

# *Complexity Science and Education: Reconceptualizing the Teacher's Role in Learning*

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**ABSTRACT:** This writing is structured around the question, “What is teaching?” Drawing on complexity science, we first seek to demonstrate the tremendously conflicted character of contemporary discussions of teaching. Then we offer two examples of teaching that we use to illustrate the assertion that what teaching *is* can never be reduced to or understood in terms of what the teacher *does* or *intends*. Rather, teaching must be understood in terms of its complex contributions to new, as-yet-unimaginable collective possibilities.

**KEYWORDS:** Learning, teaching, teacher education, complexity science, curriculum studies.

Over the past several decades, one of the more prominent themes of the educational literature in general, and the curriculum studies literature in particular, has been the nature of learning. Much of this writing has been represented in the form of critical responses to commonsensical beliefs about learning as a subjective process of “taking in” objective knowledge that is assumed to be “out there.” Such beliefs and assumptions, it is often argued, are prompted and sustained by a weave of metaphors that have come to be taken as literal in everyday conversation.

In response, theorists and researchers have labored to offer a broad range of alternatives that challenge such taken-for-granted separations as inner/outer, knowledge/knower, objective/subjective, and individual / collective (see, e.g., Grumet, 1988; Lather, 1991). These perspectives include a host of constructivisms, social constructionisms, activity theory, critical theories, and socio-cultural theories, as oriented by a diversity of perspectives that include post-structuralist, feminist, and postcolonial epistemologies. As we have detailed elsewhere (Davis, Sumara, & Luce-Kapler, 2000; Davis & Sumara, 2002), while such theories might be taken as conflicting and occasionally contradictory, in fact they can be read as complementary when one considers the implicit

dynamics and the varied bodies (biological, social, political, etc.) under consideration.

Curiously, however, despite the prominence and diversity of these discussions of learning, the same levels of attention have not been given to pedagogy. Simply put, the meaning of the word *teaching* is rarely the site of contestation in debates of educational reform. Although it is the case the *teaching methods* are popular topics, one does not encounter discussions of *what teaching is* with anywhere near the same frequency. Instead, arguments tend to swirl around the specific curriculum topics that should be covered, the levels of proficiency that should be demonstrated, and the classroom structures that are more or most effective. As well, for some time now significant attention has been given to the emergence of teachers' identities and what those teaching identities know (e.g., Britzman, 1991; Connelly & Clandinin, 1988).

We do not dispute the notion that the emphases on methods, identities, and teacher knowledge have been important. Our point is merely that discussions seldom involve an interrogation of the actual phenomenon of teaching. The point is brought home to us at virtually every conference that we attend. As we move from session to session, we are repeatedly reminded that we share few understandings of teaching with our colleagues – despite the pretense that the meaning of the term is settled and uncontentious.

### *Conflicting Conceptions of Teaching*

Like many words, *teaching* has shifted considerably in meaning since it was first incorporated into the English language. Unlike most words, however, *teaching* seems to be subject to a much broader range of influences and interpretations, depending on one's prevailing worldview.

For example, in a recent genealogy of conceptions of teaching, Davis (2004) traced some of the more common synonyms for teaching to an array of conceptual influences, including Western mysticism (e.g., educating, nurturing, fostering, tutoring), organized religion (e.g., disciplining, indoctrinating, inducting, training, guiding), logico-rationalism (e.g., instructing, informing, edifying, directing, lecturing), empiricism (e.g., schooling, inculcating, conditioning, remediating), structuralism (e.g., facilitating, mediating, mentoring, modeling, initiating), post-structuralism (e.g., emancipating, liberating, empowering, giving voice), and ecological thought (e.g., conversing, minding, caring, participating).

At first glance, there might seem to be little hope of a uniting theme for this collection of often-contradictory conceptions. However, there is a common strand, and it traces back to the etymological root of *teach*. According to the *Oxford English Dictionary*, the word is derived from the Old English *tæcan*, which meant something like *sign* – by which any object or event could potentially serve as a teacher. The act of teaching was originally conceived in terms of its *effect* on the learner, not at all in terms of any deliberate effort to *affect* learners. To teach was to perturbate; a teaching was, to borrow from Bateson (1979), any difference that makes a difference. So framed, the word *teaching* can accommodate both accidental and deliberate events, both tacit and explicit knowledge, both private and public happenings.

At issue here is the fact that virtually all of the diverse conceptual influences on the meaning and character of teaching continue to be represented in the ways that teaching is discussed and enacted. We qualify this discussion by clarifying that we do not mean to suggest that this situation is ameliorable or avoidable. We do not argue that teachers, or anyone else, should somehow abide by a fully consistent and coherent set of principles. Supported by a century of psychoanalytic and phenomenological research that has been buttressed by recent work in neurology, we understand humans to be highly inconsistent and conflicted beings, subject to a diversity of influences that vastly exceed the number and diversity of those suspected by even Freud (Donald, 2001; Johnson, 2003).

In fact, not only do humans have the capacity to maintain incompatible beliefs, they freely combine them into notions that are imagined to be coherent (Rorty, 1989). Consider, for example, the 20<sup>th</sup>-century movements known as *evolutionary determinism*, *naturalist metaphysics*, and *eco-Christianity*. All of these, in one way or another, involve the merging of a belief in a fixed realm of Platonic ideals with an embrace of an evolving universe of Darwinian forms – a project that numerous commentators (e.g., Dennett, 1995; Dewey, 1910) have argued to be impracticable.

The rationale statements at the start of virtually any current North American curriculum document can be used to underscore our point. It is not unusual to find references to nurturing individuals toward their full potentials, guiding them to their proper places in society, instructing them in sound habits of mind, measuring educational achievement, modeling appropriate behaviors, and empowering learners, despite the very different conceptual commitments that

underlie such notions and the significant incoherences that arise when such statements are clustered together (Davis, 2004).

### *Teaching's Complex Relationship to Learning*

With regard to our own personal histories in publicly funded educational institutions, as both learners and teachers,<sup>1</sup> almost all of our formal educational experiences have been oriented by the question, “How do you make people learn what you want them to learn?” This common concern relies on the transparent assumption that entrenched perspectives on learning are appropriate to the task of teaching. Such was certainly the premise of most of the courses on curriculum and pedagogy in our undergraduate educations. We have distinct recollections, for example, of an item on the multiple-choice final examinations in our educational psychology courses: “What is learning?” Despite the fact that we attended different universities, we met the identical question with its direct-from-the-text response: “Learning is modification in behavior due to experience.” Taking the next step along this line of thought, it followed that teaching must be the provision of experiences intended to induce the desired modifications.

At the time we were unaware that the implicit conception of teaching is tied to some deeply rooted cultural assumptions about causality and independence – or what Osberg and Biesta (2007) describe as the *calculable*. Current invocations of the word *teaching*, in both popular and academic domains, tend to be mired in assumptions of causality – and, with that, desires for predictability and measurement of outcomes that oriented so much of 20<sup>th</sup> century educational research.

To elaborate, in this section we describe three different worldviews: the determined (calculable) universe, the evolving (incalculable) universe, and the emerging (not-yet-imaginable) universe. For the sake of simplicity and clarity, we discuss these sensibilities individually and in order, but it is not our intention to suggest that they are in any way independent of one another or sequential. This rhetorical strategy is adopted simply because it enables us to underscore some significant points of departure.

Just over two centuries ago, French mathematician Pierre Simon de Laplace wrote a passage that has come to be regarded as one of the quintessential descriptions of a universe believed to be determined and calculable:

Given for one instant an intelligence which could comprehend all forces by which nature is animated and the respective situations

of the beings which compose it – an intelligence sufficiently vast to submit these data to analyses – it would embrace in the same formula the movements of the greatest bodies and those of the lightest atom; for it, nothing would be uncertain and the future as the past would be present to its eyes. (1914/1951, p. 3; published in the original French in 1796)

For Laplace and his contemporaries, the universe was mechanical. It obeyed a set of deterministic laws that could be used to untangle the linear, causal relations of all happenings. In brief, the source metaphors used to describe this universe and to define the associated mindset were based on *machines* (to characterize all manner of dynamics) and *lines* (to describe time, causality, and relationship).

About a century later, Henri Poincaré, another French mathematician, suggested that the universe actually behaved quite differently. In an early articulation of the chaos theory notion of the “butterfly effect” – that is, sensitivity to initial conditions – Poincaré explained:

Even if it were the case that the natural laws had no longer any secret for us, we could still only know the initial situation approximately. If that enables us to predict the succeeding situation with the same approximation, that is all we require, and we should say that the phenomenon had been predicted, that is governed by laws. But it is not always so; it may happen that small differences in the initial conditions produce very great ones in the final phenomena. A small error in the former will produce an enormous error in the latter. Prediction becomes impossible. (1905)

Poincaré had flagged a change in sensibility that had been unfolding through the 1800s, prompted in large part by the emergence of a scientifically defensible account of evolution. The universe had come to be seen as incalculable, as evolving, and the associated imagery moved from machines to *systems* and from straight lines to *meanderings*.

These ideas continued to be elaborated through the 1900s, with a markedly different sensibility arising toward the end of the century. As Kauffman explains,

Since Darwin, we have come to think about organisms as tinkered-together contraptions and selection as the sole source of order. Yet Darwin could not have begun to suspect the power of self-organization. We must seek our principles of adaptation in complex systems anew. (cited in Ruthen, 1993, p. 138)

*Self-organization* – or, more appropriately in the current jargon, *emergence* – refers to processes by which autonomous unities can come together into larger, more powerful unities. The reasons for emergence

are not entirely understood, but they are under intense scrutiny at the moment. Ants organize into anthills, neurons into brains, people into social units, and social units into societies. The resulting higher-order unities have capacities that can vastly surpass the potentials of their participants. Phrased differently, the higher-order unities open up brand new spaces of possibilities that might set the stage for even more complex (self-organized) forms.

The source metaphors of this emergent universe are *ecosystems* (rather than machines and systems) and co-specifying *recursive loops* (rather than lines and meanderings). In terms of its educational relevance, the shift in sensibility prompts very different attitudes toward notions of causality and predictability, especially as they relate to learning and teaching. In this frame, learning cannot be understood as *determined by teaching*, although it is certainly *dependent on teaching*. Similarly, prediction is understood to refer only to the realm of the already imagined space of possibilities. Emergent systems, however, are constantly opening up new horizons of possibility, some of which were not only incalculable, but not-yet-imaginable.

We use the term *not-yet-imaginable* to refer to that space of possibilities that is opened up through the exploration of the current space of the possible. By definition, the not-yet-imaginable is impossible to specify and difficult to describe. It is not a realm of unthinkable thoughts but, rather, thoughts that cannot yet be triggered. Decades-old science fiction, for example, presents many things that were barely imaginable to previous generations are now commonplace, even hokey. Good fiction often presents the limits of the currently imaginable, and these acts of imagining help to expand the space of the possible by orienting attentions toward unrealized prospects, which in turn enable a drift toward possibilities that lie beyond the current horizon of imagination (Sumara, 2002; Donald, 2001).

In fact, one need not turn to fiction for examples of how the not-yet-imaginable lies just beyond current innovation. There are many examples of actual technologies that were created to satisfy a specific, well defined need, but that opened up spaces of possibility that were not foreseen by (or foreseeable to) their inventors. Transistors, for example, were designed to replace unreliable vacuum tubes, but their power and flexibility soon helped to trigger the electronic revolution and the information age. Yet the portable radios, integrated circuits, microprocessors, and memory chips that were to follow simply were not on the radar screen at the time the first transistors were put to use.

Many aspects of this sort of thinking have been well represented in the post-structuralist literature. In particular, within this literature, learning tends to be reframed in terms of changes in the being of the learner, not simply modifications in behavior and especially not prespecified or predicted modifications. Also problematized is the assumption that experience causes learning to happen. Rather, experience is understood in terms of triggers, not causes. Learning is a matter of structural change of the learner – which, while conditioned by particular experiences, is due to the agent's own coherent but ever-evolving structure, not the event. Such conclusions represent a rejection of the notions of linear causality that were transposed from the analytic sciences onto discussions of teaching. Cause-effect interpretations make little sense when learners are understood to engage in recursive and elaborative processes.

However, it is our contention that post-structuralism has fallen short as a discourse that that might be taken up to address the pragmatic concerns of teaching. The theoretical attitude offers a timely critique of prevailing beliefs and common practices, but it presents little by way of practical advice to teachers. By contrast, the transdisciplinary field of complexity science appears to have reached a place that it can offer more practical and immediate recommendations – even a pedagogy that is oriented toward unimagined and not-yet-imaginable possibilities. Significantly, we are not merely, or even principally, talking about individual potentials here. Rather, complexity science compels us to attend more to the creativity and intelligence of emergent collectives such as classroom groupings and societies that to the abilities of individuals. Complexity thinking offers some specific advice on how to enhance the possibilities of collectives by ensuring that the conditions for complex self-organization are in place.

So how might complexivist ideas contribute to understandings of the relationship between teaching and learning?

We proceed by offering an example of an episode from Sumara's teaching of an undergraduate course. We then use this example to underscore core issues around the character of teaching.

### *Writing Poems*

It is a bitterly cold day and I am giving a poetry-writing workshop to 32 pre-service teachers who are enrolled in a teacher education methods class. To begin, I ask them about their previous experiences with poetry writing. They tell me familiar stories:

“We were told to just write what we felt.”

“We were told to write a sonnet for our Shakespeare unit.”

“I remember writing free verse poems.”

From what the students tell me, it seems that poems were seen as artifacts that could either be plucked from the air or extracted from deep inside one’s inner being by those few students who had some gift or talent for poetic expression. I tell them to forget everything that they think they know about writing poetry. Then we begin.

Following some of the practices for teaching poetry articulated by Luce-Kapler (2004), I begin by spreading a collection of buttons taken from many different articles of clothing on a large table in the middle of the classroom and then invite students to choose one that is interesting to them. Once they are seated, I ask the students to examine the button and decide what sort of article of clothing was previously attached to it, and to write down their decision. Next, I ask them to imagine the person who is wearing this article of clothing and, with a partner, to share what was imagined and then to create a situation where these two people meet. As they are making these decisions, I move around the room passing out envelopes that contain photographs I have gathered from different collections. I ask the pairs of students to examine the photographs and answer the questions, “What happened just before this photograph was taken?” I then ask them to incorporate this event into the situation that they just invented for their two characters. Next, I ask students to work together to write a couple of paragraphs that represent the plot they have just invented. Finally, I ask each pair to show the class the buttons and photographs they have worked with and to read the paragraphs aloud that they have written. Even though they have only been working on this activity for about 30 minutes, students always produce complex, interesting plots – the beginnings of interesting fictional narratives.

Next I present students with examples of several contemporary poems. I ask them to read these to one another in their groups, paying attention to how the authors of the poems have created poetic effects. For homework, I ask the students to collaborate with their partners to choose one of these poems that they find appealing and to use it as a model for a new poem that they are to create together, using the plot developed from the button-and-photograph activities. I remind them that they must collaborate with one another throughout the process of creating the new poem.



The next day, I ask students to read aloud the small poems they have created. One poem, written by Margaret and Dwayne, follows:

*First Date*

A sweater with puff sleeves.  
A hockey game.

We liked this poem because it used a very simple form and very few words to vividly depict a situation ripe with interpretive possibilities. Margaret told the class about her experience of creating the poem with Dwayne:

I began with a small pink button that reminded me of a sweater my older sister used to wear. Dwayne had a button that he said reminded him of a winter coat he used to wear when he was in high school.

When we talked about the two buttons, we decided that these two characters could meet on the downtown bus. They would see each other for weeks and not know that one was noticing the other – and then one day they would end up sitting next to one another.

The photograph that we were given showed a simple church in the background and a snow-covered parking lot in front. When I looked at the picture, it reminded me of going to church when I was a kid – but when Dwayne looked at it he was reminded of going to hockey practice on cold winter mornings.

We thought of many possibilities, but eventually decided that our two characters would get into a conversation on the bus about a hockey game that had happened the night before, which would lead to each revealing how much they like hockey and then to a decision to go to a game together.

Writing the two paragraphs was easy – the plot and the characters were so clear to us. Dwayne and I worked on the poem online last night, sending ideas back and forth using instant messaging. We tried to copy the style of Lorna Crozier (1992), who uses very simple structures with short phrases and everyday images. The poem that we started with was more of a narrative poem. It was a lot longer, telling the story of how these two characters met and so on. As we continued to work on it, though, we kept editing out more and more until we ended up with what we thought was the poetic essence – a poem that announced a lot of possibilities, but one that also had concrete details. To me, it's

interesting how our final poem developed on the screen. I don't think that either of us could say who wrote what.

So, what was the *teaching* here?

For us, *teaching* refers to any event that prompts a complex system to respond differently – a definition that we intend as a rejection of the pervasive anthropocentric assumption that humans are the only teaching species and the popular cultural belief that the outcomes of teaching are deliberate.

This sense of teaching recalls the roots of the word. It foregrounds that the phenomenon of teaching can only be understood in terms of its effects on a learning system. In addition, and to render things even more complex, this conception compels a reconsideration of *learning* and *learners*. As is highlighted in Margaret's final paragraph, above, *who* or *what* is generating new insights and the nature of those insights cannot always (or even often) be understood in terms of the radical individual of modern, Western philosophy. So framed, the teacher is not only another learner within the classroom, but an integral part(icipant) within a grander learning system. Along with all the other individuals, the clusters of individuals (such as Margaret and Dwayne), and the classroom collective as a whole, the teacher is teaching/learning. The teacher, that is, is constantly perturbing and being perturbed with/in the evolving, self-prompting system of the classroom collective. So far, an effective and familiar vocabulary for this sort of multi-leveled complex choreography has yet to emerge in Western cultures, much less an orientation to the unimagined, not-yet-imaginable, possibilities that are entailed.

There may be a temptation to think that this manner of activity and interpretation is better suited for English language arts classrooms than, say, mathematics or science classrooms. Before continuing the discussion, then, we offer one more, brief example from a similar context, but around a very different subject matter.

### *Multiplying Understandings*

Davis recently posed the question, "What is multiplication?" to a group of a few dozen pre-service teachers, all secondary mathematics majors. In self-selected groups of three to five, they were given sheets of poster paper and felt markers and told that they had 20 minutes to generate a response.

The activity began slowly, as participants struggled not with a response to the question, but with the question itself. Several

commented to Davis or to their peers that “the answer is obvious,” they “didn’t need so much paper,” or similar. Unperturbed, Davis insisted that they prepare responses, however transparent.

The insistence soon paid off. By the end of the 20-minute period, all of the groups were focused and hard at work, and most had filled up their sheets. The posters were put on display at the front of the room with a representative from each group. As Davis took responsibility for assembling a summary chart, the group representatives were asked to report on their conclusions – and, significantly, to organize their reportings as seemed appropriate.

They began by deciding to take turns – a decision that did not last even one round. After a few contributions, participants began to insert parts of their responses as they fit with comments already given. Before long, we had an elaborated and illustrated definition that included notions of repeated addition, grouping, hopping along number lines, folding, layering, ratios, rectangular arrays, dimension-shifts, stretching, and rotating. By the end of the hour-long large-group discussion, there was consensus that the concept of multiplication was anything but transparent. Rather, multiplication seemed to be a sort of nexus – a complex and continuously modified blend of actions, analogies, and formalizations, something greater than the sum of its parts.

More provocatively, as one participant noted, the entire body of mathematics was likely a much more complicated version of this networked example—an ever-evolving, ever-expanding space of collective possibility. In the ensuing discussion, several questioned why they had never engaged with such activities or issues through the course of the undergraduate studies in mathematics, noting as well that this emergent conception of the discipline would likely have compelled a very different pedagogy to the one they experienced in their courses.

Again, we must ask, what was the *teaching* here?

There is a temptation to offer terms like “drawing out,” “facilitating,” “problematizing,” and “informing,” but such lists do not seem adequate to account for the production of the collective understandings of multiplication, mathematics, and pedagogy that arose through the course of the activity – in large part because such terms seem to suggest a sense of predetermined ends.

In fact, although Davis did anticipate some of the outcomes (specifically, the realization that concepts such as multiplication are more complicated than is often assumed), many of the details were unimagined and, arguably, not-yet-imaginable. They depend on, for

example, participants' prior knowledge, their interests in the pedagogical relevance of that knowledge and their capacities to work together.

Teaching here is more about a conscientious participation in expanding the space of the possible by creating the conditions for the emergence of the not-yet-imaginable, rather than about perpetuating entrenched habits of interpretation (or even exploring the limits of current imagination). Teaching, like learning, is not about convergence onto a pre-established truth, but about divergence – about broadening what can be known and done. In other words, the emphasis is not on what *is*, but on what might be brought forth. Teaching thus comes to be a participation in a recursively elaborative process of opening up new spaces of possibility while exploring current spaces.

In terms of the teacher's particular responsibilities, a notion that we find particularly compelling is that the teacher acts as the *consciousness of the collective*. To elaborate, one can be consciously aware of only a tiny portion of one's perceptions and cogitations at any moment (cf. Norretranders, 1998). Despite this limitation, consciousness often projects a sense of broad awareness, of being in control, of being "on top of things." However, consciousness tends to be relatively uninvolved in such core activities as making decisions and directing actions. It is more a commentator than a player.

This is not to say that consciousness is unimportant. On the contrary, it does serve to *orient attentions* and, with that orienting, to affect horizons of possibility that are presented to the conscious agent. Such, we argue, is the principal role of the teacher: to orient the attentions of learners and, in the process, to assist in the exploration of the space of the existing possible, thus opening up spaces of the not-yet-imaginable.

### *What Might Teaching Be?*

Our major point in this writing is not that a new vocabulary for teaching is needed – although this point is an important one. Rather, the critical issue for us is that there is an unsettling variety of opinion represented in the vocabularies that currently frame teaching.

We believe that one must be careful not to allow this diversity to fade into the backdrop of debates on educational reform. Different senses of the goals and purposes of schooling are entailed in a complexivist attitude toward pedagogy. Here, the possibilities for interpretation and action are not predetermined – a proposition that

may at first glance seem to be incompatible with the ends-oriented, test-driven characters of contemporary curricula.

However, we suspect that the issue is not the explicit intentions of modern curricula, but their implicit structure. For example, taking the example of junior high school mathematics in Alberta, since the mid-1980s the provincial program of studies has increased from only a few pages per grade to literally hundreds of pages per grade. Whereas individual topics were once specified in a single line of text, they now constitute entire sections, complete with illustrative examples, assessment strategies, extensions, connections, and so on. In our estimation, such micro-engineering militates against flexible, explorative, collective engagement.

Our worry is that this manner of curriculum specification contributes to the maintainance of the assumption that *teaching* is reducible to *what the teacher does*, as opposed to its effects on learners. Returning to our poetry writing and mathematics examples, we would argue that the teacher's main task is to present signs – including, as illustrated by the cases presented, artifacts, images, analogies, gestures, genres, and other forms of representation – that swirl around a topic. At the same time, the teacher must attempt to foster a space in which these signs might be explored and juxtaposed in different ways.

In both cases, the products arose in the complex interplay of signs. Margaret and Dwayne's poem emerged in the way that artifacts and interpretations were made to play against one another, all within a structure that was created by the teacher. In the mathematics example, the eventual definition of multiplication emerged in (indeed, consisted of) the images, actions, and analogies that students, prompted by the teacher, were able to identify. In both cases, the final product, while clearly originating with the parts provided and within the structures specified, cannot be sensibly reduced to those parts or structures.

So, what is the teaching here? We return to the origins of the term. To restate, *teaching* derives from a word that meant something like sign, by which any object or event could serve as a teacher. Within the very deliberate spaces of modern education, the accidental character of this original sense of teaching need not be lost or abandoned in the desire for specific outcomes. Within a complexified conception of teaching, happenstance and intention are complements in emergent possibility.

## NOTES

1. Note that, consistent with the preceding discussion, we do not mean to present “learners” and “teachers” in some sort of oppositional or mutually exclusive relationship with the phrase “learners and teachers.”

## REFERENCES

- Bateson, G. (1979). *Mind and nature: A necessary unity*. New York: E.P. Dutton.
- Britzman, D. (1991). *Practice makes practice: A critical study of learning to teach*. Albany, NY: State University of New York Press.
- Connelly, M.F. & Clandinin, D.J. (1988). *Teachers as curriculum planners: Narratives of experience*. New York: Teachers College Press.
- Crozier, L. (1992). *Inventing the hawk*. Toronto: McClelland & Stewart.
- Davis, B. (2004). *Inventions of teaching: A genealogy*. Mahwah, NJ: Lawrence Erlbaum.
- Davis, B. & Sumara, D. (2002). Constructivist discourses and the field of education: Problems and possibilities. *Educational Theory*, 52(4), 409-428.
- Davis, B, Sumara, D.J., & Luce-Kapler, R. (2000). *Engaging minds: Learning and teaching in a complex world*. Mahwah, NJ: Lawrence Erlbaum.
- de Laplace, P.S. (1951). *A philosophical essay on probabilities* (F.W. Truscott & F.L. Emory, Trans.). New York, Dover. (Original French version published in 1814; Original English version published 1914)
- Dennett, D. (1995). *Darwin's dangerous idea: Evolution and the meanings life*. New York: Touchstone.
- Dewey, J. (1910). The influence of Darwin on philosophy. In *The influence of Darwin on philosophy and other essays* (pp. 1–19). New York: Henry Holt.
- Donald, M. (2001). *A mind so rare: The evolution of human consciousness*. New York: W.W. Norton.
- Grumet, M. (1988). *Bitter milk: Women and teaching*. Amherst, MA: University of Massachusetts Press.
- Johnson, S. (2003). *Mind wide open: Your brain and the neuroscience of everyday life*. New York: Scribner.
- Lather, P. (1991). *Getting smart: Feminist research and pedagogy with / in the postmodern*. New York: Routledge.
- Luce-Kapler, R. (2004). *Writing with, through, and beyond the text: An ecology of language*. Mahwah, NJ: Lawrence Erlbaum.
- Norretranders, T. (1998). *The user illusion: Cutting consciousness down to size* (J. Sydenham, Trans.). New York: Viking.
- The Oxford English dictionary, new edition*. (1991). Oxford, UK: Clarendon Press.

- Poincaré, H. (1905). *Science and hypothesis*. London: Walter Scott Publishing.
- Rorty, R. (1989). *Contingency, irony, and solidarity*. New York: Cambridge University Press.
- Ruthen, R. (1993, January). Trends in nonlinear dynamics: Adapting to complexity. *Scientific American*, 268, 130-140.
- Sumara, D. (2002). *Why reading literature in school still matters: Imagination, interpretation, insight*. Mahwah, NJ: Lawrence Erlbaum.

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