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# The logic of wikis: The possibilities of the Web 2.0 classroom

**Michael Glassman · Min Ju Kang**

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**Abstract** The emergence of Web 2.0 and some of its ascendant tools such as blogs and wikis have the potential to dramatically change education, both in how we conceptualize and operationalize processes and strategies. We argue in this paper that it is a change that has been over a century in coming. The promise of the Web 2.0 is similar to ideas proposed by Pragmatists such as Charles Peirce and John Dewey. Peirce proposed the logic of abduction as critical for the types of unique/progressive thinking that leads to creative problem solving and/or discovery. While logic based in deduction offers outcomes with certainty, logic based in abduction offers potentially valuable insights. Dewey tried to implement progressive education in the classrooms. Dewey's ideas, while influential, were often misunderstood, or considered too idealistic and/or unworkable in the traditional classrooms. Logics based in abduction required that different major premises and hypotheses for problem solving be held simultaneously and over time. This type of scenario is often times difficult if not impossible in education based on direct interactions. Hypertext, especially as capture through emerging tools of Web 2.0, may offer the technologies that enable the type of information based networks within the education process that promote abduction and the democratic classroom as Dewey envisioned.

**Keywords** Wikis · Web 2.0 · Cooperative/collaborative learning · Improving classroom teaching · Interactive learning environment

## Introduction

The emerging tools of the Internet—specifically the reading/writing tools of Web 2.0 have the potential for the development of important innovations in the way we conceptualize the

M. Glassman
Department of Human Development and Family Science, The Ohio State University, 1787 Neil Avenue, 135 Campbell Hall, Columbus, OH 43210, USA
e-mail: Glassman.13@osu.edu

M. J. Kang (✉)
Department of Child and Family Studies, Yonsei University, 262 Seongsanno, Seodaemun-gu, Seoul 120-749, South Korea
e-mail: mjkang@yonsei.ac.kr

relationship(s) between learning and thinking, especially in the ways we operationalize these relationships in educational processes. Web 2.0 is technology that emerges not only out of the Internet, but also out of many of the ideas on which the World Wide Web was originally based. At the core of Web 2.0 tools is control of data by users, architectures of participation, remixable data and the ability to transform data, and the harnessing of collective intelligence (Oreilly 2007). These abilities were foreshadowed by work three decades earlier in hypertext (Nelson 1965) and mind augmentation (Bardini 2000). These Web 2.0 applications take education, perhaps for the first time, beyond the metaphors of page (Oreilly 2007) and print to a wholly new relationship between human thinking and information (Glassman and Kang 2010).[1] The two Web 2.0 tools that have made the qualities of hypertext accessible to most users are *blogs* and *wikis*.

However, it is also possible to view Web 2.0 as harbinger of innovations a long time coming. These innovations are similar in many ways to ideas on human thinking, learning, creating and educating envisioned more than a century ago by Charles Sanders Peirce, John Dewey and the Pragmatists. Peirce suggested that human thinking is part of a system with shifting balance and converging/diverging hypotheses (Peirce 1923/1998). Dewey looked to develop classrooms as process-oriented systems, where individuals collaborate by bringing their premises and understandings of particular problems together in search of unique approaches for solutions to new challenges (Dewey 1916). Dewey's emphasis on the processes of progressive/creative problem solving and novel, forward-looking thinking are at the core of his ideas of democratic education (Glassman 2004). Dewey never really saw his ideas of democratic education succeed at a policy level. He lamented late in his life (Dewey and Bentley 1949) that unless we developed a new way to recognize human action as part of a larger, inter-related system, we would not gain a true understanding of the complexities of thinking, or it can be surmised a meaningful way to educate.

We argue in this paper that the development of the Internet, and its most pervasive tool the Web, has for the first time created the possibility for transparent, on-demand dynamic systems of activity: the types of counter-balancing systems that help promote progressive, creative thinking. Hypertext as originally conceived and the way it has been operationalized as part of the Web provides the type of non-linear, scale-free networks of interconnected nodes that promote logics of discovery. The new technologies of the Internet and their abilities to bring the precepts of hypertext into the everyday classroom offers possibilities for direct education models that nurture and foster one of the most exceptional human abilities: individuals working together and generating new thinking and hypotheses out of old to meet demands of an ever shifting ecology.



## Three logics of human thinking—deduction, induction, and abduction

At the heart of the human ability to adapt quickly and adjust to changing environments is the capacity to engage in what C.S. Peirce referred to as the logic of abduction.[2] Abduction

[1] In this paper we concentrate on only two tools, blogs and wikis, because we believe them to be the most relevant for education processes, but Web 2.0 is much larger in scope (including platforms such as Google Documents and Double Click) and still very much in its infancy.

[2] Peirce actually used three different labels for this "third" logic (after deduction and induction) (Paavola 2004). Early in his career he referred to this third logic as hypothesis (inference). Later in his career, because of confusion about how Aristotle used the term, he switched to retroduction. During the period when Peirce's thinking was most closely aligned with the early development of Pragmatism (last decade of 19th century, first decade of 20th century (Menand 2001)) he used the word abduction. Primarily for that reason we used the label abduction in this paper.

represents the ability to recognize and respond to important information almost immediately, and use that response to change our scientific problem solving as the circumstances demand. Many educators reading the previous sentence will wonder "what is abduction?" to which we would respond, "Exactly." The concept of abduction receives little overt reference in many current discussions of teaching and learning. One possible reason is that the logic of abduction is more difficult to fit into learning confined by space and/or time. In Peirce's scheme there are actually three types of logical inquiry: the syllogistic logic of deduction where premises are pre-set and generated hypotheses are pre-determined, the more creative but also more volatile logic of induction, and the logic of discovery and hypothesis generation, abduction.

## Deduction and certainty: A classroom apart

The current emphasis on standardized tests that tend to examine how well students can reason based on accepted major premises suggests the dominant logic in much classroom education is deduction. Deduction proceeds from major premises, to inevitable minor premises and conclusion: e.g., All men are human (accepted major premise), Socrates is a man (obvious minor premise), therefore Socrates is human (inevitable conclusion that is already contained in the premise). Deduction is an important part of any educational program. But misusage and/or overemphasis of deduction as the primary route to problem solving can stifle the type of thinking necessary for inventive resourceful thinking, engendering adaptations to new circumstances.

Deduction is so dominant that whenever the term logic is used deductive/analytic structures are assumed to be what we are talking about.[3] Peirce himself believed deduction to be the paradigmatic syllogistic logic (Paavola 2004) and that it is the strongest type of logic from an evidentiary perspective. Educational strategies and practices based on logics of deduction suggest that dependable premises exist as a natural part of nature. There is a defined logic and (limited participation) architecture to the world that we either recognize through our mind's innate tendencies (Chomsky 1986) or discover through our interaction and experimentation with the universe (Piaget and Inhelder 1969). What is common to deductive teaching strategies is that however the major premises are taught, once learned they will naturally serve as the default architecture for guiding our actions, overriding all other thinking structures by virtue of obviousness and efficacy. This is the view shared by cognitive theorists as disparate as Chomsky (1986), Piaget and Inhelder (1969), Vygotsky (1987) and Flavell (1979).[4] The only things that can keep these deductive structures from dominating our thinking are "non-cognitive" issues such as "emotions."

The reason deductive logic is dominant is because it is representative of the way the world actually works and therefore enables us to develop the types of hypotheses most



[3] In this paper when we use the term logic we are talking about any cohesive thinking structure(s) that guide the way that we recognize and understand the world around us. Logic is very close to the concept of cognitive architectures proposed by Connectionists (Rumelhart and McClelland 1986), systems theorists (Bateson 1979), and/or network theorists (Sun 2002)—interrelated pieces of information that coalesce through experience, interconnections, and preferential attachments (Barabasi 2003) into a defined, active, and engaged system for organizing the world.

[4] There are only three logics for Peirce—deduction, induction and abduction, and abduction has its roots in Pragmatism. It might be possible to make the argument that a theorist such as Vygotsky actually promotes inductive problem solving, but that is a discussion for another time.

likely to control it. Conclusions are foretold as long as the thinking is clear. On the other hand, there are two interrelated reasons deductive logic tends to be insufficient in real world problem solving (and therefore should not be the sole focus or even the primary focus of educational strategies)—there are far fewer of these pre-existing patterns in the world than most people believe (many claim the mantle of deductive logic for their belief systems) and deduction is a back-looking form of thinking (based on what has already occurred) rather than a forward-looking form of thinking (based on trying to understand what may occur).

*Deduction is the most common logic found in the classroom. It is an important part of human thinking but it is not representative of all logics.*

## Induction and disparate understandings

A second set of educational strategies, less common, is based on logics of induction. These strategies prioritize the individual experiences of the learner over instruction in pre-determined premises. A series of individual cases a logical thinker comes across can be developed into a major premise (every swan I see is white, therefore all swans are white). Logical structures are pieced together through ongoing experience, usually involving some type of real-world problem solving, and tied directly to issues the individual faces in everyday life. Because of this, the developed logical structures are thought to be more immediate, more applicable, and therefore both more worthwhile and more meaningful in the life of the learner. There is less recognition that deductive reasoning is a more efficacious and/or more dominant problem-solving tool. Those ascribing to the importance of inductive reasoning sometimes argue that major premises in deductive thinking can too easily be simple misapprehension of agreed upon variations of institutionalized inductive thinking. For these reasons, it can be useless or even detrimental to push supposed deductive logic on learners. Those proposing inductive models might further argue that pushing of logics of deduction and the universal patterns they are based upon is frustrating and ultimately inconsequential for both the learner and the teacher, especially when they do not share the same everyday experiences in the building of thinking architectures.

A more generalized social argument for induction arises around the idea that imposing one social group's institutionalized inductive logic structures on a more marginalized group is unjust and a version of oppression. Many of those who follow an inductive approach to education are inspired by the works of John Dewey (Glassman 2001). (Although we contend that a close reading of John Dewey's approach argues for an abductive stance—one of the reasons his ideas have difficulties in application). Many of the ideas and strategies suggesting student-centered educational practices (Kilpatrick 1936) such as long term projects (Katz and Chard 2000) and the Reggio Emilia approach (Edwards et al. 1998) are based on inductive educational practices. Individuals are constantly building and rebuilding their thinking based on relevant everyday experiences.

Logics of induction often fall prey to a general criticism that runs from David Hume (1748/1957) to Stephen Jay Gould (1987)—criticisms that can be used with devastating effect. It is too easy to recognize systems that you are pre-disposed to recognize in the pieces of evidence you encounter. This can lead to claims of cohesive logical systems that are more a product of the interpreter's belief systems than any true system of thinking—or as Gould put it, a compilation of "just so stories." This danger has often relegated logics of induction to secondary status in educational strategies.

The logic of abduction: Generating new hypotheses for new problems

Peirce argued for abduction as a third type of logic, and we suggest in this paper that it can also be central to a third educational strategy. The process of abduction has mostly been forgotten in overt practice, perhaps because it is so difficult to recreate in on-demand educational settings (e.g., the classroom). Abduction is the most systems-oriented type of logic with an emphasis on lateral relationships in thinking systems or architectures (Bateson 1979). Abduction is also more dynamic in character and based on the types of continuously changing interrelationships that you usually find in organic systems (Bateson 1972). It is also the most closely related to modern ideas about hypertext and the Web (Nelson 1965; Berners-Lee 1999).

Peirce's conception of abduction evolved from his initial interest in a third logic that concentrated on inference and the development of hypotheses (Paavola 2004). The ideas on abduction presented here emerged during the same period. Peirce, James and Dewey were forming intellectual alliances and laying the groundwork for the Pragmatic philosophy (Menand 2001). It was during this period of intense theoretical development in Pragmatism that abduction became less about establishing some type of major premise based on inference to a more process oriented logic: a logic that attempts to discover the most efficient possible hypothesis, which serves as first step in drawing a conclusion about why something unique occurred. Peirce's (1903/1997) own formulation was,

> The surprising fact C is observed
> But if A were true, C would be a matter of course
> Hence there is reason to suspect that A is true.

The next step in the reasoning/evidentiary process is to scientifically test A to see if it is indeed true. What is implicit in this logical formulation, but explicit in Peirce's larger framework is that there are always competing premises (beyond just A) that might make C true as a matter of course.

The key to the logic of abduction is to pick the hypothesis/premise that has the best chance of surviving a rigorous scientific exploration. This initial step is the most important but also the most difficult because you must examine each premise in relation to every other possible premise as part of a whole system. This phenomenon was captured by Yu (1994) in partial syllogistic form,

> The surprising phenomenon X is observed.
> Among hypotheses A, B, and C, A is most capable of explaining X.
> Hence there is reason to pursue hypothesis A (in scientific experiment).

The most difficult part of this logic, the part that many thinkers have struggled with (including early Pragmatists James, Dewey, and Mead), is how you move from *among hypotheses A, B and C to A is most capable* so that the process involves what Paavola (2004) referred to as an *"economy of research."*[5]

The argument that we will make in this paper is that Dewey (among others) attempted to establish a workable process for this efficient type of hypotheses generation through his democratic classroom, but ultimately failed. This failure we believe can be attributed, at

[5] This is why abduction is different from just multi-voice perspectives (Bakhtin 2004). Abduction is not just about recognizing other perspectives but organizing them in an attempt to differentiate the best possible hypothesis. Q1

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least in part, to a lack of appropriate tools. The actual process of abduction does not begin until a relevant problem presents itself. Abduction is more relational (and systems-oriented) than other logical processes because the generation of distinctive hypotheses to solve new problems is dependent on interrelationships between individuals as independent information sources with different histories, experiences, and premises for solving the problem. The interconnections need to be lateral (at least begin that way) rather than hierarchical (e.g., just because node A generated an economical hypothesis for problem 1 does not in any way predict node A will come up with the best hypothesis for problem 2). A generated hypothesis only gains credence if it provides concrete outcomes in solving the targeted problem.

It is the relational quality of abduction that is most problematic in education. It is also where we believe the Internet in the form of Web 2.0 tools as hypertext can have the greatest impact The relational aspect of abduction requires that different premises and hypotheses exist concurrently with independent identities as integrated parts of a cooperative milieu (so that ideas are not competing with each other for dominance). Ted Nelson (1965) first established the concept of hypertext as an "adjunct to creativity." Hypertexts are files (interconnected systems of information nodes) with *"idiosyncratic arrangements, total modifiability, undecided alternatives* ..." (p. 84): The type of system where Peirce's logic of abduction could come to fruition. Web 2.0 tools such as wikis and blogs makes hypertext accessible and open to participatory educational initiatives.

*Abduction is the type of logic that can often lead to creative problem solving. It has been difficult to implement within the classroom because it is dependent on non-hierarchical, lateral connections between members of a group. Abduction also demands that different premises and hypotheses be maintained simultaneously through the process of problem solving.*

## The certainty-value continuum in education

Peirce saw the different types of logics as being on a continuum with deduction offering the most certain outcomes and abduction offering outcomes with the least certainty but the greatest value.[6] Abduction creates new ideas and new ways of understanding and thinking about the world. Abduction is really the only true logic of discovery (Simon 1987) and is almost certainly the process by which much scientific and social progress is made, and yet lessons using abduction as a primary tool of problem solving can be difficult to find in many traditional classrooms, especially those geared towards standardized testing (standardization of content knowledge by definition promotes deduction). Abduction allows for adaptation through creation of new hypotheses but deduction often remains the default information system. It is easier to develop and transfer information based on already accepted major premises. Such transfers are more amenable to available tools for storing and disseminating information up until now (e.g., print media), and fit the needs of social systems concerned with maintenance and their own re-creation (Dewey 1922).

In spite of the complexities involved in the development of creative hypotheses, hypothesis generation plays an important and necessary role in human activity. The more efficient the initial hypothesis is, the greater the possibility of finding a solution to the

[6] By value we mean relative economic worth is solving a problem along Peirce's idea about an "economy of research."

problem (hence the value of the best possible hypothesis). Abduction demands not only lateral recognition of competing premises and hypotheses, but also time, patience, and a willingness to accept (some times high levels of) uncertainty.

*While lessons based on deduction offers outcomes with greater certainty, thinking with logics of abduction have the potential for greater creativity and added value to the process. Educational processes need to incorporate both ways of thinking.*

## From the democratic classroom to Artificial Intelligence: The search for abduction

We believe the timing of Peirce's development of his mature ideas on abduction is critical in understanding its relationship to education and the classroom. Peirce's more developed conception of abduction seemed to evolve during Pragmatism's seminal stages of development as James, Peirce and Dewey were struggling to develop the philosophy of Pragmatism.[7] Dewey published his seminal article on the "Reflex Arc Concept" (see Glassman 2004 for an extended discussion of this article) in the same year that Peirce wrote "Lessons from the History of Science," the first work that clearly marked the new trajectory in his thinking about abduction (Paavola 2004). Some researchers have suggested that Peirce, James and Dewey were developing distinctly different philosophical approaches (e.g., Yu 1994). Some suggest that Dewey didn't come under the influence of Peirce until later in his career (Prawat 2001). We suggest that Pragmatists of this period were all working on the same project and converging on the same philosophical ground, albeit with different priorities.[8]

Dewey was attempting to take the core ideas of Pragmatism (which includes a focus on scientific, empirical inquiry and a logic of discovery) and develop an Instrumental Pragmatism that could directly influence how people become part of the world around them in their everyday lives (Eldridge 1998). Initially, Dewey saw his Instrumental Pragmatism having its greatest salience and resonance in society through education (Glassman 2001; Glassman and Kang 2009). We believe Dewey used many of the general tenets of Pragmatism to help him develop his early curricula for the Chicago Laboratory School. Menand (2001) thinks that it was his work in the laboratory school that pushed Dewey further towards James' Pragmatism. In either case, there is a good chance that Pragmatism as it was developing at the time and Dewey's educational project influenced each other in important ways.

One of the purposes of democratic education was to develop a technology that prioritized hypothesis generation as the initial phase of inquiry in the learning process. Dewey wanted to find a way to create an environment conducive to linking individual perspectives on real world problems through lateral dialogue. Each person should have an equal opportunity and equal weight in proposing their hypothesis for a solution to a targeted, real world problem. Dewey seemed to view deduction as a fallback position in human conduct (Dewey 1922), necessary (providing information with high levels of warranted assertability) but insufficient for true progress (Dewey 1938). It is important if not critical, to use major, agreed upon general premises for much of everyday living activity. But this can quickly develop into habits of thinking. Dewey believed education's primary role is fostering the more difficult (and often uncomfortable because it promotes

[7] The relationship between Peirce and Dewey was contentious.

[8] It is useless to try and determine who influenced whom. The record for this type of historical understanding simply does not exist at this point.

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the unknown) logic of discovery.[9] Certainty is the safety net for both society and the individual, but discovery is ultimately more valuable because it represents society's promise. Acceptance of simultaneity and symmetry of ideas, along with the inevitable uncertainty of original hypotheses, has to be learned through successful interest-based problem solving (Dewey 1916)—a thesis similar in some respects to Nelson's original conception of hypertext. A class should be a dynamic file filled with nodes generating alternative hypotheses.

Dewey's educational models may have been demanding too much in the traditional classroom. He was asking educators and students to do something psychologically difficult (give up certainty) by doing something close to operationally impossible (maintaining an equal footing for every hypothesis generating node/participant in the problem-solving community). Dewey's ideas in practice often devolved in one of two directions. Either the process is declared unworkable (or too idealistic), teachers and students opt for the more comfortable certainty of deductive logic; or Dewey's ideas were translated into a student-centered and primarily inductive approach with greater emphasis on student's interest. The role of interest is also important in Dewey's approach but worth far less when not integrated into a larger systematic approach to problem solving in particular and human conduct in general.

Dewey's attempts to introduce a rigorous logic of discovery into the classroom never gained a strong foothold in education. Positing of major premises and teaching deductive strategies for general problem solving became a more important focus of practices, research and policy in education.[10] Even though a strong argument can be made that abduction is both more natural to the way humans think when attempting to adapt to new environments/ecologies (Glassman and Kang 2010), and more important to human progress and problem solving, abduction has fallen by the wayside because the right technology just did not exist to cultivate this logic in the classroom. Dewey's idea of small problem-solving groups was too open to pitfalls (inability to promote multiple premises simultaneously, time and space constraints, distance from everyday social and societal expectations).

The emerging tools of the Internet offer new technologies that overcome many of the natural constraints on abduction. The "abduction friendly" nature of electronic information was foreshadowed by research in Artificial Intelligence (AI) and attempts to recreate abduction through computer programs (Konolige 1992). The AI experiments in abduction suggest two things—that abduction is the most compelling aspect of human thinking, and it is also the most difficult to recreate in any type of artificial or on-demand ecology. The AI researchers actually provide a reason as to why Dewey's vision of a democratic classroom was never able to gain traction—abduction requires the balancing of multiple premises and hypotheses at the same time and not weighted, with none taking initial precedence. The quality of the generated hypothesis is determined solely through the initial stages (logic) of the problem-solving process. If a hypothesis does not work, it is reintegrated into the general file of information nodes[11] so that another efficient hypothesis can be generated.



[9] Dewey never used Peirce's label of abduction for his logic of discovery. This may have been the result of Dewey's resistance to Peirce's sometimes obscure word use. For example Dewey was very resistant to the label Pragmatism which is one of the reasons he started calling his own work Instrumentalism (Menand 2001).

[10] We would make the argument that the report "A Nation at Risk" (National Commission on Excellence in Education 1983) gave deduction preeminence as educational strategy and goal that it has not relinquished.

[11] We define node as defined information source. A node can be as small as information in the mind or as large as an institution. What is critical is that there is equivalence between nodes in a given network such as a "classroom." For the most part in this paper, it refers to humans acting within a socially defined network.

Generally, even when using carefully written computer programs to help balance and choosing, the possible hypotheses (and therefore the problem) must be constrained in order for abduction to not evolve into chaos.

What AI researchers did, in their early abduction-based protocols, was to establish their premises that (human-based) thinking is distributed (Hollan et al. 2000), systematic (Peirce 1923/1998; Bateson 1972), and dynamic in nature (Dewey 1922; Bateson 1979). The ability to hold different premises and hypotheses simultaneously is critical. The value of each premise lies in its ability to function as an independent information source (node) that communicates laterally with other nodes to develop an original, probable hypothesis that serves as the initial step of inquiry into the problem at hand. To take the example of a classroom environment, a teacher walks into a room with 20 “students” who have different premises for how to solve a particular problem they are facing. If the teacher is taking a deductive approach, the general premise of the learning activity has already been set (and indeed the setting of specific goals for even a 40 min lesson is considered an important part of “good” planning) and a hierarchy of information has been established (with more marginalized information nodes—those who have the least overlap with the teacher—going unrecognized). The teacher is focused on getting students to appropriate pre-set major premises, and then develop minor premises and conclusions as a matter of course.

The space of the traditional classroom—defined by four walls and closed doors—is both concrete and metaphorical in establishing constraints on the learning process. Even if teacher and students have high levels of overlap in their major premises, the lesson sacrifices the value in having students generate, balance and test their own hypotheses to the certainty afforded by the teacher-generated hypothesis. Learning is based more on habit than discovery, and while this might help in the development of specific skill sets in solving pre-determined problems, it is less helpful in the processes of solving new problems in a dynamic ecology. If a teacher bases the lesson on abduction rather than deduction in a traditional classroom learning activities can easily devolve into educational anarchy where certainty is lost but nothing of value is actually created—no efficient, capable hypothesis in which the entire group is invested will emerge. The group becomes a cacophony of competing information sources where teacher and students begin to crave any type of ordering. The sources of information (nodes) act independently, but fail to coalesce into a problem-solving system.

Hypertext based tools not only present, but by their very nature promote a system where almost any number of concurrent nodes can easily and constructively engage each other without fear of being overrun or eclipsed. Internet-based, hypertext-capable tools such as blogs and wikis offer the opportunity for non-linear, simultaneous interrelationships between information sources that makes Pragmatic education more possible. Internet tools offer a systematic approach that recognizes the role of certainty, but emphasizes the value in ways that might better reflect both the cultural development of human thinking and the way in which the human mind works (Glassman & Kang, 2010).

*Dewey's democratic classroom lacked the types of communication/ information technologies that promote, or even enable, abduction. Researchers in Artificial Intelligence attempted to recreate abduction through programming, but even they ran into trouble maintaining and balancing different premises in problem solving. Internet-based tools such as blogs and wikis have the potential to create the type of transparent, on-demand hypertext environment where abduction is much more likely to become part of the problem solving activity.*

**Scale free networks and the logic of abduction**

Computers have been used to great effect in deductive learning strategies, increasing the available quantity, quality, and speed of information. But we suggest that the true promise of computers lies in the Web and its ability to link nodes as hypertext (Berners-Lee 1999), in non-linear, scale-free systems (Barabasi 2003).

In order to understand why Web 2.0 tools provide such an opportunity for abduction-oriented educational practices, it is important to understand their line of descent as the computer has developed as combination cognitive/social tool. This line of descent includes Douglas Engelbart's original ideas about computers as augmenting the human mind (Bardini 2000), Nelson's conception of hypertext (Nelson 1965, 1995), and Berners-Lee's vision for creating an inter-linking system of hypertext files (Berners-Lee 1999).

One of Engelbart's primary ideas about the computer centered on its role as a distributed information system that could extend the human mind out into the information universe to work with other extended minds in developing solutions to unique problems (Bardini 2000). Engelbart suggested that computers, by being able to store, make accessible, and maintain simultaneously different types of linked information, could qualitatively change the way humans approached problem-solving tasks. During approximately the same period, Nelson (1965) was developing the concept of hypertext—non-linear text that could move beyond its initial, linear structure by allowing the readers to extend their thinking out *as a natural function of the interactive process between human and text*.

The development of the Internet as a powerful tool for retrieving, accessing and storing information in many ways brought ideas posited by Engelbart and Nelson to fruition (Berners-Lee 1999). When Berners-Lee first envisioned the Web he was thinking primarily in terms of interlinked hypertext pages (very similar to wiki pages) that could influence and recreate each other using processes very similar to the logic of discovery (abduction) that we have described in this paper. Information should be continuous, non-linear in nature, able to access other nodes through simple links with the ability to recreate information based on new possibilities. Web 2.0 tools such as blogs and wikis offer the potential to create problem-centered scale-free systems (or files) that focus on a logic of discovery by inter-linking nodes, incorporating any number of users as partners in the system.

Scale-free networks are self-generating, interconnected, functional systems with unlimited connectivity between nodes (Barabasi 2003). Rather than developing through a series of consecutive one-to-one interactions (node A connects with node B and then node B connects with node C), they develop through interconnections between nodes existing and acting simultaneously within a field. To bring this idea down to the concrete level of education, most classrooms and educational strategies assume traditional network development. Node A (the teacher) makes a direct connection with node B (the student) allowing them to become part of a larger pre-existing system that the teacher is already part of. For example, the teacher makes a connection in a social studies class about the reasons behind the Civil War bringing the student into the socially accepted system of thought. Node B eventually becomes a teacher and makes a connection with a future node C (a student of the next generation), bringing the next student into the same pre-existing system of acceptable information.

The network advances one direct connection at a time. In many cases this is the accepted model of teaching, but sometimes the idealized model of education, where a special teacher makes a connection with a particular student and "makes a difference" by successfully bringing them into the larger system. The teacher must be careful of in-connections during this network-developing process (too many competing ideas make lessons chaotic and difficult to get the point across)—referred to as "in-power" in network theory. The teacher must also be careful of out-connections during this process (the teacher must differentiate between those students who are truly interested, giving them high grades, and marginalizing students who show less interest in the information)—referred to as "out-power." If the teacher is forced to make too many (inconsequential) connections, it diminishes the power of the original information. The building of networks through direct interaction is dependent on establishing logics of deduction.

In a scale-free network model, node A is not limited to direct interaction with node B in building a functional information system. And the power (i.e., network status) of the node is increased, rather than decreased, through higher levels of connectivity. Each of the nodes in the classroom (teacher and students) is interconnected with each other and important connections are made laterally and simultaneously rather than in direct one-to-one interaction. Moreover, the ability of the teacher (or really any node) to have influence within the system is increased as the power of "in" and "out" connections increase. A node that takes into account different information, even contradictory information, and responds to it will naturally achieve greater influence within the system as a whole. This type of scale-free system building has much greater opportunities for establishing logics of abduction (without abandoning deduction). As we have argued, this is a very difficult information-building model when it is implemented in the traditional classroom, but very possible when connectivity (information sharing) is occurring online, especially using Web 2.0 intelligence-harnessing tools such as blogs and wikis.

*The idea of scale-free networks evolved partially out of research done on the Web. It suggests networks develop out of a series of lateral connections with hubs gaining status through high degrees of "in" and "out" connections. Scale-free networks suggest continuous, integrated interconnections increases status within the network.*

## Certainty or value? The logic of blogs

A primary question that teachers face—especially in heterogeneous classrooms—is the type of shared logic possible and/or preferable in the immediate problem-solving activity. The logic needs to be tied to the way students perceive and process information. Children in a classroom recognize information and the efficacy of educational processes emphasizing certainty based on how successful similar information has worked in life experience. We develop our thinking based on what brings us positive reinforcement (Sun, 2002), which is often context driven. The major premises that we use to determine conclusions offer us a sense of certainty and we have little motivation to abandon those premises unless we perceive value in the new activity (i.e., brings us some new form of positive reinforcement).[12]

If students do not perceive any value in presented information, there is little to be gained by offering major premises for arguments and teaching students how to follow through on logical deduction. Just as important, teachers may be unaware of the connections and weighting of information students are making in their own thinking. The technology of the Internet offers the opportunity to move beyond this impasse by breaking down the barrier between minds in a classroom and between classrooms. Rather than relying on direct

[12] Kuhn (1962) actually outlined this idea when describing the way in which scientists hold on to a paradigm for as long as possible.

interactions, classroom participants recognize and communicate with each other within a focused system where the development of hypotheses takes precedence.

We suggest that blogs offer a natural extension of not only how human minds connect with each other in a natural problem-solving situation, but the way individual minds connect and weight different pockets of unique information (see the way in which Bereiter (1991) and Sun (2002) describe this process). The blog is short for Web Log and originally was considered a type of personal diary kept on the Internet. Blogs, through the addition of hyperlinks and commentary (sometimes combined), have developed hypertext capabilities, allowing individuals within a community to extend each other's thoughts beyond simple posts. Blogs offer two crucial, interrelated qualities for system development beyond other simple conversation forums (e.g., WebCT). First, they offer the possibility of identifiable, stand-alone posts that serve as independent nodes in a system. The premises (and possible hypothesis) that each student has for solving the problem can take on a unique, recognizable identity that can be traced back to its originator. These identities exist within what is, at least initially, a level playing field for promoting the information they believe has certainty. Second, blogs allow for hyperlinks to be integrated into posts (and with best possible technology into interceding commentary). It is impossible for any blog post to dominate without being linked to other (multiple) blog posts. Perhaps just as important, it is difficult for any blog to receive multiple "in" links without making multiple "out" links.[13]

An innovation that is extremely important to this process (in general, but especially from an educational perspective) is the integration of the Semantic Web[14] (Davies et al. 2002; Stross 2009) with blog (or wiki) technology. The Semantic Web allows users creating a (hyper) link to rename a URL[15] (as a URI) through a name chosen by the individual creating the link. This enables links between nodes (and through the links, the nodes themselves) to take on symbolic identities within the system to go along with their process identities. When members of the system (teacher or students) rename links as "good ideas" or "interesting approaches" or "confusing to me," or even "take a look at this," they are creating, or attempting to create, shared meaning based on their own experience-derived understandings of the information, for the nodes they are linking to. It is the users (members of the networks) who determine both the types of symbols and the legitimacy of symbols describing each node (some URIs will be maintained while others quickly disappear).

We suggest the use of blogs can help in the development certainty-value continuum as part of the learning process. To help illustrate some of the possibilities of blogging and some of the difficulties, we offer some examples from teacher/researchers who have attempted to integrate blogs into their educational processes at different age/grade levels, including some of our own experiences with blogs.



[13] Some blog posters are already famous having established other arenas for out links such as traditional or social media and therefore do not need out-power to establish hub status.

[14] The Semantic Web actually has a much broader meaning than we are using in the confines of this paper. Currently the relevance of web pages on the Web is judged primarily through mathematical algorithms. The web pages with the highest level of links are determined as the most important and when you do a search these are the first pages to which you are directed (increasing the "power" of the page). Vinton Cerf, sometimes considered as the "father of the internet," argues that this idea of Page Ranking is flawed because it is based on numbers rather than human judgment (Stross 2009). The Semantic web would replace numbered pages rankings with actual human generated phrases that describe the page or a group of pages. Technology has not yet caught up to this idea in broad based networks, but use of the Semantic Web can be a powerful tool in small networks such as those developed out of class activity.

[15] A URL simply locates a resource. This means that a URL can often be a string of letters that has no other function than to take you to the information being sought. A URI both locates information and names it so that it has a specific, recognizable identity.

In an article exploring the use of blogs in elementary education (grades three to six) (Boling et al. 2008), students used blogs to make links to new information but also to understand course content as hypertext. In a third grade classroom, a character named Jefferson Bear (serving as a centralized hub for student in-links and out-links) asked students to respond to questions such as how to protect endangered animals or respond to being teased. Students would search for answers (either other information sources or their own experience) and link them back to the Jefferson Bear hub creating a dynamic system in which the students serve as active nodes expanding the knowledge base through their own experiences (cultural, historical, or educational). In a fourth grade class, a teacher had students read a text then blog about it (asking questions about the text in search of new information). One original poster wonders why a young girl is locked in a kitchen if there are eggs and flour and an oven there. A student from another, distant class responds with sympathetic sensibilities to this post by wondering why the girl was not locked in some type of “doungen.” The students use the blog to recreate the story through their own experiences about the meaning of kitchen (it might have been a house of horrors for the author but it was more of a safe place for the two readers) turning the story into hypertext that is more meaningful and/or understandable to the sensibilities of the immediate audience. Sixth grade students used blogs to recreate new experiences with each other by sharing their creative work. Students from the Philippines, who were sharing the blog, explained in response to a poem that they have no experience with snow, changing the meaning of the poem for engaged students. Meaning becomes shared and dynamic.[16]

In another study, researchers examined the effects of blogging in a college level distance course that included students from both Japan and Taiwan (Lin et al. 2006). Students became voluntarily more self-reflective and in some cases attempted to align their own experiences with the course objectives. Some students also took comments to their blog posts as important feedback that motivated them to blog more. The addition of in-links through direct commentary turns writing into a continuous process rather than a terminal process (one of the goals of Dewey’s educational philosophy (Dewey 1916)). In our own classrooms, where blogs have been integrated as central parts of both graduate and undergraduate classes, we also found that students, especially undergraduates, are motivated to align their own experiences and history with the overall course objectives. Many of the students take the course content (e.g., interactive lectures, linked readings) and relate it to their own histories and cultural belief systems. Students might offer a personalized narrative of something they witnessed or experienced in their lives and then provide an embedded link to illustrate/prove their point. Other students comment on the original posts, usually as a result of a particularly interesting link or provocative comment. Often, students end their post with the phrase “what do you guys think?” (or something similar) suggesting they are treating their writing as open-ended. The blog posts can become alternative hypotheses to course content, and comments challenge, reinforce, or offer their own alternative hypotheses.

Blogs allow students to take course content and develop it into hypertext, not only by offering alternative hypotheses based on experience but, at least in the case of our own classes, offering links to promote their original ideas. Creative hyperlinks can take an idea in new and unforeseen directions (garnering support through comments that might eventually allow students to establish themselves as hubs in the emergent learning system). There are two important capabilities lacking however in blogs. The first is that blogs can



[16] Vygotsky (1987) has a discussion of how cultural-based differences in the audience’s sense of a single word can change the entire meaning of an entire story.

become hypertext but they can just as easily become a series of self-contained posts where there is little communication, let alone the development of discussions about alternative hypotheses. The second is that it is difficult to establish viable end products in blogs. Students are able to share their thinking and experiences through links and commentary, but we have yet to see any students take the next step in a logic of abduction—determine the most efficient hypotheses out of competing premises (theoretically in a new post). We still believe that blogs can be used for this purpose but it would take a high level of facilitation from teachers and/or blog managers. But we believe the self-containment of blog posts and difficulty in recreating ideas as interwoven hypertext are two of the primary reasons why the use of blogs has been uneven in educational settings (Kim 2008).

It is difficult to point exactly the types of development that would improve blogs for educational purposes. The relationship between blogs and the teaching-learning process will most probably go through a process of co-evolution (Bardini 2000). As we grapple with how teachers and students use blogs in educational contexts, programmers will develop a better idea of the directions the technology needs to move. We have already discussed the importance of hyperlinks and the ability to embed them in meaningful ways in both posts and comments. It might also help to develop one click links between blogs and wiki discussion pages (which we will discuss in the next section) that allows for seamless transitions and integrated development of "advanced posts."

Perhaps the most important development on the horizon for using blogs in an educational context is "blog management." Management is in many ways critical in keeping blogs as active and safe (especially important for students). A tool that has been used to great effect for filtering and managing blogs is a ranking system for posts and comments. Ranking systems emerged out of a combination of blog evolution and the Open Source movement (Stalder and Hirsh 2002). In its simplest form, "trusted users" within the blog community rate different posts and comments—one worthwhile, 0 or no rating for neutral, and −1 for destructive (sometimes referred to as a "troll" rating). We are ambivalent about using these types of tools in an educational context. It probably would not be beneficial to differentiate "trusted users" from other users of the blog. While there should be some type of blog management for removing ad hominem attacks or otherwise destructive posts, the general value of posts is probably better determined organically. The amount of comments a post has is a marker for value in much the same way Google Page Rankings determine value for URLs in the large information universe. What would be advantageous for blogs used in educational contexts is if posts could move and maintain position on the blog based on number of comments and/or individual post views.

*Blogs can serve as a first step of interactive communication in a classroom. They allow each member of the classroom to maintain an independent identity (through blog posts), while engaging a community in transparent sharing of ideas (through open commentary). Blogs can allow a teacher to understand the different thinking of all members of the posting community. Blogs can also help a teacher determine if a lesson would be best moving in the direction of certainty (deduction) or value (abduction).*

## Value and abduction: The logic of wikis

The information nodes in a Wiki-based network are more dynamic than in a blog. With blogs, it is possible to comment on another's premise but not to directly change it in any way. The linkages allow for development of a natural weighting system but often times, nothing novel is actually created out of the process (i.e., no new hypotheses through abduction). Wikis enable users within the network to actually enter the shared node and change content (either unrestricted or with limited restrictions), thus developing a new node based on a combination of previous information and “in power” links. It is possible to set up a number of fail safes to ensure that the evolving information nodes remain constructive and collaborative and do not become corrupted either by imposition of deductive hypotheses or “information vandalizing.” The history of changes can be traced back to their original source. Each person who enters a wiki page and makes some type of change is leaving an “informational footprint.” Also, and perhaps more important, the evolving technology of wikis allow additions and changes that are controversial and disputed to be removed to a secondary discussion page.

Wikis are, in one sense, a step beyond blogs in bringing a logic of abduction (discovery) into the educational process. While blogs under the right circumstances, can function as impromptu hypertext (e.g., the issue of the kitchen in the previous section), wikis are hypertext—this is their primary and in many ways, their only true function. But there is also little opportunity for wiki users to become accustomed to non-linear, shared knowledge creation, or to retreat back to some more traditional form of linear communication. You either use accessible wiki pages as hypertext, or you ignore the unique qualities of wiki technology and treat the page as traditional text.

Studies on the use of wikis in educational settings encapsulate both the promise and the difficulties of using this new technology. In a wiki-based study of storytelling (Désilets and Paquet 2005), the goal was for students to write a story together (going beyond simply re-inventing a story based on their own experiences). Students (4th to 6th grade level) engaged in two (and in one condition three) collaborative activities. The first activity was story design, the second activity story writing, and the third activity story editing. Students worked in synchronous fashion in the activity that was most distant from traditional educational practices (story design in which students used arcs to connect nodes on different web pages). However, in the more common story writing and editing activities, students worked almost exclusively asynchronously. Especially in the writing activities students showed more individual ownership over their own work and a hesitancy to intrude upon the work of others.

This sense of ownership and reluctance to add to another’s creative work has shown up in other studies, using almost the same age group (Grant 2006) and older students (Grant 2006; Forte and Bruckman 2010), and reflected our own experiences as we attempted to get university students to migrate from blogs to wikis. Even graduate students were reluctant to give up individual ownership and responsibility for their work (commenting that they would note even post to a wiki until they had gone through multiple drafts, which they then considered a finished product). The students were also very reluctant to interfere with other students’ writings. Almost all posts and documents were simple additions (often times on a completely different tangent from the previous post) rather than any type of change to the text.

In spite of the inherent difficulties in using wiki technology, the possibilities in collaborative knowledge development are extraordinary. Both Wikipedia (Lih 2009) and development of Open Source projects (Raymond 2001) offer windows into the types of community-based activities wiki technology makes available. In both Wikipedia and the Open Source movement, emergent communities of users came to believe that traditional knowledge strategies leading to useful end products had fallen short (Glassman and Kang 2010) and were highly motivated to engage in alternative activities in the development of knowledge-generating systems.

Wikipedia was an unplanned and unexpected phenomenon. The original, envisioned product was actually a site called Nupedia, a traditional online encyclopedia with entries written by experts. Nupedia's major contribution would be more efficient access with an online database. While developing a plan for entries the founders of Nupedia put up wiki pages so that individuals could discuss the possible entries. Very quickly activity on the wiki pages swamped interest in Nupedia (the project was eventually abandoned). Users became far more interested in alternative hypotheses for possible topics than pre-determined expert entries. While the published entries of Wikipedia have garnered deserved attention and respect, what may be more important are the dynamic nature of these entries and the archived background discussions that lead to their development. Information that is challenged by alternative hypotheses must go through rigorous debate to remain on the end product page.[17]

A second example of the constant sharing and recreation of information through a multitude of interweaving nodes (voices) is the way in which ideas develop at the company Google (Stross 2009). In describing the process of generating new ideas, a senior software engineer offers an approximate replica of Dewey's intermingling of democracy, logic through abduction and experimentation, and education.

> *Ideas at Google do not burst forth from the heads of geniuses and find their way unimpeded to huge audiences of receptive users. Rather ideas emerge, are torn to shreds, reformulated, prototyped, torn to shreds, launched to internal users, torn to shreds, rebuilt and relaunched, torn to shreds, refined some more....* (Stross 2009, p. 15)

What is even more relevant than the process is the degree of internal cooperation and non-hierarchical problem solving that continues to exist at Google. We would argue that as with Wikipedia, it is the process of lateral interconnections that engenders the cooperation and leads to successful problem solving through abduction.

## Wikis as a vehicle for knowing

The possibilities for a wiki as an educational tool presented here are a little bit different than some other conceptualizations of wikis—more akin to Engelbart's ideas on augmentation (extension) of the human mind (Bardini 2000) than as a tool in "knowledge building" (Cress and Kimmerle 2008; Scardamalia and Bereiter 2006). This difference relates to the Q4 distinction Dewey (Dewey and Bentley 1949) made between *Knowing and the Known*. Knowledge building is primarily about the known, or "the production and improvement of ideas that are shared within a community." (Peters and Slotta 2010, p. 5). One of the major purposes of inquiry is establishment of a knowledge base through collaborative work such as community of inquiry (Palincsar 1998) or scaffolding (Slotta and Peters 2008) that can be accessed to solve problems. Wikis have been shown to be successful tools for this type of collaborative knowledge building (Peters and Slotta 2010; Forte and Bruckman 2010). We suggest though that this type of community knowledge building represents only part of the wiki's potential.



[17] A couple of years ago, a colleague in a well-known but controversial field of social sciences complained about a related entry in Wikipedia. Academics in the field offered up alternative hypotheses and most of the entry migrated to the discussion page. On a recent visit to the entry page, I found the end product still relatively short while the discussion continued on.

As defined by Dewey, knowing is far more focused on the process of how we solve problems, and he believed this emphasis on the "how" should play a critical role in the way we educate—teaching students to solve critical problems in a manner that is open but also uses an "economy of research." Knowing is, at its most basic level, well designed problem-solving experiments, including the development of hypotheses, reliable testing, and concrete, direct solutions (Dewey 1938). As possible sources of information increase (sometimes exponentially thanks to the Web), problems become more complex, and solutions more easily manipulated to fit agendas, it becomes more and more important that we educate our students to be objective, interested problem solvers. The ability to find, organize, and differentiate information in a scientific process is one of the most important human talents. Wiki platforms offer the potential for a dynamic, shared "knowing" where individual minds are able to extend out to meet other minds to solve problems as a virtual community (Rheingold 2002). Wikipedia is so successful because every post is a constant process of negotiation in what Eric Raymond (2001) has referred to as the "principle of shared understanding." Hypotheses are always up for discussion and testing within the parameters of the larger community. To see Wikipedia only as a very good, easily accessible, collaboratively built knowledge base is to miss its importance as a social, political, educational and even economic phenomenon.

We are not so naive to believe that the Wikipedia dynamic can be easily recreated in the classroom. These types of projects heed the type of open, shared ethos towards learning and knowing that you find in Open Source communities (Raymond 2001). The implementation of wikis we describe here requires a natural co-evolution (Bardini 2000) between students understanding of the world around them and new technologies. Successful use of wiki technology may be as much about changing student and teacher mind sets and social expectations about education as development of new technologies (and technologies will also evolve as our expectations about teaching and learning evolve). However, this is not a reason not to pursue this technology in the context of a new type of education. The implementation of wikis as knowledge building vehicles is a beginning, but we suggest only a beginning.

*Wiki technology may fit the promise of Web 2.0 in education more than any other technology. It fosters integrated problem solving, and advanced understanding of the fungible nature of information and cooperation.*



## Conclusion

There have been two information revolutions in modern history. The first revolution was the invention of the printing press which provided a means to transfer the product of thinking quickly and across all types of boundaries. The second revolution we believe is the Internet and especially its most ubiquitous tool, the Web, which now gives us a means to develop educational strategies that focus on the process of thinking. The printing press in many ways created the modern day classroom. Education became a process in which information stored in print—end products of human thinking processes—were discussed, taught and appropriated en masse. There is little doubt that this print-based technology increased the store of human knowledge from generation to generation and brought humans new ways of thinking about their world. One of the difficulties with this form of education is that end products are—end products, static symbols of particular processes that came before, and often dealt with the problems of distant and prior worlds. A kitchen is always a kitchen in the way the original author envisioned it. The printed word, when used as the major teaching tool, can be a product of social constraint as much as individual discovery. For those with little or no connectivity to the author's premises this stored information can actually be debilitating—a problem that becomes larger as the world grows smaller.

When Dewey first suggested the democratic classroom as a vehicle for purposeful, process-based education, we believe it was primarily out of intuition. He tried to translate what he believed to be the best and most dynamic aspects of human thinking in goal-directed activity to the traditional classroom—but he lacked a way to conceptualize this systems (network) based process, let alone operationalize or provide a way to measure progress in the process. Dewey and those who followed in his wake were not willing to give classrooms over to deduction-based strategies because deduction does not result in activities that get to the core of what made humans unique, and engenders the possibility for dark outcomes (controlling, rather than inventing behavior). Dewey knew that there were deductive lessons to be learned, but wanted to maintain at least some doubt of certainty (Dewey 1938). Up until recently, there was no mechanism that allowed the classroom to function as a living, breathing system capable of growth that mirrored human progress. It took another revolution on the scale of the printing press. The Internet heralds that revolution, changing the way we understand and use information—which in essence changes who we are. The Internet takes Dewey's intuitions and makes them concrete concepts observable in action.

Too often the changes the Internet brings are seen in terms of quantity—the speed in which we can send, retrieve, find and access information or the ability to modify, store and present information in different forms. While all this is true, we believe the true promise of the Internet is in qualitatively changing the way we think about information and goal-driven activity—and the processes of teaching and learning. The Internet, in a time frame at times too fast to comprehend, has taken us to the cusp of a revolution in education—a revolution at least in part first envisioned a century ago.

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