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Introduction: Education through an Evolutionary Lens

By Gabrielle Principe

Take a look at the picture. Does it look familiar? It could be a snapshot from almost any elementary classroom in Western society. If you were to ask the boy in the front row how he spends his schooldays, he probably won’t tell you he’s collaborating with mixed-aged peers on meaningful tasks that are obviously relevant to survival. Rather he’d probably tell you the same thing that almost any American schoolchild would: That instead, he spends a disproportionate amount of time preparing for standardized exams. That he is more likely than the usual young nomad to do word-study worksheets while sitting quietly at a desk. That he belongs to the only hominid species whose young are required to be sedentary as they memorize times tables, state capitals, and the periodic table. And you can see for yourself that he does most of his learning in a physical environment very different from that of most primates.

Children today are educated in a very different way than they used to be. But even though the ways in which we educate children have changed, their brains have not. Modern children have essentially the same brains and accompanying tendencies, abilities, and adaptations as their nomadic hunter-gatherer ancestors. Further, many parts of their brains originated even deeper in the evolutionary past – long before written symbols, spoken language, deliberate instruction, or creatures like us even existed.
When humans (i.e., members of the Homo genus) first emerged two or so million years ago, we lived in small, nomadic bands and made our living hunting and gathering. Children spent their days playing on their own in packs in the outdoors. Their education was informal and new skills were learned “on the job” as they collaborated with multiage peers on tasks meaningful to everyday life. The reasons for learning each new skill were apparent. We didn’t show children how to identify edible plants merely so they could demonstrate that knowledge on next Tuesday’s biology exam. Rather children learned this skill so they could forage for lunch safely.

Such was education until about 10,000 years ago when humans gave up their nomadic ways, established stationary communities, and domesticated plants and animals. Maintaining this new sedentary and agrarian lifestyle from one generation to the next depended on a certain amount of technological knowhow being transmitted to children. At first, much of this education was still done on the job. But as the tools and technological skills needed to thrive in adulthood ratcheted up in complexity over time, instruction “out of context” emerged.

Today, formal education is necessary for success. But the newness of this practice cannot be understated. Humans evolved some two or so million years ago, yet it’s been only within the last few hundred years that formal schooling has become part of the ecology of childhood. That’s about 1/100th of 1 percent of the human brain’s entire existence – an evolutionary wink-of-an-eye.

This recognition of the deep evolutionary history of our brains means that we were not designed for formal schooling, but rather we evolved to be educated in a very different way. Today’s children come into the world with the very same brains as their hunter-gatherer peers, yet we sit them down in classrooms, give them textbooks, and ask them to take standardized exams. We ask them to learn things that their brains never expected and in contexts that are completely foreign. It is this mismatch between children’s evolutionary past and their modern human present that makes today’s formal education system ineffective for some children and stultifying for others.

An appreciation of this deep history of our brains makes it clear that the classroom and many of the skills that we teach in school, like reading, writing, and most of modern day mathematics, are foreign elements in the natural ecology of children. Considering the unnaturalness of formal education, we should not be surprised that not all children thrive in the classroom and that many lack the motivation for the out-of-context learning that goes on in most schools. Significantly, an evolutionary framework can provide keen insights into the sorts of instructional approaches, curricular materials, and educational contexts that best fit children’s natural dispositions and tendencies. Indeed, an evolutionary perspective can help educators understand a range of classroom behaviors and learning styles that make little sense through any other lens.

Despite the breadth of fields represented in this series on education, a common strand that runs throughout the pieces is the ways in which an evolutionary lens affords deep understanding of how individuals teach, learn, and lead in educational contexts. This collection of essays demonstrates potently how evolutionary theory can serve to unify seemingly disparate findings and, in this case, produce a comprehensive science of education that is much more meaningful when couched within an evolutionary frame. While all of the authors agree that there is much to be gained by viewing education through an evolutionary lens, their perspectives for remedial pedagogies differ.
Evolutionary developmental psychology is the application of the basic principles of Darwinian evolution to explain contemporary human development. From this perspective, not only are behaviors and cognitions that characterize adults the product of natural-selection pressures operating over the course of geologic time, but so also are characteristics of children’s behaviors and minds. In fact, although natural selection works at all stages of the lifespan, selection will have greatest effects on early stages of development: getting born, surviving infancy and childhood, and developing to sexual maturity.

If you believe, as all evolutionists do, that natural selection produces adaptations, then there must be adaptations of infancy and childhood, distinct from those of adulthood. Although some adaptations of infancy and childhood may prepare children for life as adults, others were selected to serve an adaptive function at specific times in development, termed ontogenetic adaptations. This means that some aspects of children’s immature functioning are adaptive in their own right, providing infants and children with immediate (and perhaps deferred) benefits.

For example, there is evidence that infants’ inefficient sensory and learning abilities may protect young animals from overstimulation and enhance the learning of species -
appropriate content. This is seen in studies of precocial birds (Likeliter, 1990) that are given premature visual stimulation that subsequently results in improved visual abilities but at the expense of important auditory-learning abilities, and in monkey (Harlow, 1959) and human infants (Papousek, 1977) whose performance on simple learning tasks is impeded when they started the learning tasks earlier as opposed to later. Such results provide evidence that not all learning experiences are necessarily good for infants – that sometimes, learning experiences will not only be useless for infants who lack the requisite cognitive abilities, but they may actually be detrimental to later learning and development.

These ideas have implications for preschool education. For instance, “educational” DVDs and videos, such as “Baby Einstein” have been touted to accelerate infant cognitive development, but scientific evaluation of such videos with infants much younger than two years of age show that they have either no impact or are actually associated with lower levels of learning. Similarly, preschool programs that emphasize teacher-directed instruction typically provide no immediate or subsequent academic advantage to children compared to those that emphasize developmentally appropriate practices (that is, more play oriented). Moreover, children attending developmentally appropriate programs typically show advantages not only in subsequent academic performance, but also with respect to motivation and psychosocial factors, including liking school better, feeling less stress, and having greater creativity, pride in accomplishment, and self-confidence than children attending direct-instruction programs.

What can we conclude from all this? Natural selection has adapted children’s cognition and behavior to learn from experience – to educate themselves in many respects. Much of what we consider to be "immature" thinking in young children may actually be adaptive ways of gaining knowledge and developing intellectual skills. This may extend beyond childhood to the juvenile and adolescent periods. We should take advantage of children’s cognitive immaturity to foster their education, rather than trying to educate immature thinking out of children.
To borrow from our colleague, David Bjorklund, it is pretty fair to conclude, "Children did not evolve to sit quietly at desks in age-segregated classrooms..." (2007). Yet here we are in 2017, under the remnants of No Child Left Behind, where children are doing just that – individually and passively ingesting quantities of information for high stakes tests (Hirsh-Pasek, Golinkoff, Berk, & Singer, 2009). Yet in the 21st century, children will be required to operate in a world where information will be at their fingertips. Content is necessary, but it is not the whole story. Our most successful citizens will be required to use the “6C’s” (Golinkoff & Kirsh-Pasek, 2016): collaboration (building new knowledge and approaches with others); communication (persuasively arguing – and listening – to share ideas); content (the 3R’s and so much more); critical thinking (selecting and synthesizing the information needed to perform the task at hand); creative innovation (using content and critical thinking to envision new solutions to old problems); and confidence (the old saws about perspiration and perseverance have much to offer).

What if we could wave a magic wand and change the sterile pedagogical approach used in many schools today? What kind of a more evolutionarily sound pedagogy would replace silent classrooms, where well-meaning teachers drone on while children fill in blanks...
on worksheets that constrain the answer space? We suggest that “playful learning” – an umbrella term that includes both “guided play” and “free play” – might be the antidote to today’s atavistic classrooms. Playful learning provides a middle ground between positions like Peter Gray’s, where children are expected to learn entirely through self-directed play and exploration, and David Geary’s approach that emphasizes the importance of didactic instruction for “biologically secondary knowledge” like mathematics.

Free play allows children to be in charge and to explore their surroundings with or without social partners. Watch two children muck about with a net and a bucket at the seashore. They can be absorbed for hours, extending their attention spans, formulating hypotheses (what happened to the animals that lived in these shells?), and fueling their intellectual engine to want to know more about their world. While free play has many cognitive, psychological, and emotional advantages, it turns out that if you want children to learn something, it is better to provide a framework, or lens, for them to see it through. Here is where guided play comes in. An example illustrates the concept and attests to its power.

We and Kelly Fisher (with Nora Newcombe, 2014) wanted to see whether preschoolers would best learn the properties of geometric forms if they were told these properties (think didactic instruction), versus if they were guided to discover them (think guided play), versus if they were simply given geometric forms to play with (think free play). Learning that triangles, for instance, must have three sides and three “corners” seems easy until children are presented with non-standard forms like right or scalene triangles. Then, if they haven’t figured out what makes a triangle a triangle, they are lost.

After experiencing these three different kinds of pedagogy in the controlled experiment, 4-year-olds were all able to identify four different, standard variety, geometric forms. It was on the non-standard forms that the children who had learned with guided play – where the teacher followed their lead – shined. The children who had didactic instruction or free play bombed, while the children who had been active participants in their own learning did marvelously. Active, engaged, and meaningful learning creates learners who can extend (“transfer”) what they know to new instances.

If we are to prepare our kids for a future where the 6C’s are essential, we will need to change classrooms to breed engaged and energetic learners who eat ideas for breakfast. Questioning and meaning-making will need to be de rigueur. Training children to fill in blanks correctly only seems more effective and efficient than inviting them to participate. Learning “sticks” when teachers with learning goals follow children’s lead and encourage debate and wonder.
I often hear, “Science is just tough to learn, so is evolution really any different?” It’s true that students struggle to learn concepts like photosynthesis or gravity, but evolution presents some unique challenges not inherent in all science learning. The challenges are evidenced by the near flat line of acceptance in the United States over the last several decades (Miller, Scott, & Okamoto, 2006).

Recently, my colleagues and I brought together over 40 psychologists, science educators, and evolutionary biologists to explore just what makes evolution particularly vexing to teach and learn (see Rosenberg, Evans, Brem, & Sinatra, 2012, also see Sinatra, Brem, & Evans, 2008). Our findings? Evolution: 1) conflicts with intuitive ideas, 2) requires overcoming misconceptions, 3) is conceptually complex, 4) challenges individuals’ identity, and, 5) presents emotional and motivational hurdles. Let’s consider each of these challenges in turn.

1. Young children come equipped with intuitive ideas about biology, often called folk biological knowledge. For instance, children tend to believe that members of a category have an underlying immutable essence (Gelman &
Rhodes, 2012). Essentialism helps children learn to categorize living things, but it conflicts with the idea that species change over time. Children also tend to believe that things are made for a purpose (teleological thinking) by an intentional agent (intentionality) notions much more consistent with creationism and intelligent design than evolution (Evans, 2000).

2. Misconceptions like “Humans evolved from modern day apes” are common among evolution learners. Conceptual change is the process of overcoming misconceptions, and is notoriously difficult to promote and achieve (Sinatra & Mason, 2013).

3. Emergent systems, deep time, and uncertainty are extremely complex, abstract ideas. Each of these concepts have been shown to be a rough go for learners but combined, they present a high bar.

4. Accepting the scientific explanation of the interrelatedness of all living things may raise unsettling questions about one’s identity and fundamental questions about who we are and what is our place in the universe.

5. Conflicts with knowledge, beliefs, and identity can evoke strong emotions. Even students who accept evolution find it disheartening (Brem, Ranney, & Schindel, 2003). Motivations such as goals, values, openness to new ideas, and beliefs about knowledge can either facilitate learning or create resistance to learning about evolution.

Students can and do overcome these challenges and learn about evolution. Evolution educators may be more successful if instruction is designed to address the challenges head on and promote conceptual change (Heddy & Sinatra, 2013). It also helps if evolution is taught with an eye toward appreciating the nature of science and how we come to know facts about evolution. Finally, the relevance of evolution to learners’ everyday life (i.e., antibiotic resistant bacteria) should be central to any evolution curriculum.

Evolution is a challenging topic for many learners, but with the right approach, we can budge those stubbornly resistant numbers and help promote a more scientifically literate populace.
Evolutionary educational psychology is changing the face of instructional design. By providing us with a base that explains critical aspects of human cognitive architecture, we are able to devise instructional techniques that can work. On the other side of this coin, in the recent past, many popular instructional procedures have failed. Evolutionary educational psychology can explain some of those failures and provide highly effective substitutes.

Over the last one or two decades, instructional design recommendations have increasingly emphasized generic skills. Teaching learners generic problem solving skills that can be used to solve a variety of unrelated problems or teaching thinking skills that can be used in any curriculum area provide examples. While it is intuitively plausible that teaching such skills should be useful, evidence that they are teachable is sparse. They certainly are learnable because we all have problem solving and thinking skills, suggesting that generic skills are learnable but not teachable. Why would a skill be learnable but not teachable?

Until David Geary’s distinction between biologically primary knowledge that we have evolved to acquire and biologically secondary knowledge that is culturally important but that we have not specifically evolved to acquire,
we had no real answer to this question. The distinction between primary and secondary knowledge provides an answer. We all have evolved to easily and automatically acquire those general problem solving and thinking skills that are necessary for survival. We take them for granted because the skills were acquired without being taught or even named. Of course, a skill that has already been learned cannot be taught.

In contrast, we do not easily or automatically acquire biologically secondary knowledge. Secondary knowledge encompasses almost everything that is taught in educational and training institutions that were devised precisely in order to assist learners to acquire such knowledge. Secondary knowledge has several characteristics that only become intelligible when considered from the perspective of evolutionary educational psychology.

1. Since we have not evolved to automatically acquire biologically secondary knowledge, it is unlikely to be acquired by “immersion” in a suitable environment. Unlike primary knowledge, it requires explicit instruction. Children will learn the biologically primary tasks of speaking and listening simply by immersion in a speaking and listening society. Explicit instruction is unnecessary. In contrast, they are unlikely to learn how to read and write without explicit instruction. Suggestions that students would learn school subjects as easily as they learn outside of school if the same techniques were used are misguided. On evolutionary grounds, the information acquired outside of school is categorically different from the information that students acquire within school. We should not expect the two categories of information to be acquired in the same way.

2. Biologically secondary knowledge and skills are domain-specific. We do learn problem-solving strategies, for example, but they are specific to a particular domain. Learning that when faced with an algebraic problem such as, \((a + b)/c = d\), solve for \(a\), the first move should be to multiply both sides by \(c\), will help a person solve similar problems. It will not be of assistance in solving unrelated mathematics problems or indeed, how to start a car that will not start or how to solve personal problems. Skilled problem solvers in a knowledge rich domain have learned to solve literally tens of thousands of relevant problems and it is that knowledge that results in expertise, not biologically primary, generic skills. Because of that immense knowledge base that is required, it can take many years to acquire high levels of expertise in a given area.

3. An immense knowledge base held by a human is analogous to the immense amount of information held in a genome. The structures and functions required by human cognitive architecture can be mapped directly onto the structures and functions that we call evolution by natural selection. Both are examples of natural information processing systems. A genome is analogous to long-term memory; reproduction with its transfer of genomic information is analogous to humans obtaining information by imitating other humans, listening to what they say or reading what they write; random mutation is analogous to random generate and test during problem solving; the epigenetic system has the same function as human working memory. In effect, the structures and functions of evolution by natural selection provide a template for the structures and functions of human cognitive architecture when it deals with biologically secondary knowledge. Over the least two decades, that architecture has been used to generate a considerable array of instructional procedures designed to assist learners to acquire biologically secondary, domain-specific, information. In many cases,
instructional effectiveness can be improved by using techniques that reduce an unnecessary working memory load and assist in the transfer of information to long-term memory.

In conclusion, evolutionary educational psychology has influenced instructional design by firstly, providing us with a scheme for categorizing knowledge into biologically primary and biologically secondary knowledge. Most knowledge categorisation schemas have not had instructional consequences but this scheme has profound consequences. Biologically primary knowledge can be learned but not taught. In contrast, secondary knowledge that is taught in educational institutions should be explicitly taught rather than left for students to discover. The second way in which evolution by natural selection has influenced instructional design is by providing a template for human cognitive architecture. Both evolution by natural selection and human cognitive architecture provide examples of a natural information processing system and that system, in turn, has generated a variety of instructional procedures designed to reduce working memory load and facilitate the acquisition of information held in long-term memory.
This paper addresses a broad and fundamental question: Is culture transmitted to or acquired by the rising generation primarily by teaching or by the self-initiated and autonomous efforts of the young? Most parents, educators, and scholars whose world-view has been shaped by membership in a Western, Educated, Industrialized, Rich, Democracy (WEIRD) would identify teaching. From this ethnocentric view, recent scholars have gone further and claim teaching as an evolved, universal, and fitness enhancing trait unique (among primates) to humans. Drawing on a broader cross-cultural and historical perspective, this paper argues that teaching is rarely employed in cultural transmission, that the costs almost inevitably out-weigh the benefits, that adults or parents are, generally, neither willing nor gifted teachers, that children prefer to learn autonomously, and even that traditional "educational" institutions such as rites of passage and apprenticeship exhibit relatively little evidence of "good" teaching practices.

Teaching is common in contemporary societies that I have characterized as Neontocracies – where children are elevated to a very high status and afforded generous resources by their families and the society at large with little expectation of a later return. It is uncommon in the far more widespread Geronotocracy, where children remain largely...
invisible or disregarded until they are old enough to be useful.

Infanticide, chronic illness, high infant mortality, inter-family strife, and the mother’s important role as a provider mean that infants are secluded or otherwise kept in a quiescent state – for their own well-being. Teaching and other means to stimulate the infant’s cognitive and linguistic development would not be compatible with this model.

In both the ethnographic and historic records, we have ample evidence of children learning their culture through observation, emulation, and make-believe play and practice with toy tools in their own garden patches. Children learn through their assistance to the mother in child-care, gardening, and household maintenance. They learn from emulating their slightly older and more competent sibling caretakers. Furthermore, when anthropologists query children and adults regarding culture transmission, there is a clear consensus that independent, self-paced learning is the default mechanism, and teaching is dis-preferred. Numerous studies show that – absent teaching – children become competent in the characteristic skill set (hunting, finding tubers, collecting marine resources, herding, planting) at relatively young ages.

The thesis that teaching is unlikely, unnecessary, and uncomfortable is also borne out by a cross-cultural and historical analysis of the more formal pedagogical institutions designed to transmit pieces of the culture. These include the rite of passage and apprenticeship. Puberty rites are quite common and, not surprisingly, they adhere to a general pattern. This includes the removal of the child from the natal home, isolation and hardship shared with others in the same age cohort, painful body modification – often circumcision or clitoridectomy – and a steady stream of threats of dire consequences for the youth’s failure to demonstrate obeisance and respect for older, more senior members of the community. The apprenticeship may be quite similar involving hardship, physical punishment, and menial, exhausting labor. This ordeal insures the apprentice will uncomplainingly comply with the requirements imposed by the master. The master does little more, by way of teaching, than demonstrate correct practice and then harangue and abuse the student for inadequate performance. The earliest schools were based on the apprenticeship, and the punitive and unsympathetic pedagogy of these institutions continued to be the norm until well into the modern era in the West and are still the norm in most village schools.
Essentially, the child’s mind comes with built-in scaffolding that prepares them to learn about other people, plants and animals in their local ecology [...] There are, however, no built-in scaffolds for learning how to read, write, and do arithmetic, much less algebra, calculus, science or many other complex topics children will encounter in school and in the modern world outside of school.

Schools are the interface between culture and evolution. They are the primary contexts within which children learn the knowledge and skills necessary to be successful in the modern world, but this is a world that differs in many ways from the world in which the mind evolved.

Essentially, the child’s mind comes with built-in scaffolding that prepares them to learn about other people, plants and animals in their local ecology, how to navigate from one place to another, and how to use tools. The scaffolding is fleshed out as children engage in self-initiated play, exploration, and social activities. There are, however, no built-in scaffolds for learning how to read, write, and do arithmetic, much less algebra, calculus, science, or many other complex topics children will encounter in school and in the modern world outside of school. Nor are children inherently motivated to learn to read or to solve arithmetic problems in the same way they are motivated to play with their friends. Evolutionary
educational psychology is the study of how the evolved mind is adapted through schooling to meet the demands of the modern world, and how children’s evolved motivations (e.g., to play with peers) influence their engagement with this schooling.

Language, for instance, is an evolved and universal cognitive ability. Children are prepared to learn the language to which they are exposed and do so implicitly and automatically, that is, without conscious thought or effort, as they engage in social activities. But, learning the evolutionarily-novel competencies of reading and writing does not come as easily to the vast majority of children. It is known that the same brain and cognitive systems that support language (e.g., that allow one to discriminate the sounds ba and pa) are engaged during the act of reading, suggesting that schooling modifies built-in scaffolds, at least to some extent, in ways that allow children to acquire skills and knowledge that were not common during our evolutionary history. Building onto evolved scaffolds in these novel ways, however, requires effortful attentional focus and explicit, conscious problem solving.

Children easily learn the difference between bat and pat when expressed in natural speech, but associating these sounds with strings of arbitrary symbols (letters and words) when learning how to read does not come as naturally nor as easily.

From a motivational perspective, it is not surprising that children like to play with their friends. These activities automatically and effortlessly flesh out their social-cognitive scaffolds; these activities help them to learn about themselves and other people and how to negotiate relationships. There is no reason to believe that children have a corresponding inherent motivation to write or to solve algebra problems, for instance. For many children, the motivation to learn these skills will require social and cultural supports (e.g., highlighting accomplishments of engineers) and encouragement (e.g., focus on the payoffs to effort and hard work). Evolutionarily-novel learning requires, to some extent, disengagement from natural ways of learning (e.g., play).
People want others to be rewarded equally for equal work, that is, they value fairness. However, previous research tends to conflate a desire for equality with a desire to be generous and increase welfare overall. Generosity is often directed toward those who have less, which often has the side effect of reducing inequality but is not necessarily motivated by a concern with equality. Would people still value fairness if it conflicted with generosity? We investigated this question in 6- to 8-year-old children and found that children value fairness even when doing so meant being ungenerous; children preferred to throw a resource away, even their own, rather than to share unequally by giving one recipient more than another recipient. 

In our next set of studies, we investigated if children’s behavior in our previous experiments was driven by them wanting to be fair or merely appear fair to others. We found that, when children knew that an experimenter would be aware of their choice, they preferred to do the fair thing, discarding a resource in the trash rather than create inequality by taking it for themselves. However, when children believed that the experimenter would not be aware of their choice, they were considerably more likely to unfairly take the resource for themselves. These results demonstrate that children’s...
concern with fairness is at least partially driven by a motivation to appear fair to others. Knowing that children are motivated to signal their fairness to others leaves open the question of why fairness behavior is seen as socially desirable and worthy of signaling in the first place. Although many researchers suggest that the goal of fairness is to avoid inequity, unequal pay for equal work, this answer is not the only possibility. We suggest that fairness concerns are rooted in an aversion to appearing partial to others. That is, inequity is acceptable if it does not entail partiality. To examine this, we investigated whether 5- to 8-year-old children endorse inequitable outcomes determined by an impartial procedure. We found that children were quite willing to use an impartial (but not a partial) procedure to create inequitable outcomes. This suggests that children's fairness concerns are driven by an aversion to partiality, not inequity, because children thought creating inequity was fair if it was determined by an impartial procedure.

In discussion, I speculated on why a desire to avoid partiality may have evolved. On the surface, impartiality appears to be a bad strategy; it seems an individual would do best by delivering benefits only to his or her allies and expecting the same preferential treatment from them. However, open displays of favoritism could cause conflict with non-allies or less highly ranked allies who may see new alliances as a threat. It may therefore be a good strategy to conceal open displays of favoritism and instead make efforts to strengthen or initiate alliances primarily in private. This leads to a possible explanation for why fairness might have evolved: for people to avoid being condemned by third parties for demonstrating or initiating alliances through preferential sharing. I further suggested that, contrary to many theories in the literature, fairness did not evolve to increase reciprocity because fairness can often interfere with reciprocity when three or more people are involved in an interaction; fairness (avoiding the appearance of partiality) can lead people to not reciprocate previous generosity.

Understanding the different psychologies that underlie resource sharing is quite important as conflicts over resources are ubiquitous in the classroom and on the playground. If people do indeed have these different psychologies, then certain instructions from adults may have counterproductive effects on children’s behavior. If you insist that children share, this may reduce their selfishness and make them more likely to think about being generous and fostering reciprocity with others but can also lead to insular groups of friends who exclude others while sharing with each other. Similarly, if you want to promote generosity in the classroom, telling children to be fair may often achieve this but can lead children toward inefficient decisions to waste resources.

Understanding these psychologies is essential if teachers and parents want to make sure that children are internalizing the desired lesson from their messages.
Human memory is adaptive. Our capacity to remember and forget helps us solve problems, everything from remembering where the car is parked to recognizing the person who owes us money. Understanding the architecture of human memory, including its evolutionary and cultural origins, has obvious relevance to educational practices. Creating informed education curricula benefits from understanding the natural constraints that shape the way people learn and remember.

To understand those constraints, the first step is to acknowledge that memory evolved – having been shaped and sculpted by the processes of natural selection. Specific selection pressures conferred selection advantages to organisms capable of using the past in the service of the present. Nature’s main criterion, as embodied through the process of natural selection, is the enhancement of inclusive fitness. At some point in our ancestral past, memory developed because it helped solve problems related to survival and ultimately, reproduction. An organism with the capacity to remember the location of food, or categories of potential predators, was more likely to survive than an organism lacking this capacity.

For much of the past decade, our laboratory has been investigating whether human memory
is biased or tuned to solve fitness-relevant adaptive problems. Such problems include remembering threats to survival, sources of nourishment, sources of contamination, potential mating partners, cheaters and free-riders, and so on. This idea that memory is problem-oriented – and specialized to retain certain kinds of information – is controversial and novel in the memory field. Most memory researchers assume that memory is controlled by a few domain-general processes, such as the “richness of encoding,” that apply to any kind of information content. We have argued instead that memory evolved to solve specific adaptive problems, such as remembering the locations of predators, and that general remembering is largely derivative of these specialized functions. Then to maximize retention, one needs to develop learning strategies that piggyback on these natural tendencies.

For example, our laboratory has shown that memory is strikingly good when information is processed with respect to its fitness consequences. We asked people to imagine being stranded in the grasslands of a foreign land, one in which they would need to find steady supplies of food and water and avoid predators, and then to rate the relevance of information to this imagined scenario (e.g., “How relevant is the word wagon to surviving in this context?”). Later surprise retention tests revealed very strong retention advantages for items processed with respect to this survival scenario – even better than the “best of the best” of known encoding strategies such as forming a visual image or relating information to the self. We have also found strong retention advantages for animate (living) versus inanimate (nonliving) things. Even attributing animacy to a non-word, such as imagining “plave” to be a living thing, boosts memory for that item compared to standard controls. We have also shown that it is easier to learn foreign language words when the definitions refer to animate as opposed to inanimate things.

Recognizing these inherent mnemonic tunings, such as a bias to remember information when it is processed for its fitness consequences, is a vital step in the development of effective learning strategies: ones that facilitate learning and lead to long-lasting retention. Application of these strategies to applied educational contexts is an ongoing concern of the lab.
David Geary has outlined an evolutionary perspective on education that assumes a rather clear distinction between “primary” and “secondary” abilities. He contends that children acquire primary abilities (e.g. native language and ability to make social attributions) through their natural play and exploration but do not acquire secondary abilities (e.g. reading and mathematics) in these ways. According to Geary, primary abilities are those that have been crucial to human survival and reproduction throughout our evolutionary history, and secondary abilities are those that are evolutionarily novel. Thus, according to Geary (Educational Psychologist, 2008), “If our goal is universal education that accompanies a variety of evolutionarily novel academic domains (e.g. mathematics) and abilities (e.g. phonetic decoding as related to reading), then we cannot assume that an inherent curiosity or motivation to learn will be sufficient for most children and adolescents.”

My views on education are also informed by evolutionary theory but are very different from Geary’s. Through analysis of the literature on hunter-gatherer cultures and a
survey of anthropologists, I have found that children in these cultures acquire, through their self-motivated play and exploration, skills that are cognitively complex and evolutionary novel. For example, hunter-gatherer groups in different climates and terrains have very different ways of tracking game, and these change over time. Learning these tracking skills requires enormous effort and focus, yet essentially all boys learn them through their self-directed play and exploration. In our culture, today, children and adolescents similarly acquire complex computer abilities that amaze the adults around them and are certainly evolutionary novel.

In a nutshell, my evolution-based education theory is this: We have been cultural animals throughout our evolutionary history. The key adaptation, which distinguishes us from other apes, is our ability to acquire the unique skills, beliefs, and values of the culture into which we are born. Until very recently, the responsibility for this always lay with children. Natural selection led children to attend to the activities around them, to be curious about those activities, and to incorporate the skills that seem crucial to success in the culture into their play so as to develop expertise in them.

One observation that runs counter to Geary’s view, concerning reading, is that some children learn to read fluently well before they start school – without any explicit instruction. Research indicates that these children do not necessarily have higher IQs than others, but instead are children who – for one reason or another – became engaged with reading at an early age.

What would happen if we didn’t force-teach reading, writing, and arithmetic to young children in schools but instead provided an environment in which children would regularly see these skills used around them and would have ample opportunity to play and explore with peers (some older than themselves) who have already acquired these skills and use them in their play? I have been studying children’s learning in precisely such contexts, both at a radically alternative school and among homeschooling families that adopt the philosophy of natural learning referred to as unschooling. I have found that essentially all children in these conditions learn to read, write, and perform whatever numerical calculations are useful to them through their own initiative and motivation with minimal, if any, formal instruction. I described these observations in my talk and have summarized them in online articles (here, here, and here).
In 2011, a science commentary by David Sloan Wilson appeared in the newspaper, Education Week, entitled “Teaching Evolution and Using Evolution to Teach”. Although the meaning of the first phrase of this title is immediately obvious, how evolution can be used for teaching is much less apparent. To clarify this idea, Wilson begins his piece by stating “Whenever evolution and education are mentioned together in my circles, it is usually to discuss teaching evolution and keeping creationism out of public school classrooms. But evolution has an even more important role to play in education as a theory that can inform the design of more effective school programs and improve the teaching of all subjects.” The objective of the present article is to describe the evolutionary precepts that can guide research and theorizing in this rapidly developing area.

One might initially respond to the idea of using evolution to teach by asking precisely how a perspective based on the way our ancestors learned can inform the design of contemporary educational programs. After all,
is it not true that the academic competencies which today’s youth have to acquire to prosper in modern-day economies differ appreciably from the types of skills that youngsters in hunter-gatherer societies had to learn in order to successfully adapt as adults during the late Pleistocene period? Furthermore, as the latter abilities were probably acquired predominantly through observation, imitation, and apprenticeship, how could these modes of learning have any practical implications for the design of instructional strategies needed to facilitate the learning of abstract concepts and reasoning skills demanded by present-day educational requirements? In this essay, I will attempt to answer such questions by describing some of the leading theoretical perspectives concerning the implications of evolutionary science in general and evolutionary psychology in particular for improving educational policy and practice.

In order to properly frame both the educational and evolutionary contexts for this piece, I first need to provide some relevant background information. For those unfamiliar with the current status of research in the field of education, it should be recognized that education science has matured significantly during the past decade, developing a generally higher degree of methodological rigor than had previously characterized this discipline (e.g., the interested reader might wish to browse the standards of evidence for evaluating the efficacy of interventions established by the Institute of Education Sciences’ What Works Clearinghouse). A variety of comparatively sophisticated research designs and data-analytic approaches are currently being employed to provide a solid, evidenced-based foundation for implementing effective educational policies and practices.

Despite the commendable methodological advances that have been achieved in this field, by far the vast majority of contemporary educational research is designed to explain “how” economic, organizational, school leadership, curricular, pedagogical, psychological, social, and other situational factors influence the academic learning and achievement of students. Evolutionary scientists refer to these kinds of causes as “proximate” explanations in that they focus on the manner in which such immediate factors operate. Correspondingly, efforts to improve academic outcomes increasingly make use of research approaches that are designed to develop and test educational interventions based on theories of change which incorporate potentially modifiable mediators. From an evolutionary perspective, such mediators constitute the proximate or temporally contiguous mechanisms through which an educational intervention may exert its effects. However, what has received much less consideration is the potential value of designing instructional interventions informed by “ultimate” explanations, which focus on the “functionally adaptive origins” of children’s learning. This type of framing can provide insights into “why” natural selection may have favored specific modes of learning over the course of our species’ phylogenetic history (Scott-Phillips, Dickins, & West, 2011). Such a perspective could assuredly foster innovative studies about the goodness of fit, or lack thereof, between evolved learning and motivational biases and the modern-day demands of formal schooling.

Although proximate and ultimate causes frequently have been characterized as contrasting approaches, in actuality they constitute complementary explanations, with both being required for achieving a complete understanding (Scott-Phillips et al., 2011). Indeed, as Confer and colleagues (2010)
point out, these explanations mutually inform one another in that "Knowledge of ultimate functions is invaluable in guiding the search for the proximate causes, just as understanding proximate implementation informs the search for ultimate function" (p. 112).

Evolutionary Perspectives on Formal Schooling

Evolutionary developmental psychologist David Bjorklund and his colleague Jesse Bering (2002) maintain that evolutionary psychological theory should be regarded as an overarching framework for studying the ways in which youngsters’ developing cognitive and social skills may be adaptive or maladaptive in school environments. Most scholars working in this emerging area would probably agree with the following claim by Bjorklund (2007): "Children did not evolve to sit quietly at desks in age-segregated classrooms being instructed by unrelated and unfamiliar adults" (p.120).

Of course, as he has acknowledged, this view should not be taken to imply that schools ought to adopt a "back-to-nature" approach to instruction (Bjorklund & Bering, 2002). This being said, an evolutionary psychologist who probably comes closest to espousing such a position is Peter Gray of Boston College. Gray (2011) contends that an examination of education in hunter-gatherer groups suggests that through natural selection, children have evolved to acquire their culture through self-directed play and exploration. In addition, based on our phylogenetic history and data from extant traditional societies, he argues that an ideal educational environment would, among other things, permit age-mixed interactions, provide access to culturally relevant tools and equipment, and allow freedom of expression and debate. Gray suggests that a future direction for research would be to study the environmental features that maximize children's abilities to educate themselves.

The most comprehensive and well-developed evolutionary perspective on education to date is that of evolutionary psychologist David Geary (2007), who has formulated the conceptual foundations for an emerging discipline known as “evolutionary educational psychology.” This field is concerned with the study of how children's inherent motivational biases influence their ability and need to engage in activities that will lead to acquiring the evolutionarily novel academic knowledge and skills demanded by formal schooling. More specifically, this theorist has put forth a series of principles for this comparatively new domain, suggesting that these should be viewed as a “blueprint” a) for conceptualizing the development of academic skills, and b) that can guide instructional research and theorizing.

Essentially, Geary argues that the evolved cognitive systems and inferential biases that define folk knowledge (i.e., beliefs used to reason about everyday physical, social, and psychological entities and events) are not sufficient for learning the kinds of complex abstract knowledge required to succeed in contemporary society. Furthermore, he contends that children possess inherent motivational and behavioral biases to engage in activities that will adapt these folk abilities—what Geary calls “biologically primary knowledge”—to their local surroundings, such as socializing with peers and exploring their own physical environment. However, according to Geary, these motivational dispositions will often be incompatible with the need to engage in activities that will result in learning culturally-specific, novel information. Geary refers to these kinds of abilities as “biologically secondary knowledge,” which developed only quite recently in our species’ intellectual history (i.e., over the past
several thousand years)—such as learning to read or to solve math problems.

Finally, at least during the initial stages of acquiring such skills, he maintains that students need to exert an effortful focusing of their attention as well as to allocate limited working memory resources to the learning of such evolutionarily novel academic information. As it turns out, the concept of working memory limitations serves as a fundamental tenet of another educational theory that draws on evolutionary science—Cognitive Load Theory (CLT)—which has had a major impact on both educational researchers and instructional designers. Formulated by Dr. John Sweller of the University of New South Wales, this theory alleges that the evolution of the structures and functions of human cognitive architecture is analogous to the ways in which biological structures and functions have evolved (Sweller, 2004). Building on the assumption that the learning of novel information can be hindered by the limited capacity and duration of working memory, CLT has generated a series of principles for designing strategies to reduce the load on students’ working memory during instruction. One of these is the "modality effect," where using a visual presentation of pictorial material accompanied by auditory presentation (narration) of textual material yields learning that is superior to instruction using only one modality, such as presenting the same material solely in visual form—pictures accompanied by written text. (It should be noted here that this effect is only found under conditions in which the two sources of information are incomprehensible when isolated and must be mentally integrated in order to be understood.)

Historically, the explanation for the modality effect as derived from CLT is that whereas students in the single modality condition can rely on only the cognitive resources of the visual subsystem, those who are administered the information in an audiovisual format can draw on the independent cognitive resources of two separate subsystems. As a consequence, their working memory capacity is effectively increased. However, Paas and Sweller (2012) recently argued for an "evolutionary upgrade" of CLT based on Geary’s evolutionary account of the distinction between biologically primary and biologically secondary knowledge, and the accompanying cognitive demands associated with the latter. In this paper, they explain how several cognitive load effects can be interpreted as relying on the use of biologically primary knowledge to assist in the learning of biologically secondary information. For example, with respect to the modality effect, these scholars suggest that from an evolutionary perspective, the use of both an audio and a visual instructional format is advantageous because “We may have evolved to listen to someone discussing an object while looking at” (p. 39). Concomitantly, they note that “We certainly have not evolved to read about an object while looking at it because reading itself requires biologically secondary knowledge” (p. 39).

Conflicting Instructional Practices Informed by Evolutionary Theory

The theoretical positions of Gray and Geary, both derived from an evolutionary perspective, are relatively commensurate with respect to acquiring biologically primary knowledge, especially as it occurs in children prior to their introduction to formal schooling. As Bjorklund and Bering (2002) aptly describe it, this kind of knowledge consists of evolved abilities acquired universally in species-typical environments for which...
children are inherently motivated to learn and practice, often spontaneously. And although the implications of Geary’s and Gray’s views as they pertain to the optimization of educational settings and practices for young children are generally similar, the instructional practices advocated by these two scholars for the acquisition of evolutionarily novel (biologically secondary) knowledge differ markedly. Namely, whereas Gray contends that self-directed learning will be sufficient for acquiring even complex abstract knowledge, Geary maintains that direct or explicit instruction will be needed when students have to learn such information. According to Gray, as long as students have the freedom to explore their academic environment and have free access to books, computers, and knowledgeable as well as caring adults (if they request such assistance), they will be able to learn what they need to know to become successful even in today’s modern economy. In contrast, Geary argues that to acquire evolutionarily novel concepts and skills, like solving linear algebra problems or learning basic Newtonian physics, students have to execute complicated and effortful cognitive operations, such as inhibiting automatic and implicit processing of folk-related knowledge. It is because of these kinds of challenges that he strongly recommends the use of formal, well-organized, and explicit instruction by teachers.

At this point, one might ask whether Geary’s evolutionary perspective has any implications for using a cooperative learning or small group approach for acquiring biologically secondary knowledge. A major reason for posing this question is that many teachers believe such methods to be effective—even though their actual use, as measured by classroom observational studies, appears to be quite rare (Pianta et al., 2007). From Geary’s point of view, although social interactions permit children and adolescents to learn about their peer group as well as how to organize and manipulate the dynamics of these groups, socializing with one’s peers may not be beneficial for mastering abstract, evolutionarily novel information (Geary, 2007). I have argued elsewhere (Berch, 2007) that it should be possible to co-opt students’ interest in socializing with their peers by having them engage in cooperative learning and problem-solving in the service of acquiring biologically secondary knowledge and skills. But the key to doing this successfully appears to require orchestrating the interactions among students and forming a reward structure that regulates their motivation in a way that directs it toward working cooperatively to reach a shared goal. In addition, as Dansereau, Johnson, and Druckman (1994) pointed out almost 20 years ago, improving individual achievement in cooperative learning situations can be achieved if teachers supply explicit interaction scripts, train students in essential peer interaction skills, and guide as well as monitor these interactions.

Consistent with the latter recommendations, David Sloan Wilson and colleagues (2011) recently carried out a study with at-risk high school students (9th and 10th graders) in Binghamton, NY who qualified for a program called the Regents Academy if they had failed at least three of five courses taken during the previous year. This program was based on three bodies of knowledge: 1) the work of the late Elinor Ostrom, a political economist who won the Nobel Prize for economics in 2009, by adapting the eight design features she developed for groups to cooperate in order to manage common pool resources. These include, for example: consensus decision-making, monitoring to detect lapses in cooperation, rapid conflict resolution that is perceived by group members as fair, and
relations among groups that correspond to the same principles as relations among individuals within groups; 2) providing a safe and secure school environment; and 3) giving short-term rewards for cooperating and for learning. Using a randomized-control design, these investigators demonstrated that the Regents Academy students not only outperformed the comparison group, but also performed as well as the average high school student in Binghamton on state-mandated exams in all subjects. Importantly, Wilson et al. point out that although none of the program’s design features were unusual, the use of a theoretical framework based on evolutionary science permitted them to be organized in a manner that yielded a remarkably successful set of outcomes.

In sum, it should be noted that the learning environment and some of the instructional approaches (e.g., cooperative learning) implemented by Wilson and colleagues seem more closely aligned with those recommended by Gray than by Geary. That said, a detailed examination of their design features reveals the use of a more structured set of approaches than Gray might endorse, including behavior management techniques (e.g., extrinsic rewards), specific curricula, learning progressions, and various assessment strategies. Consequently, one can view the methods used by Wilson et al. as representing a rapprochement between the more extreme positions advocated by Geary and Gray. Furthermore, it should be recognized that the conflicting instructional approaches advocated by these two theorists constitute legitimate scientific differences and also demonstrate that adopting an evolutionary perspective does not necessarily lead to a monolithic theoretical stance (Confer et al., 2010).

An Evolutionary Perspective on Bullying

Although we have seen how evolutionary theory can inform the design of educational environments as well as effective instructional strategies, the potential benefits of incorporating such a perspective when developing other kinds of school-related programs, practices, and activities are much greater than most educators and policymakers might appreciate. One such example concerns the escalating growth of bullying in schools. According to Anthony Volk and colleagues (2012), bullying is universal across cultures with an estimated several hundred million adolescents directly involved when considered on a global scale. Although many researchers view that bullying behaviors emerge as a consequence of maladaptive development, evolutionary psychologists consider bullying to be an evolved, facultative adaptive strategy in that it is likely to develop and be manifested only under particular environmental conditions (Ellis et al., 2012).

More specifically, even with a predisposition to engage in bullying, adolescents will do so only when its benefits outweigh its costs. The benefits include greater access to somatic (health and survival), sexual (e.g., increased dating or sexual opportunities), and/or dominance (social status) resources (Volk et al., 2012). Furthermore, as Ellis and colleagues convincingly point out, many anti-bullying interventions do not succeed because they are based on an erroneous stereotype that bullies are socially incompetent. These researchers also contend that from an evolutionary perspective, for an intervention to be effective in school settings it would need to modify the cost–benefit ratio of engaging in bullying so that adopting such a strategic approach for acquiring resources would cease to be adaptive.
The Evolutionary Origins of Teaching

Although an evolutionary approach to the design of instructional strategies has great potential for improving academic learning and achievement, proper application of such techniques of course constitutes only part of the expansive toolkit that teachers must employ to be effective in their classroom practice. Among numerous other day-to-day responsibilities, they have to create an optimal learning environment, implement the designated curriculum with fidelity, monitor student progress, and make judicious use of both formative and summative assessments. Although the study of pedagogy, the constellation of skills needed to teach something to someone, is of great interest to contemporary educational researchers, it is primarily the role of proximate explanations of high quality teaching that are the focus of most such investigations. But it is the ultimate or functional origins of teaching skills that are of principal interest to evolutionary scientists, including anthropologists, archaeologists, zoologists, and psychologists. These researchers and theorists use a variety of methods to investigate the phylogenetic history of pedagogy, including the analysis of archaeological and ethnographic records to assess how ancestral youth acquired hunting, craft, and tool-making skills through observation, imitation, and formal apprenticeships. Although still a nascent domain of inquiry, this research has begun to yield some exciting findings and novel theoretical developments that may eventually have important practical implications for modern educational policy and practice.

To begin with, Kim Sterelny (2012), a leading philosopher of biology acknowledges in his book The Evolved Apprentice that the role of explicit teaching in traditional society is recurrently controversial. Take for example the position of anthropologist David Lancy, who after reviewing the ethnographic and to some extent the historical record asserts in an article provocatively titled “Learning from Nobody” that “Teaching has been largely superfluous in the process of cultural transmission throughout human history” (2010, p. 97). Rather, according to Lancy, skills such as herding, foraging, gardening, and caring for infants in pre-modern society were acquired through observation, imitation, replication, and practice in a stepwise sequence he refers to as “the chore curriculum.” He concludes that children have traditionally acquired their culture through “self-guided learning” rather than a dependence on “active” teaching by an adult who systematically intervenes with the objective of changing a learner’s behavior.

Alternatively, evolutionary anthropologist Jamshid Tehrani and archaeologist Felix Riede arrived at the following conclusion after they reviewed ethnographic case studies and the archaeological record pertaining to the learning of complex craft skills: “The evidence we present suggests that pedagogy has played an essential role in securing the faithful transmission of skills across generations, and should be regarded as the central mechanism through which long-term and stable material culture traditions are propagated and maintained” (2008, p. 316). Their review suggests that pedagogy in these contexts can be characterized as entailing “the gradual scaffolding of skill in a novice through demonstration, intervention and collaboration” (p. 316).

Yet another perspective on the evolution of pedagogy has been put forward by cognitive psychologists Gergely Csibra and
György Gergely (2009). These scholars have hypothesized that what they call “natural pedagogy,” a type of human communication, arose during hominin evolution to enable the rapid and efficient transmission of generic knowledge and skills between individuals. In contrast to Lancy’s perspective, Csibra and Gergely argue that even craft and tool-making skills include content, features, and action sequences that are “cognitively opaque” to the naïve observer (i.e., both causally and teleologically), thus making them difficult to acquire solely through observational learning.

After reviewing these different perspectives along with other findings, Strauss and Ziv (2012) recently concluded that teaching is not only species-typical, appearing to be ubiquitous across cultures, but also unique to our species. They claim that this uniqueness is based on the requirement of a “theory of mind,” meaning that teaching consists of: a) an intentional activity that is b) undertaken to increase a learner’s knowledge or understanding (i.e., based on recognizing the learner’s mental state).

But precisely how can we account for the emergence of teaching in our evolutionary history as well as the factors that led to the selection of the requisite behavioral traits that were adaptive with respect to their fitness consequences? Although we still know very little about such ultimate causes, some headway has been made in characterizing how these changes may have transpired. As Thornton and Raihani (2008) have pointed out, “Teaching will be favoured by selection only where the costs to teachers of facilitating learning are outweighed by the long-term fitness benefits they accrue once pupils have learned, and these benefits will be scaled by the ease with which pupils could learn without teaching” (p. 1823). Furthermore, they suggest that natural selection probably favors different types of teaching, depending on whether it advances the learning of declarative information (i.e., “knowing that,” meaning content and facts) or procedural information (i.e., “knowing how” to perform skills).

At the very least, this brief review of multidisciplinary research and theorizing about the evolutionary origins of pedagogy indicates that some important progress is being made in uncovering the phylogenetic history of explicit teaching skills and behaviors. What we learn from this work may well have important implications for how to best prepare and train not only teachers, but also parents—with respect to their pedagogical role in facilitating their children’s acquisition of cultural norms, practices, and knowledge. Importantly, however, for those who maintain that active teaching has been relatively uncommon in our species’ history, this does not preclude adults from trying to construct children’s home, school, and after-school settings and surroundings so as to maximize conditions that will enhance learning and achievement. In other words, as Sterelny (2012) has cogently pointed out, “... while the role of teaching in traditional societies is often quite limited, adults can and do structure and engineer the learning environment, even without explicit teaching” (p. 36).

Conclusion

Taken together, the research and theoretical frameworks I have described here clearly demonstrate the promise that evolutionary science holds for improving educational research, practice, and policy. However, it is equally obvious that it will take a concerted effort on the part of not only researchers, practitioners and school administrators, but also parents and other education stakeholders before the full potential of adopting an evolutionary perspective on schooling can be realized.
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