lead us to believe.

In this chapter, we want to explore the role of technologies in learning, and in particular, technologies that can be used to assess for evidence-of-learning. Our focus is what Alan Turing called 'computing machinery', to highlight the thing-ness attributed to machines. To be specific, we want to examine the ways in which and the extent to which computing machines can provide an artificial complement to the intelligence of teachers and students in the business of pedagogy and assessment. To the extent that we limit our focus on the thing-ness of machine-mediated learning, we can observe the ways in which the application of technologies change educational practices.

However, taking a perspective in which technologies and their application are only ever a human construction, tangible objects that are the product of human designs and designed to have human effects, the formulation becomes somewhat different. Technologies of various kinds can be created to serve various agendas, and then, in their application, they can be used in quite different ways, some obvious, some based our imagination of alternative uses and better human lives. Technologies do not (simply) determine the patterns of our action. They offer us affordances, or a range of different modes of action.

Moreover, as we will set out to show, the machines can be set to very different kinds of work. To the extent that computing machines are software-driven, they can structure human action in very different ways—collecting different kinds of data, proving learners and their teachers with very different kinds of feedback, extending their human intelligence in very different ways to very different ends.

In order to make our case about the range of social constructions and human possibilities in machine-mediated learning and software directed patterns of interaction with these machines, we're going to start by describing the objects that constitute educational technologies. Then we analyze the range of affordances offered by these technologies as evidenced in a range of very different kinds of application to the processes of pedagogy and assessment. Some uses apply and intensify traditional pedagogies and assessment modes; other uses—sometimes using the same foundational technologies—open out new and transformative modes of pedagogy and assessment.

A Very Short History of Technologies in Education

In a 1954 article published in the *Harvard Educational Review,* B.F. Skinner foreshadowed the application of 'special techniques ... designed to arrange what are called "contingencies of reinforcement" ... either mechanically or electrically. An inexpensive device,' Skinner announced '... has already been constructed' (Skinner, 1954 (1960): 99, 109-110). The teaching machine that Skinner was referring to was not yet 'electrical'. It still used analogue technologies similar to a mechanical cash register or calculator. Some assumptions about pedagogy and assessment were written deeply into the machine. A lone child is presented material, a question is posed by the machine as substitute teacher, the student gives an answer, and then she is judged right or wrong. If right, she can move on; if wrong she must answer again. This is behaviorism epitomized, and also mechanized.

FIG. I. A recent model of a teaching machine for the lower grades. The machine operates on the principles described in the accompanying article. Material is presented in a window with a few letters or figures missing. The pupil moves sliders which cause letters or figures to appear. When an answer has been composed, the pupil turns a crank. If the answer was right, a new frame of material moves into the window and the sliders return to their home position. If the answer was wrong, the sliders return but the frame remains and must be completed again. (This is a later version of the device described in Skinner's 1954 paper.)

Source: (Skinner, 1954 (1960))

The technologies that Skinner called ‘electrical’, or ‘computing machines’ in Turing’s terminology, were first applied to learning with the creation of the PLATO (Programmed Logic for Automatic Teaching Operations) learning system at the University of Illinois, starting in 1959. The University had been designing and testing the ILLIAC mainframe computers since 1951, the PLATO system on ILLIAC was the first time a computer had been used for an educational application. ‘Application’, however, is a misnomer because the computer could not simply be applied to education. It had to be (re)designed to align with the social construction that is education. The following now foundational technologies were invented to serve this social end. This was the first time a computer was used as a mediator in human-to-human messaging, the first time they had been used as a conduit for written language. This was the first time that visual displays were needed, so the plasma screen was invented. To represent visuals, a graphics application generator was created. Synthetic sound was created. This was where the first simulations, games, synthesized music and online chat were created.

The PLATO story is apocryphal. The ‘objects’ that are technology were constituted by social need, and education was at the center of their initial design. The moral of the story for educators it to take the lead in technology development, and not to simply apply hand-me-down technologies. We can and should be social constructors, demanding that technology follows.

Through the decades following, PLATO’s foundational technologies have been transferred into the everyday lives of billions of people, initially in the form of personal computers. These were subsequently connected up via the wires of the internet, and then wirelessly via a panoply of ‘smart’, mobile devices. These have changed our lives, and are changing education.

Fast forward now to the twenty-first century. If technology-mediated learning is by no means new, developments of the past half-decade stand out: deep network integration of digital learning environments through ‘cloud computing’, and the generation of ‘big data’ (Mayer-Schönberger & Cukier, 2013; Podesta, Pritzker, Moniz, Holdern, & Zients, 2014) that can be connected and analyzed across different systems. The effects of these developments are destined to intensify over the next few years.

Once again, the significance of ‘cloud computing’ (Erl, Puttini, & Mahmood, 2013) is social more than it is technological. We characterize this as a shift from personal computing to interpersonal computing. From the 1980s, personal computing provided mass, domestic and workplace access to small, relatively inexpensive computers. From the 1990s, the internet connected these for the purposes of communications and information access. Cloud computing moves storage and data processing off the personal computing device and into networked server farms. In the era of personal computing, data was effectively lost to anything other than individual access in a messy, ad hoc cacophony of files, folders, and downloaded emails. In the era of interpersonal computing, the social relations of information and communication can be systematically and consistently ordered.

This opens out the social phenomenon that is popularly characterized as ‘Web 2.0’ (O'Reilly, 2005). It also supports massively integrated social media. This turns data that was before this socially inscrutable, into socially scrutable data. By interacting with friends using social media such as Facebook or Twitter, one is entering these providers’ data model, thereby making an unpaid contribution to that provider’s massive and highly valuable, social intelligence. By storing your data in webmail or web word processors, Google can know things about you that were impossible to know when you had your files on a personal computer and downloaded your emails, and this ‘social knowing’ has made it into a fabulously valuable advertising business.

More and more learning also happens in the cloud, not in separately installed programs or work files on personal computing devices. In education this includes: delivery of content through learning management systems; discussions in web forums and social media activity streams; web writing spaces and work portfolios; affect and behavior monitoring systems; games and simulations; formative and summative assessments; and student information systems that include a wide variety of data, from demographics to grades. How do we harness this social intelligence in the service of pedagogy and assessment?

‘Big Data’ in Education

First, a definition: in education, ‘big data’ are: 1) the purposeful or incidental recording of interactions in digitally-mediated, network-interconnected learning environments; 2) the large, varied, immediately available and persistent datasets that are generated; and 3) the analysis and presentation of the data generated for the purposes of learner and teacher feedback, institutional accountability, educational software design, learning resource development, and educational research (Cope & Kalantzis, 2015a).

Since the middle of the first decade of the 2000s, two new subfields in education have begun to emerge: ‘educational data mining’ and ‘learning analytics’ (Martin & Sherin, 2013; Siemens, 2013). The principal focus of educational data mining is to determine patterns in large and noisy datasets, such as incidentally recorded data (e.g. log files, keystrokes), unstructured data (e.g., text files, discussion threads), and complex and varied, but complementary data sources (e.g., different environments, technologies and data models) (R. S. J. d. Baker & Siemens, 2014; Castro, Vellido, Nebot, & Mugica, 2007; Siemens & Baker, 2013). Although there is considerable overlap between the fields, the focus of learning analytics is to interpret data in environments where analytics have been ‘designed-in’, such as intelligent tutors, adaptive quizzes/assessments, peer review and other data collection points that explicitly measure learning (Bienkowski, Feng, & Means, 2012; Knight, Shum, & Littleton, 2013; Mislevy, Behrens, DiCerbo, & Levy, 2012; Siemens & Baker, 2013; West, 2012).

Leaders in the emerging fields of educational data mining and learning analytics speak clearly to what they consider to be a paradigm change. Bienkowski and colleagues point out that "educational data mining and learning analytics have the potential to make visible data that have heretofore gone unseen, unnoticed, and therefore unactionable" (Bienkowski et al., 2012). West directs our attention to "'real-time' assessment [with its] ... potential for improved research, evaluation, and accountability through data mining, data analytics, and web dashboards (West, 2012). Behrens and DiCerbo argue that "technology allows us to expand our thinking about evidence. Digital systems allow us to capture stream or trace data from students' interactions. This data has the potential to provide insight into the processes that students use to arrive at the final product (traditionally the only graded portion). ... As the activities, and contexts of our activities, become increasingly digital, the need for separate assessment activities should be brought increasingly into question" (Behrens & DiCerbo, 2013). Chung traces the consequences for education in these terms: "Technology-based tasks can be instrumented to record fine-grained observations about what students do in the task as well as capture the context surrounding the behavior. Advances in how such data are conceptualized, in storing and accessing large amounts of data ('big data'), and in the availability of analysis techniques that provide the capability to discover patterns from big data are spurring innovative uses for assessment and instructional purposes. One significant implication of the higher resolving power of technology-based measurement is its use to improve learning via individualized instruction" (Chung, 2013). DiCerbo and Behrens conclude: "We believe the ability to capture data from everyday formal and informal learning activity should fundamentally change how we think about education. Technology now allows us to capture fine-grained data about what individuals do as they interact with their environments, producing an 'ocean' of data that, if used correctly, can give us a new view of how learners progress in acquiring knowledge, skills, and attributes" (DiCerbo & Behrens, 2014). Pea also foreshadows a shift in pedagogy and assessment, facilitating increasing personalization and individualization of learning (Pea, 2014).

But in making these assertions, have we allowed the apparent thing-ness of technology get the better of us? The technology will not make these changes. The social agendas that produced the technologies will be the agents of change. These social agendas are various, and deeply contested.

Education in Two Social Constructions

Schooling as we know it—mass, institutionalized compulsory education for children, and post-compulsory formal education in schools, colleges and universities—can take a variety of forms. In our book, *New Learning* (Kalantzis & Cope, 2012), we described and analyzed three pedagogical paradigms: didactic, authentic, and transformative. For the purposes of this chapter, we are going to speak of just two paradigmatic forms of education, one which we will here call ‘didactic/mimetic’ and the other ‘reflexive/ergative’. With the second, we hope to recapture what we had previously called transformative pedagogy, while acknowledging its roots in authentic pedagogy. With this renaming, we want to call out some salient features relevant to the assessment of evidence-of-learning.

Our purpose in characterizing these two forms is to illustrate the quite different ways in which education can be socially constructed. These social constructions, moreover, are frequently at odds with each other. They are deeply contested, and the roots of this contest are centuries long. They represent some of the great debates in education. Then, when it comes to the application of educational technologies to learning and assessment in the twenty-first century universe of cloud computing, the social web and ‘big data’, the two frames of reference are put to work in completely different ways. This supports our claim that technology does not in itself produce effects. Rather, it can be put to very different uses depending upon your social construction of education. Technology offers affordances. It does not in itself determine social agendas, actions or outcomes. These remain as wide open as ever.

Of course, alternatives are never so simple as a quintessential two. We simply use this is an heuristic, as a way to classify and interpret the different social constructions and educational applications of technologies in learning and assessment. In the messiness of reality, we find shades of one merging into shades of the other. Nor is either of the two necessarily older/newer, ethically good/bad, or more/less effective in the achievement of educational purposes. In the first instance, all we want to suggest is that social constructions imbricate technologies, and these imbrications have effects.

Here, in brief are our two paradigms:

Didactic/Mimetic Pedagogy

The traditional classroom is an information and communications technology. Here is that classroom: we find ourselves in a space confined by four walls, just large enough for one-to-many oral exegesis by a teacher without voice amplification. The desks or lecture theatre seats are in rows, arranged so the eyes of learners are directed to the teacher and not each other. The teacher faces the opposite way, the only person in the room able to observe every learner within a single field of vision. They have the blackboard for writing. These are the spatial aspects of the technology. There are also necessarily temporal aspects: logistically, the same class must be offered in the same timeframe. There is an essential synchronicity, represented by the cells of the timetable and the disciplinary practice of punctuality. This is a peculiar technology, quite different from others in the world, and immediately recognizable as formal education.

This classroom is also a discursive regime. St Benedict is credited as the founder of western monasticism, precursor to modern universities of schools. His ‘rule’ was that it ‘belongeth to the master to speak and to teach; it becometh the disciple to be silent and to listen' (St Benedict, c.530 (1949)). To the limited extent that students have an opportunity to speak, there is a gestural routine of a 'hands-up', if and when a student is asked to speak or is requested by the teacher to speak. The scope for students' speaking in this techno-social frame is limited pragmatically by the time delimitations of a lesson in which it would be wasteful for everyone to speak to everything. So, typical teacher talk was directed by their peculiar script—an initiating question ('what?', 'how?', 'why?' ...) anticipating a correct answer; followed by a response (in which a student selected by the teacher attempts to align their response to what the teacher was expecting); followed by an evaluation ('that's right', 'that's good', 'no, think again', 'can someone else suggest ...'). As the selected student stands as a proxy for the rest of the class, there can usually only be one answer. This is classical classroom discourse (Cazden, 2001).

A few things change with twenty-first century educational technologies, but not as much as it would first seem. For the 'flipped classroom' (Bishop & Verleger, 2013) the teacher records a video of their lecture and distributes it online. It is possible to view the lecture at any time and in any place, but the student remains in the same discursive relation to the teacher and knowledge as originally prescribed by St Benedict. Even putting up one's hand to ask a question is eliminated. The electronic whiteboard may be interactive and bring into the classroom the endless knowledge resources of the internet, but all students' eyes still need to be directed to the board and its master, the teacher.

Then we have the technology of the textbook. The pedagogies of the Academy of Ancient Athens were dialogical and dialectical. After the invention of the printing press, the sixteenth century textbooks invented by the prolific Petrus Ramus, professor at the University of Paris, were designed in a completely different way (Ong, 1958). Page by page, chapter by chapter, the students followed the professor—all on the same page as the same time. The textbook resigned knowledge (Euclid's geometry, for instance) in a pedagogical order, in digestible synoptic chunks, from the knowledge components deemed simpler and foundational by the textbook writer, to components deemed more difficult and logically consequent. It was laid out in a spatial array, a series of strictly sequential chapters, sections and subsections. Textbooks referred to an outside world, resynthesizing (summarizing, simplifying putting that world in a pedagogical sequence) any and every conceivable aspect of that world. Their reference point was always exophoric—for instance, the geological, poetical, or enumerable things in an externally-referable world. Students read this peculiar textual genre; they may have annotated the book or made notes as a mnemonic; and they took tests at the end to demonstrate what they had remembered. E-textbooks reproduce this textbook form, with a few textually and pedagogically trivial differences—the pictures can move, and the quiz at the end of the chapter is a little smarter than the questions in a printed book with the answers printed upside-down in the back of the book. But the students are still positioned as knowledge consumers—absorbers of information to be remembered, routines to be replicated, or definitions to be applied.

Whether the technologies are those of the twenty-first century or those of the classroom in earlier modernity, the pedagogical mode remains fundamentally the same. They are didactic in the sense that the teacher and textbook tell while the student listens. They are mimetic in the sense that the student offers evidence of learning by demonstrating that they have copied the received knowledge as their own, that they have remembered what they have been told.

The unit of measurement of learning is the individual—what a lone person has managed to remember. It is retrospective, looking back from the end of a learning experience to see how much of the prescribed knowledge has been absorbed. In the era of technology-mediated learning, we might intensify the experience of individualization and mechanize the processes of memorization with personalized or adaptive learning. However, we have always been able to do a version of that by allowing some students to progress faster through the textbook. If anything, personalization intensifies the individualization of learning that typifies didactic/mimetic pedagogy. The listener to a lecture, the reader of a textbook, and the taker of a test have always been essentially alone. They are still alone, perhaps even more alone, when learning is just between them and their computing machine.

In didactic/mimetic pedagogy, learners are also assumed to be the same, or at least their relative success or failure ease measured against a standard set to normality. Lectures, Q&A routines and textbooks, whatever their media, reflect a one-size-fits-all pedagogy. The subsequent tests to measure evidence-of-learning are then 'standardized'—meaning that if every learner is expected to learn the same thing, and if we give them all the same test, we can make comparative judgments of what has been learned on the basis of a singular, homogeneous set of expectations.

Reflexive/Ergative Pedagogy

For as long has it has been around, story-ists and biographers have portrayed children's awful experiences of didactic/mimetic pedagogy—Dickens' fictional Mr Gradgrind or Winston Churchill's actual Latin teacher. Educational reformers and the philosophes of liberal modernity have long railed against this pedagogy. Here, at the end of the eighteenth century is Rousseau:

> *Teach your scholar to observe the phenomena of nature; you will soon rouse his curiosity ... . Put the problems before him and let him solve them himself. Let him know nothing because you have told him, but because he has learnt it for himself. If ever you substitute authority for reason he will cease to reason, he will be a mere plaything of other people's thoughts* (Rousseau, 1762 (1914): 126).

Then, in the twentieth century, the great educational reformers, beginning with Montessori and Dewey—at once theorists and experimental practitioners—set to work designing alternatives that were an explicit counterpoint to didactic/mimetic pedagogies. We call these alternatives 'reflexive/ergative'. By 'reflexive' we mean cycles of interaction with ideas, and objects and other learners, designed and coordinated by teachers. By ‘ergative’, we mean work-focused—the work of making knowledge rather than memorizing received truths, and evidence-of-learning in the form of made knowledge artifacts.

Rousseau and his successors all wanted learning to break out of the confinements that are the four walls of the classroom, the cells of the timetable and the chapters of the textbook. In the same spirit, today, ubiquitous computing opens the possibility of ‘ubiquitous learning’—learning any place, any time, any how (Burbules, 2009; Cope & Kalantzis, 2009b). Our personal computing devices have self-teaching pedagogical routines in the form of help menus and learning sequences with an accessible entry point but which systematically and progressively expand one’s capacity for doing and knowing (Gee, 2003). A whole world of knowledge—a real and highly varied world of knowledge rather than the univocal synthesis of knowledge by the textbook writer—is a hyperlink away.

We can also move away from inferences about the inner nature of mind, manifest in the focus on memory and cognition that distinguishes didactic pedagogy and its characteristic assessment modes. John B. Watson, founder of behaviorism, warned against trying to infer inner mental states but to focus on activity in the context of an environment (Watson, 1914). Today, behaviorism has been discredited for its focus on the mechanics of stimulus-response-reinforcement, as if the learning mechanisms that can be induced in a caged rat or pigeon, could be applied as the central focus of pedagogical science in the case of humans. Lost in this critique of behaviorism, however, was its powerful case for looking at learning-action in learning environments, rather than trying to infer abstractions about cognition. The tests of the twentieth century became more and more elaborate attempts to extrapolate from test answers cognitivist abstractions—the ‘g’ of general intelligence (IQ) or the ‘theta’ of understanding. The most sophisticated of computer adaptive and diagnostic tests today use complex statistical computational methods to do the same thing.

Returning to the spirit of Watson, in an ergative pedagogy, we propose a focus once again on activity in environments. We mean ‘works’ here, in two senses. The first sense comprises sequences of visible knowledge-actions. Elsewhere, we have classified these actions as experiential (experiencing the known and the new), conceptual (naming/defining/classifying, and building theoretical schemas), analytical (causal/procedural and critical), and applied (appropriately within an anticipated frame of reference, or creatively beyond) (Cope & Kalantzis, 2009a, 2015b). The second sense in which we use the word ‘work’ is to focus in the trace that is left when the focus is making knowledge artifacts. Here, we position ourselves in a long tradition of active knowledge making and project-based learning (Kilpatrick, 1918; Waks, 1997). In undertaking a ‘work’, students go through an active, phased process that we characterize has knowledge design, from conception to realization. Whether it be a worked solution, a documented experiment, an historical interpretation, or a diagramed argument, the business of making a knowledge artifact is a staged work process that has a beginning-middle-end narrative structure. Traces are left in the form of a finished product. The provenance of this product can also be traced, when the stages of the knowledge work are also documented. Now students are conceived as creators of knowledge and not just consumers. They are knowledge workers, who produce knowledge artifacts. So, we will not attempt to assess cognitive abstractions to determine the outcomes of learning. We will assess the things they have made, and the processes of their making. By your works, you shall be known.

In this case, we are now able to credit the distributed, social sources of cognition (Bereiter, 1994, 2002; Gee, 1992 (2013)). And we can make learning a more social, more collaborative experience. Instead of closed book, memory-based exams that create the fiction of individual cognition, students can work on knowledge projects in which they link to their sources by way of acknowledgement. Instead of working on their own, they can offer peer feedback and acknowledge that feedback. They can work together, creating collaborative knowledge works. In today's online writing and assessment environments, it is possible to trace the social provenance of every component in a knowledge work, and to create a culture of recognition of the social, distributed and collaborative nature of intelligence. In such learning environments, stealing others' work not only becomes unviable; it becomes what it always was, an un-necessary byproduct of the fiction that cognition is individual.

And finally, in a work-focused pedagogy, the differences between learners come to be clearly voiced. If your making knowledge rather than just remembering what you have been told, the content of your experience and timbre of our voice will inevitably come through. No two knowledge expressions can be the same, and the differences become a productive resource for learning (Kalantzis & Cope, 2009).

Clearly, we're advocating reflexive/ergative pedagogy here, in preference to didactic/mimetic—but not entirely. First, it's harder to do—though e-learning technologies make it much more practicable than in the past. However, second, for some domains and in some contexts, didactic pedagogies are simply more efficient and less circuitous. Such might be the case, for instance, of 'intelligent tutors' which teach skills that can be broken into a clear sequence—algebra or chemistry, for instance. In this sense, our two paradigms might be seen as strategic pedagogical partners, each more appropriate in some learning contexts than others.

Assessment in the Mechanization of Didactic/Mimetic Pedagogy

Now, we'll look closely at the use of computer-based assessment in each of these pedagogical frames. The latest computing technologies can be used to support processes as broad and divergent as the range of alternative social constructions of learning. The social construction, in other words, is more importantly determining of pedagogical modes and outcomes, than the technologies. Technology is no more than a means to social ends. Its forms and functions are determined by those ends. In the case of didactic/mimetic pedagogy, computer-mediated assessments can reproduce, even intensify, its social agendas.

Temporality: Retrospective and Judgmental Assessments

In didactic pedagogy, the test is a peculiar artifact. It is in most respects different from the processes of learning—books are closed, interactions with others are forbidden, time is strictly delimited. It is retrospective and judgmental. At the end of a defined stretch of learning, the examinee answers questions created by an expert examiner, and the examiner uses the results determine the extent of learning. Assessment artifacts include select-response tests, supply response item-based tests, and essay assessment. Mechanization suits these kinds of tests.

Select response tests were made machine-readable with the pen-and-paper 'bubble test' in the third quarter of the twentieth century. In the twenty-first century, the item-based test has been moved onto the internet, with secure access from personal computers and laptops. Because these kinds of test are relatively cheap to mechanize, test makers and administrators come to reframe disciplines around what is testable using that technology. So, for instance, item-based reading comprehension tests become a proxy for literacy in general, to the neglect of writing. And it was a particular kind of reading at that, one which is able to elicit relatively straightforward yet frequently not-crucial 'facts' from a text, but not meanings that require interpretation (which character do you relate to? which argument do you find the more powerful?). In recent decades, psychometric techniques have grown in sophistication (and statistical obscurity), in order to measure comparative performance of learners as they undertake standardized assessment tasks. Computer-adaptive testing offers a group of students' questions that are continuously recalibrated to be at just the right level of difficulty for each student. A wrong answer means that the next question you are given to answer will be easier, a correct answer and it will be harder (H. H. Chang, 2014).

More recently, machine learning and data mining techniques have been applied which 'train' machines to match trace data with data to which human judgments have been applied. Examples include essays analyzed using statistical natural language processing algorithms (McNamara & Graesser, 2012; Shermis, 2014; Vojak, Kline, Cope, McCarthey, & Kalantzis, 2011), the tracking of navigation paths through games, simulations or intelligent tutors (Fancsali, Ritter, Stamper, & Berman, 2014; Mislevy et al., 2014; VanLehn, 2006), and patterns of keystroke or clickstream activity in learning management systems. In each case, these patterns are correlated with expert appraisals of performance or test scores created in other environment. The machine is then able to predict success based on the correlations with patterns associated with success or failure in the other environment.

These techniques, however, remain retrospective and judgmental. They do not provide much feedback, if any, which a learner could constructively act upon going forward. They produce grades containing a general exhortation ('well done!' or, 'try harder!') but are not actionable. They position a student in a cohort without giving meaningful feedback about their own progress (because the progress of the whole norms away individual progress). Psychometric constructs such as 'g' and 'theta', and the machine-estimated grades of educational data mining, can only offer overall judgments of success and failure because the constituent components of what they are measuring are themselves meaningless—an isolated question in a test where an a/b/c/d answer may be accidentally right or wrong, keystroke patterns, or statistical parallels in language patterns between human graded essays and newly processed ungraded essays. The principal focus is to mechanize the process of generation of an overall, retrospective judgment. This was ever the case with tests.

These methods of mechanization also expand the scope of the testing process, meaning that students are subjected to more tests, and more frequently. The statistical and computational voodoo, whose logic and procedures are accessible only to expert 'learning scientists', serves to add an aura of scientificity and hypermodernity. Pedagogically and in their social construction of education, however, these tests are the same old thing.

Knowledge: Mimetic-Mnemonic

Didactic/mimetic assessment processes, as high-tech as they may have become, still test memory, or the replicability of 'skills' in the form of non-negotiable epistemic routines. Curriculum (a time for memorizing and skill-building) is still mostly separated from assessment (a time to demonstrate memory through recall and the successful application of skills in the form of correct answers). Learning management systems and e-textbooks present content, then test in order to make cognitive inferences. Intelligent tutors lead learners through hierarchical knowledge sequences, helping them to remember these as replicable 'skills'. Even if cycles of memorization and recall are small, the two processes remain separated. To the extent that learners replicate the steps for themselves, eventually coming to a right answer (or failing to come to that answer), following Piaget (Piaget, 1971), this process is deemed 'constructivist' (Windschitl, 2002).

Learners: Individualized

Because memory and skills are located in the brains of separate persons, assessment in the regime of didactic/mimetic pedagogy is individualized. Indeed, assessment is even more intensely individualized than the experience of pedagogy because tests are designed to isolate individual memory from its past social sources and present surrounds.

Source: http://www.scmp.com/news/asia/article/1297468/thai-university-mocked-over-examblinkers

Some of the more recent technologies intensify this process further. Computer adaptive and personalized learning bring continuous assessment of memory and skills into learning. Learning is thus further mechanized in a relationship between the lone learner moving forward on their learning on the basis of the test answers they give to their machine.

Learner Differences: The Normalization of Inequality

The norm-referenced, 'standardized' assessments of didactic/mimetic pedagogy position learners in a cohort in a way that presupposes inequality, and to this extent constructs inequality. For the few to succeed, the many need to be mediocre, and some must fail. This is the mathematical logic of the normal distribution curve (Meroe, 2013). And some tests come to be called 'high stakes' because they really do determine life destiny; they really do manufacture inequality. The machine assessments and sophisticated psychometrics of today merely extend the human structuring of inequality through education, via processes that are now all the more effective for being more thoroughly mechanized.

Assessment in e-Learning Ecologies: Towards a Reflexive/Ergative Pedagogy

Many of the technologies of assessment that we have just mentioned can be differently applied to effect a very different social construction of education. Or different assessment technologies can be developed to serve the peculiar needs of the social learning ecologies that we call education. We'll focus here mainly on the affordances of assessment using 'big data' and 'cloud computing' technologies.

Temporality: Towards Reflexive Pedagogy

Formative assessment is assessment during and *for* learning, providing feedback to learners and their teachers which enhances their learning. Summative assessment is retrospective assessment *of* learning, typically a test at the end of a unit of work, a period of time, or a component of a program. This distinction was first named by Michael Scriven in 1967 to describe educational evaluation, then applied by Benjamin Bloom to assessment of learning (Airasian, Bloom, & Carroll, 1971; Bloom, 1968). The subsequent literature on formative assessment has consistently argued for its effectiveness (E. L. Baker, 2007; Bass & Glaser, 2004; Black & Wiliam, 1998; OECD Centre for Educational Research and Innovation, 2005; Pellegrino, Chudowsky, & Glaser, 2001; Shepard, 2008; Wiliam, 2011). There have also been frequent laments that formative assessment has been neglected in the face of the rise of standardized, summative assessments as an instrument of institutional accountability (Armour-Thomas & Gordon, 2013; Gorin, 2013; Kaestle, 2013; Ryan & Shepard, 2008).

However, a new generation of embedded assessments enabled by computer-mediated learning, may reverse this imbalance (Behrens & DiCerbo, 2013; Knight et al., 2013; Pea, 2014). Indeed, it is conceivable that summative assessments could be abandoned, and even the distinction between formative and summative assessment. Take the practice of big data in education, or the incidental recording of learning actions and interactions. In a situation where data collection has been embedded within the learner's workspace, it is possible to track back over every contributory learning-action, to trace the microdynamics of the learning process, and analyze the shape and provenance of learning artifacts.

Here are some examples from the research and development work we have done to create the *Scholar* web learning environment (Cope & Kalantzis, 2013).[1] One assessment traditional mode, particularly for project-based learning and representations of complex disciplinary performance, is rubric-based review. In a traditional retrospective/judgmental perspective, an expert assessor assesses the work after it has been completed, asking questions such as 'did the creator of a knowledge work support the claims in their argument with evidence?'. In a prospective/constructive frame of reference, this can be reframed, addressing the same criteria of quality intellectual work after an initial draft. In

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[1] US Department of Education Institute of Education Sciences: 'The Assess-as-You-Go Writing Assistant: A Student Work Environment that Brings Together Formative and Summative Assessment' (R305A090394); 'Assessing Complex Performance: A Postdoctoral Training Program Researching Students' Writing and Assessment in Digital Workspaces' (R305B110008); 'u-Learn.net: An Anywhere/Anytime Formative Assessment and Learning Feedback Environment' (ED-IES-10-C-0018); 'The Learning Element: A Lesson Planning and Curriculum Documentation Tool for Teachers' (ED-IES-lO-C-0021); and 'InfoWriter: A Student Feedback and Formative Assessment Environment for Writing Information and Explanatory Texts' (ED-IES-13-C-0039). Scholar is located at http://CGScholar.com

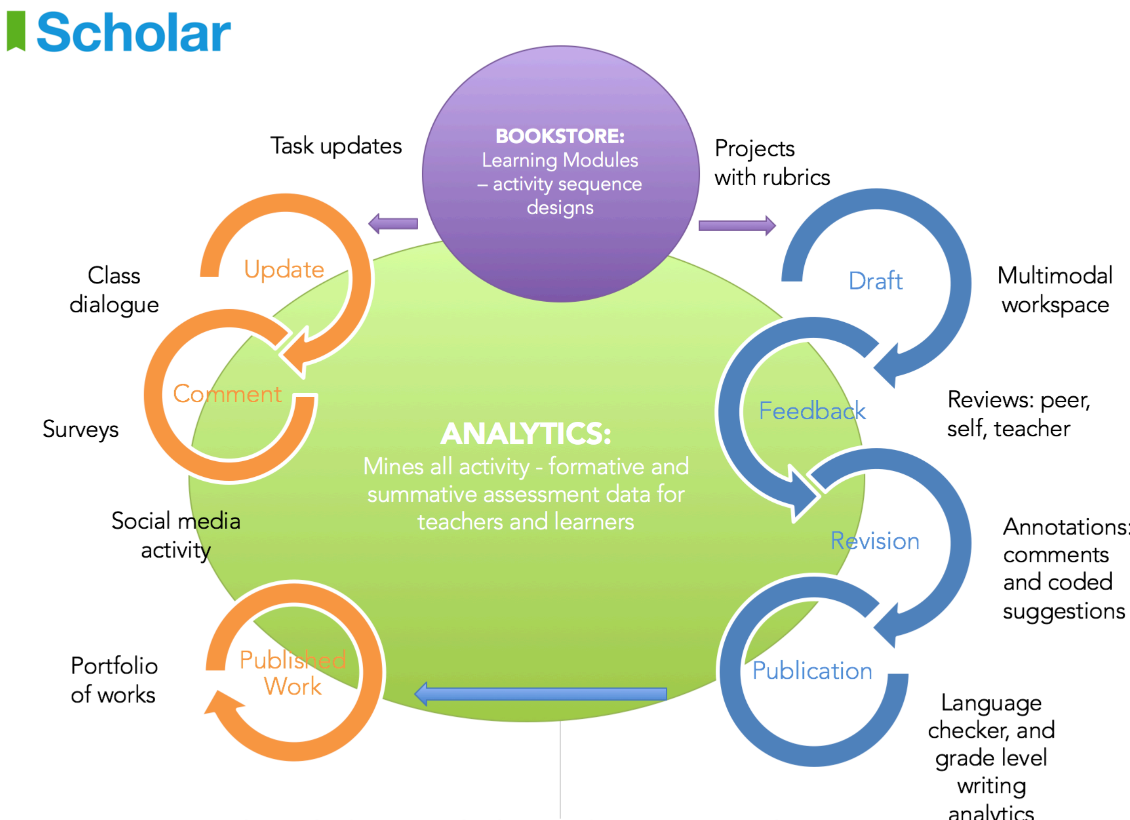
this case, the same review criterion in a rubric might be suggestive: 'how might the evidence offered by the creator in support of their claims be refined or strengthened'? There can be multiple steps in this process, before a work is finally 'published'. And there can be multiple perspectives: peer review, self-review, teacher or expert review. The difference in a cloud computing environment is simply logistical—many perspectives can be contributed to the same source text simultaneously, with rapid iteration from version to version. Then, it is possible to track the changes that have been made. This is a measure of progress rather than ends. It is also possible to evaluation social contributions, as outputs as well as inputs. What emerges also is a phenomenon called 'crowdsourcing' where the 'wisdom of crowds' (Surowiecki, 2004) is at least equal to the wisdom of experts. Indeed, our research shows that mean scores of several non-expert raters come close to those of expert raters, in addition to the value of receiving rapid qualitative feedback from multiple perspectives (Cope, Kalantzis, Abd-El-Khalick, & Bagley, 2013). Clear rating level distinctions, accessible to learners, also increase inter-rater reliability among peers (Kline, Letofsky, & Woodard, 2013; McCarthey, Magnifico, Woodard, & Kline, 2014; Woodard, Magnifico, & McCarthey, 2013).

Select response assessment can also be extended to provide helpful feedback that is constitutive of learning. We have been developing an extended learner-reflexive item type for our 'knowledge survey' module in *Scholar*. Learners receive a post-response explanation, where they an opportunity for the student to rank the fairness of the question and rate its difficulty. And in a 'think aloud' area, the student describes their original and revised thinking, or comments on the reason why they believe the question to be unclear or unfair if they consider it that.

Another area of our work has been to apply natural language processing technologies, not for grading, but to provide feedback for learners. Within *Scholar,* we have created a 'Checker' tool which makes change suggestions, including not only grammar and spelling, but synonyms as well. This tool presents alternatives which may or may not be correct, coded by change type (e.g. complex => simpler expression, or informal => formal/technical vocabulary). We have also created an Annotations tool in which peers or teachers can make comments or suggestions, coded for suggestion type. We are now working to extend this by developing a crowdsourced training model where a learner accepting a machine or human change suggestion progressively trains the system, and these changes are contextualized to learning level, discipline area and topic (Cope, Kalantzis, McCarthey, Vojak, & Kline, 2011; Samsung, Cheng Xiang, & Hockenmaier, 2013; Roth, 2004).

And a final example, we have begun to apply semantic tagging technologies (Cope, Kalantzis, & Magee, 2011) by means of which students can create diagrammatic representations of their thinking. This builds on a strong tradition of using computers for concept mapping (Cañas et al., 2004; K. E. Chang, Sung, & Lee, 2003; Kao, Chen, & Sun, 2010; Liu, 2002; Pinto, Fernandez-Ramos, & Doucet, 2010; Su & Wang, 2010;

Tzeng, 2005). We have applied semantic markup technologies to formative assessment of written project work—interim self-assessment to clarify one's thinking, and peer assessment to provide feedback to others (Olmanson et al., 2015 (in review)).



The Scholar Knowledge and Learning Ecology

This reflects a mix of machine assessment and crowdsourced human assessment, as well as linking technology and persons by applying machine learning and artificial intelligence methods so the system becomes smarter as more data are collected—smarter in the sense that, based on past patterns that have been analyzed, the system can learn to provide progressively better feedback.

What we now propose in the contexts we have just described, is a learning environment where networked computers support intense human interaction and collective intelligence, in addition to machine-feedback. There are a variety of data types, for instance a qualitative comment by a peer against a review criterion, a language suggestion made by the machine, an annotation made by a peer, an answer to a select response question, a comment made in a class discussion. Every one of these is semantically legible in the sense that immediate, intelligible, actionable feedback is provided to the learner. And the datapoints are numerous: thousands and then millions for a student in an educational program; or for a teacher in a course over the duration of a unit of work; or a cohort of learners in a school over a period of weeks. Learning analytic processes can be used to produce progress generalizations at different levels of granularity, but it is always possible to drill down to specific programs, learners, all the way down to every and any of the semantically legible datapoints on which these generalizations are based. Now all our assessment is as formative, and summative assessment is simply a perspective on the same data.

Two main conclusions can be drawn from this work. First, assessment can now be readily embedded into learning. As a consequence, the traditional instruction/assessment distinction is blurred. Learning and assessment take place in the same time and space. Every moment of learning can be a moment of computer-mediated feedback. The grain size of these datapoints may be so small and so numerous that without learning-analytic systems, they would have almost entirely been lost to the teacher. For instruction and assessment to become one, however, every datapoint needs to be semantically legible datapoint, or learner-actionable feedback. In this way, every such datapoint offers an opportunity that presents to the learner as a teachable moment. Such learning environments, where the distinctions between instruction and assessment are so blurred (Armour-Thomas & Gordon, 2013), might require that we move away from the old assessment terminology, with all its connotative baggage. Perhaps the notion of 'reflexive pedagogy' that we are now proposing might replace the traditional instruction/assessment dualism.

Second, the distinction between formative and summative assessment is blurred. Semantically legible datapoints that are 'designed in' can serve traditional formative purposes (Black & Wiliam, 1998; Wiliam, 2011). They can also provide evidence aggregated over time that has traditionally been supplied by summative assessments. This is because, when structured or self-describing data is collected at these datapoints, each point is a waypoint in a student's progress map that can be analyzed in retrospective progress visualizations. Why, then, would we need summative assessments if we can analyze everything a student has done to learn, the evidence of learning they have left at every datapoint? Perhaps, also, we need new language for this distinction? Instead of formative and summative assessment as different collection modes, designed differently for different purposes, we need a language of 'prospective learning analytics', and 'retrospective learning analytics', which are not different kinds of data but different perspectives and different uses for a new species of data framed to support both prospective and retrospective views.

Knowledge: Towards Ergative Pedagogy

Classical testing logic runs along these lines: cognition developed in learning => observation in a test => interpretation of the test results as evidence of cognition (Pellegrino et al., 2001). The test was a separate object, located after learning and supporting a retrospective interpretation. However, when then focus is on knowledge artifacts, we have direct observation of disciplinary knowledge practice as-it-happens. Knowledge is assessable in the form of its representation in the artifacts of disciplinary practice (Knight et al., 2013). Now we have the basis for a less mediated interpretation of learning.

The focus of our attention to evidence of learning in the era of machine-mediated learning can now be the authentic knowledge artifacts, and the running record that learners create in their practice of the discipline. Our focus for analysis now is not on things that students can think, but the knowledge representations that they make. These artifacts constitute evidence of complex epistemic performance—a report on a science experiment, an information report on a phenomenon in the human or social world, a history essay, an artwork with exegesis, a video story, a business case study, a documented invention or design of an object, a worked mathematical or statistical example, a field study report, or executable computer code with user stories.

These are some of the characteristic knowledge artifacts of our times. In the era of new media, learners assemble their knowledge representations in the form of rich, multimodal sources—text, image, diagram, table, audio, video, hyperlink, infographic, and manipulable data with visualizations. These are the product of distributed cognition, where traces of the knowledge production process are as important as the products themselves—the sources used, peer feedback during the making, and collaboratively created works. These offer evidence of the quality of disciplinary practice, the fruits of collaboration, capacities to discover secondary knowledge sources, and create primary knowledge from observations and through manipulations. The artifact is identifiable, assessable, measurable. Its provenance is verifiable. Every step in the process of its construction can be traced. The tools of measurement are expanded—natural language processing, time-on-task, peer- and self-review, peer annotations, edit histories, navigation paths through sources. In these ways, the range of collectable data surrounding the knowledge work is hugely expanded.

How, raising our evidentiary expectations, can educational data sciences come to conclusions about dimensions of learning as complex as mastery of disciplinary practices, complex epistemic performances, collaborative knowledge work and multimodal knowledge representations (Behrens & DiCerbo, 2013; Berland, Baker, & Blikstein, 2014; DiCerbo & Behrens, 2014; Winne, 2014)? The answer may lie in the shift to a richer data environment and more sophisticated analytical tools, many of which can be pre-emptively designed into the learning environment itself, a process of 'evidence-centered design' (Mislevy et al., 2012; Rupp, Nugent, & Nelson, 2012).

Our evidentiary focus may now also change. We can focus on less elusive forms of evidence than traditional constructs such as the 'theta' of latent cognitive traits in item response theory (Mislevy, 2013), or the 'g' of intelligence in IQ tests. In the era of digital we don't need to be so conjectural in our evidentiary arguments. We don't need to look for anything latent when we have captured so much evidence in readily analyzable form about the concrete products of complex knowledge work, as well as a record of all the steps undertaken in the creation of these products.

In these ways, artifacts and the processes of their making may offer sufficient evidence of knowledge actions, the doing that reflects the thinking, and practical results of that thinking in the form of knowledge representations. As we have so many tools to measure these artifacts and their processes of construction in the era of big data, we can safely leave the measurement at that. Learning analytics may shift the focus of our evidentiary work in education, to some degree at least, from cognitive constructs to what we might call the 'artifactual'. Where the cognitive can be no more than putative knowledge, the artifactual is a concretely represented knowledge and its antecedent knowledge processes.

Learners: The Social Mind

The environments we have been describing can also support social learning by recognizing and tracing the sociability of knowledge. The phenomenon of individual memory becomes less important as learners increasingly rely on the accessibility of social memory. Instead of mental recall, they can acknowledge social provenance of knowledge, the things they have looked up, that can readily be looked up again if and when needed. Far less important than memory, now, is a learner's capacity to navigate, discern and reassemble knowledge whose sources are acknowledged to be social. They can use also computing devices as cognitive prostheses—the data manipulations and information mashups by means of which the machine can extends their thinking. They can work collaboratively in environments where the relative contributions of different participants be traced and recorded. Then, the whole jointly constructed knowledge artifact can be acknowledged to be greater than the sum of individual contributions.

Today, we need to know more than individualized, 'mentalist' (Dixon-Román & Gergen, 2013) constructs can ever tell us. We need to know about the social sources of knowledge, manifest in quotations, paraphrases, remixes, links, citations, and other such references. These things don't need to be remembered now that we live in a world of always-accessible information; they only need to be efficiently discovered and aptly used. We also need to know about collaborative intelligence of a working group. And we can know this through the analyzable records of social knowledge work, recognizing and crediting for instance the peer feedback that made a knowledge construct so much stronger, or tracking via edit histories the differential contributions of participants in a jointly-created work.

Learner Differences: Equity and Diversity

The critique of norm-referenced, standardized tests is now well established, commencing perhaps with Benjamin Bloom's notion of 'mastery learning' (Airasian et al., 1971; Bloom, 1968). The objective of teaching and learning is for every student will attain mastery of a particular aspect of a domain, and formative assessment can help to achieve this. Instead of retrospectively judging relative success and failure across a norm, formative assessment can tell a learner and their teacher what they still need to learn to achieve mastery. Every student then keeps working away, taking the formative assessments until they reach the knowledge criterion. Digitally-mediated learning environments can provide a repertoire of formative assessment processes that make mastery by all students logistically more feasible—criterion referenced instead of norm-referenced assessment (Kalantzis & Cope, 2012: Chapter 10). Moreover, making the knowledge process more sociable, creates learning artifacts that are more comparable to each other. For instance, making peers' works visible in during the processes of their development allows the creators of more developed works to give useful feedback to those whose works are less developed. Conversely, seeing others differently developed works in review means that you are in position to improve your own. And seeing exemplary finished works of others in their published portfolios creates clear models and expectations for works still in process. Such environments for learning and assessment offer a foundation for achieving greater equity in education, rather than institutionalizing inequality.

These are also environments where differences of learner identity, interest and aspiration can be recognized and put to productive use. The 'hands-up' routine in classical classroom discourse anticipates that one person, as a proxy for the rest of the class, will give the expected correct response. Discussions in a social media activity stream produce a manifest variety of responses and cross-class dialogue about the differences. Tests of memory and skill application anticipate replication of received knowledge, the same from one student to the next. Complex knowledge representations produce artifacts which are invariably different, evidence of differential voice, perspective and distinctive modes of thinking. The measure of success becomes comparability against disciplinary rubrics rather than sameness. Instead of assessing the standardized, epistemically-complaint bearer of received knowledge, we begin to assess the unique artifacts of the knowledge designer, who finds designs in the word to be sure, but redesigns these, refiguring knowledge in their own voice and from their own perspective (Cope & Kalantzis, 2000). This refiguring is the wellspring of creativity, innovation, and ultimately social change.

Conclusions

This chapter has attempted to address the ways in which technologies in education are only ever creatures of their social construction. It has also aimed to demonstrate the ways in which technologies can shape the full gamut of social constructions of education. For the purposes of argumentation, we have posited two archetypical pedagogical frames—didactic/mimetic and reflexive/ergative pedagogy. Both of these paradigms have deep roots in the educational project of modernity. Educational technologies, we have argued, can intensify traditional didactic/mimetic pedagogies. Sometimes this may prove helpful, for instance in learning domains where their explicitness is simply efficient or their transparency is illuminating. At other times, we might accuse these pedagogies and their commonly associated methods of assessment for supporting the reproduction of inequalities and for being anachronistic in a world where we now put less premium on memory and the replication of skill routines, and more on problem-solving, innovation, creativity and knowledge agency. While there is nothing necessarily new about what we have termed reflexive/ergative pedagogy, educational technologies may simply serve to support the complex processes of social learning, making them more logistically feasible.

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