

Evolution and education

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Evolutionary educational psychology is the study of how children's evolved learning and motivational biases influences their ability and motivation to learn in school. Evolved learning and motivational biases are organized around the domains of folk psychology, folk biology, and folk physics. There are also domain-general systems that comprise attentional control, working memory, and problem-solving competence that can be used to act on and modify folk systems. The combination supports the creation of cultural and academic innovations and children's learning of these evolutionarily novel innovations in school. The basic premises and principles of evolutionary educational psychology are described, and their potential utility is illustrated by discussion of the relation between folk psychology and children's learning to read and the relation between evolved motivational dispositions and children's academic motivation.

Evolución y educación. La psicología evolucionista de la educación estudia cómo los sesgos de aprendizaje y motivación de los niños generados durante la evolución influyen su habilidad y su motivación para aprender en la escuela. Dichos sesgos de aprendizaje y motivación se organizan en torno a los dominios de la psicología intuitiva, la biología intuitiva y la física intuitiva. Existen también sistemas de dominio-general que comprenden el control atencional, la memoria de trabajo y la competencia para resolver problemas, que pueden ser empleados para operar y modificar los sistemas intuitivos. Esta combinación permite la creación de innovaciones culturales y académicas, así como el aprendizaje infantil de estas innovaciones evolutivamente novedosas en la escuela. Es este artículo se describen las premisas y principios básicos de la psicología evolucionista de la educación, y su utilidad potencial se ilustra a través de una discusión sobre la relación entre psicología intuitiva y aprendizaje infantil de la lectura, y la relación entre las predisposiciones motivacionales evolutivas y la motivación académica de los niños.

The human developmental period is at least 50% longer than that of our closest living relatives and that of our predecessors (Bogin, 1999). One presumed benefit is the opportunity for children to learn the nuances of the social, biological, and physical worlds in which they are embedded. The skeletal structures of the corresponding knowledge bases in folk psychology (e.g., face processing), folk biology (e.g., knowing living and nonliving things differ), and folk physics (e.g., navigation) are inherent but fleshed out with children's self-initiated play and exploration, imitation of more competent children and adults, and by cultural knowledge and traditions transmitted from one generation to the next through rituals, storytelling, and mythologies (Bjorklund, 2007; Brown, 1991). The evolved plasticity in folk systems and the mechanisms of attentional control, working memory, and problem solving appear to support the generation of culturally-novel technologies and information (e.g., the scientific method) and the transmission of these advances across generations (Geary,

2005). A corresponding cost is the creation of a gap between the skeletal structures of folk domains and corresponding child-initiated activities that flesh out these domains, and the cultural and technological advances over the past several thousand years.

In short, the accumulation of cultural knowledge and scientific and practical innovations during our recent history has outpaced children's evolved and self-initiated motivational and learning biases, resulting in a gap between the folk competencies that emerge in traditional societies and the competencies needed to function as adults in modern ones. I highlight a few of the key implications for children's learning in modern schools (see Geary 1995, 2002, 2007, 2008). I begin with an illustration of the difference between evolved biologically-primary cognitive abilities and culturally-specific biologically-secondary abilities that children are expected to learn in school. I follow with an overview of the implications for the discipline of evolutionary educational psychology, and illustrate how these can help us to better understand children's academic motivation or lack thereof.

Biologically-primary domains and secondary learning

The universal attentional, cognitive, and attributional biases that constitute folk domains are called biologically-primary to distinguish them from abilities that are culturally-specific and dependent on more formal instruction for their emergence (Geary,

1995). Primary domains provide the foundation from which secondary ones can be built. The building of secondary abilities is only possible to the extent the underlying primary systems are modifiable through experience and through top-down processes that enable people to explicitly change primary representations or to link them together in novel ways. The details are beyond the scope of this article, but the mechanisms include the use of working memory and controlled problem solving, core components of general fluid intelligence (Geary, 2005). Following Alexander (1989), my colleagues and I have proposed that the evolution of fluid intelligence was driven by intense social competition (Flinn, Geary, & Ward, 2005; Geary, 2005); specifically, the ability to generate explicit mental simulations of social dynamics in working memory and to generate and rehearse behavioral strategies to cope with these fluctuating conditions. The key is the evolution of fluid intelligence, which allows people to explicitly represent components of primary systems in working memory and modify these systems to create or learn about evolutionarily-novel knowledge or innovations.

An example is provided by modification of biologically-primary language systems during children's reading acquisition (Mann, 1984; Rozin, 1976); these studies support the prediction that the evolved language systems underlie the core components of reading competency (Bradley & Bryant, 1983; Connor, Morrison, & Petrella, 2004). Early reading acquisition is dependent on an explicit awareness of distinct language sounds (phonemes) and the ability to decode unfamiliar written words into these basic sounds (Wagner & Torgesen, 1987). The latter requires an explicit representation of the sound (e.g., *ba*, *da*) in phonological working memory and, during the early phases of learning, an effortful association of this sound and blends of sounds with corresponding letters and letter combinations (Bradley & Bryant, 1983). Phonological working memory has also been proposed as the mechanism that supports vocabulary acquisition during natural language learning (Baddeley, Gathercole, & Papagno, 1998; Mann, 1984). However, unlike word decoding during reading, this form of word learning occurs quickly and the associated mechanisms operate automatically and below conscious awareness (Pinker, 1994).

Unlike natural language learning, which occurs during social interactions and with little effort, the majority of children learn word decoding with systematic, organized, and teacher-directed explicit instruction on phoneme identification, blending, and decoding (Connor et al., 2004; Lovett, Lacerenza, Borden, Frijters, Steinbach, & De Palma, 2000; Stevens, Slavin, & Farnish, 1991). Other components of skilled reading include fluency and text comprehension. Fluency is the fast and automatic retrieval of word meanings as they are read, and text comprehension is just that; coming to understand the meaning of the composition. Comprehension arises from several component skills, such as locating main themes and distinguishing highly relevant from less relevant passages. Again, unlike comprehension of spoken language, many children need explicit instruction in the use of these strategies to understand written text (Connor et al., 2004; Stevens et al., 1991).

Evolutionary educational psychology

By distinguishing primary and secondary abilities, we can better understand why most children learn the complexities of their native language with little effort but several years later, when

they are more «cognitively mature,» they may find learning to read difficult. Acknowledging potential differences in the mechanisms of learning and in the ease with which children learn primary and secondary abilities is only the first step in the development of instructional practices informed by an understanding of evolved biases and constraints on human learning. In this section, I review the basic premises and principles of this newly emerging field of evolutionary educational psychology.

Premises

Evolutionary educational psychology is the study of how educational interventions interact with children's evolved learning and motivational foundations to produce biologically-secondary abilities and knowledge. The first premise is that children have inherent but not fully developed attentional, perceptual, and cognitive systems that allow them to identify and process information in folk domains and that guide associated behavioral and learning strategies; see Geary (2005) for a taxonomy of folk domains. An example is infants' orientation to human motion, voices, and faces (aspects of folk psychology) which in turn engages them with their parents and other individuals in their social world, resulting in relationships that are in the infants' best interest (i.e., parental attachment) and providing the experiences needed to distinguish parents from other adults.

The second premise is that engagement in these forms of primary behaviors—others include social play and exploration of the environment and objects—recreates the ecologies of human evolution: Children's self-initiated attentional and behavioral biases create the same types of experiences that led to the evolution of folk systems, and provide the evolutionarily-expectant feedback to the developing brain and cognitive systems that is needed for normal growth of folk competencies (Greenough, Black, & Wallace, 1987). These are the experiences needed to elaborate on the skeletal folk systems; for instance, learning to discriminate one face from another. One implication is that many biologically-primary cognitive abilities are modifiable, within constraints, and thus can be adapted to the many nuances in social relationships found across cultures and generations and to the nuances of the many biological and physical ecologies in which humans live.

I have argued that the inherent link between children's primary activities, such as social play, and the experiential feedback these activities provide is not sufficient for many forms of secondary learning. This is because these activities are directed toward those features of the social, biological, and physical worlds that were recurrent during human evolution, and not the culturally-novel information that has been developed over the past several millennia. Moreover, the ways in which many forms of information are transferred from one generation to the next has changed. Ones' cultural history and knowledge of ancestors has been conveyed to children through oral traditions (e.g., storytelling), mythology, and ritual for much of human evolution (Brown, 1991), but is now conveyed through written text and formal history and social studies courses in school. In traditional cultures and almost certainly during our evolutionary history, children focused on the activities of adults and older children and selectively imitated many of their activities, which in turn contributed to their development of culturally-important competencies, such as hunting. In the same way, observation of

parental reading may make books more interesting to children than would otherwise be the case, but playing with books does not result in the cognitive ability to phonetically decode novel words in the same way that playing with a bow and arrow contributes to learning how to use this weapon.

These reasons and others lead to the third premise: The brain and cognitive systems that support humans' ability to *explicitly* represent social dynamics and other changing patterns in working memory and to reason and problem solve to create novel strategies to cope are among the mechanisms that support creative-productive individuals' generation of cultural and technological innovations (Geary, 2005, 2007). These are the systems that allow for the top-down modification of folk systems, such as language, to create evolutionarily-novel knowledge and systems, such as written text. It follows that these mechanisms that compose general fluid intelligence must be engaged by others' in order to learn these innovations during schooling.

The gist of the premises is that: 1) aspects of mind and brain have evolved to draw the individuals' attention to and facilitate the processing of information that corresponds to folk domains; 2) these primary abilities are modifiable but only within inherent constraints; 3) children are inherently motivated to learn in folk domains, with the associated attentional and behavioral biases resulting in experiences that automatically and implicitly flesh out and adapt these systems to local conditions; and 4) there are evolved aspects of mind and brain whose function is to enable people to cope with novelty and change. The latter operate by enabling people to generate mental representations of potential future conditions and then to generate and rehearse behaviors to cope with variation in these conditions. These mechanisms include the core components of fluid intelligence and are critical for secondary learning.

Principles

Creative-productive individuals (see Murray, 2003) generate new knowledge and innovations by using general fluid intelligence and other less well understood processes (e.g., creativity) to modify and link together folk systems in novel ways. The new knowledge and innovations (e.g., scientific method) are retained across generations through artifacts (e.g., books) and traditions (e.g., apprenticeships), and accumulate.

The first principle of evolutionary educational psychology is that the cross-generational accumulation of these advances have resulted in, among other things, the emergence of science to more accurately understand phenomena that are the foci of folk domains. Darwin's principles of natural selection and Newton's theory of gravity and motion resulted in a gap between people's folk biological and folk physical knowledge and these principles of modern biology and physics. As Newton stated in the *Principia* (1995, p. 13), «I do not define time, space, place and motion, as being well known to all. Only I must observe, that the vulgar conceive those quantities under no other notions but from the relation they bear to sensible objects». In other words, the "vulgar" only understand physical phenomena in terms of folk knowledge and Newton intended to and did go well beyond this. Newton's insights created a gap between intuitive folk physics and scientific physics.

The second principle is that schools themselves are cultural innovations that emerge in societies in which scientific and cultural advances, such as those of Darwin and Newton, result in a gap

between folk knowledge and the competencies most people need for living in the society. Schools organize the activities of children so they can acquire the biologically-secondary competencies that close this gap. The third principle is that biologically secondary competencies are built from folk systems but, unlike the fast implicit learning that adapts folk systems to local conditions (e.g., learning to identify one's parents), this requires the effortful engagement of fluid intelligence. Fourth, children's inherent motivational bias to engage in activities that will adapt folk knowledge to local conditions will often conflict with the need to engage in activities that will result in secondary learning.

The gist is that knowledge and expertise that prove to be useful in the social milieu or ecology in which the group is situated are retained and transferred across generations. The transfer occurs in the form of cultural artifacts, such as books, or learning traditions, such as apprenticeships (Flinn, 1997). Across generations, the result is a gap between accumulating cultural innovations and knowledge and the forms of folk knowledge and abilities that epigenetically emerge with children's self-initiated activities. There must, of course, be an evolved potential to learn evolutionarily novel information and an associated bias to seek novelty during the developmental period and indeed throughout the life span. However, the breadth and complexity of the secondary knowledge available in modern societies will very likely exceed any biases to learn in all the evolutionary novel domains (e.g., reading, algebra) needed for success in these societies. Schools provide a means to winnow this information and to ensure a core set of skills and knowledge common to all members of the society, and a venue for teaching them.

Motivation to learn

If the complexities of social dynamics were among the critical pressures that drove the evolution of the human brain and mind (Alexander, 1989; Bailey & Geary, 2009), then children will have an evolved motivational disposition to engage in activities that flesh out knowledge related to the folk psychological domains; specifically, self (e.g., self awareness), social relationships (e.g., language, face processing), and group dynamics (e.g., in-group, out-group attributional biases). Many children are also predicted to be inherently motivated to engage in activities that will flesh out folk biological and folk physical competencies; the corresponding activities would manifest as an interest in other species and exploration of the environment and objects. The point is that theoretical and empirical research on children's early attentional biases and activity preferences can be placed within an evolutionary perspective. And, a broader understanding of these preferences and how they are expressed in school has the potential to improve our understanding of children's motivation to learn biologically secondary material.

Motivation in school

Children's evolved motivational biases are predicted to focus them on engaging in activities tied to recurrent themes during human evolutionary history and result in learning nuances of social relationships (folk psychology), about other species (folk biology), and aspects of the physical ecology (folk physics). Children are also predicted to show a preference for the activities that promote the cross-generational transfer of knowledge in

traditional societies. These include the use of stories to convey morals and other themes relevant to day-to-day living, and apprenticeships; specifically, learning culturally important skills (e.g., tool making) through observation of or direct instruction by more skilled individuals (Brown, 1991). The specific content of stories and apprenticeships is predicted to center on features of social dynamics or the ecology that children will need to learn before assuming adult responsibilities. In other words, there will be universal mechanisms (e.g., observational learning) that support the acquisition of culture-specific information (Bandura, 1986), in addition to attentional, motivational, and cognitive mechanisms that automatically and implicitly adapt folk modular systems to variation that is common across cultures and was recurrent during human evolution; for instance, a bias to form in-groups and out-groups is universal but the corresponding group dynamics are variable across cultures and contexts. The combination results in human universals, such as face processing and language, as well as many cultural particulars that are variations on these universal themes.

From this perspective, it is not surprising that many children value achievement in sports—ritualized practice of organized in-group/out-group competition—more than achievement in academic areas (Eccles, Wigfield, Harold, & Blumenfeld, 1993). It is also not surprising that students, on average, report that in-school activities are a significant source of negative affect (Larson & Asmussen, 1991). Csikszentmihalyi and Hunter (2003) found that the lowest levels of happiness were experienced by children and adolescents while they were doing homework, listening to lectures, and doing mathematics, whereas the highest levels were experienced when they were talking with friends. For high-school students, the weekend is the highlight of their week, largely because they can socialize with peers (Larson & Richards, 1998). A preference for engagement in peer relationships may not be useful for mastery of algebra, but it follows logically as an evolved developmental bias for a highly social species; these social activities allow children and adolescents to learn about their specific peer group and how to manage and influence social dynamics.

These findings are consistent with principle two, that schools do not emerge from the self-organizing dynamics of peer relationships but rather are a cultural innovation imposed on children and adolescents by adults to facilitate the cross-generational transmission of secondary abilities (e.g., writing) and knowledge (e.g., that a right angle = 90°). If the activities that are common in schools and designed to impart culturally-specific abilities and knowledge do not universally emerge as a feature of children's self-initiated activities, then it follows (principle three) that there will be a gap between the activities needed to learn these abilities and knowledge and the motivation to engage in them. The formalization of schooling is not, however, completely at odds with children's learning and motivational biases because the extended length of childhood and adolescence likely co-evolved with an interest in and ability to transfer culturally important information across generations (Flinn, 1997): A curiosity about and an ability to learn evolutionarily novel information is predicted, but so are substantive individual differences in the motivation and ability to learn this information.

The point is if there were not a gap between the secondary knowledge needed to function in modern societies and evolved motivational and learning biases, then the motivational

dispositions, interests, and abilities of the creative-productive individuals, such as Darwin and Newton, who developed this secondary knowledge would be mundane and readily duplicated outside of school. As Pinker (1994) has argued, language is an extraordinary ability that is unique to humans. But its acquisition is mundane and effortless for most children. This is not the case for Newtonian physics, or even for elementary reading.

Achievement motivation

The focus of research on achievement motivation is on children's understanding of the relation between effort and ability on academic outcomes (Nicholls, 1984); their valuation of academic learning in terms of mastery (i.e., desire understanding) or performance goals (i.e., standing relative to others) (Ames & Archer, 1988; Dweck & Leggett, 1988); their academic self efficacy (Bandura, 1993); and their expectancy of success and attributions regarding the sources of success or failure (e.g., ability vs. bad luck; Weiner, 1990). These are important research topics and literatures that have helped us to better understand children's motivation to learn in school. I illustrate how these topics can be placed within an evolutionary perspective by using Bandura's (1997) model of self efficacy.

"Among the mechanisms of agency, none is more central or pervasive than people's beliefs about their capabilities to exercise control over their own level of functioning and over events that affect their lives" (Bandura, 1993, p. 118). Self efficacy is an aspect of this personal agency and at its core is a self-referenced appraisal regarding the likelihood of success in various domains and through this influences the pursuit of achievement in these domains. Bandura emphasizes one's explicit appraisal of efficacy and attributions regarding associated outcomes (e.g., cause of failure). From an evolutionary perspective, these map onto the folk-psychological domains of self awareness, self schema, and the ability to explicitly represent associated information in working memory as part of the mental simulations that people use to strategize about and cope with evolutionarily-novel situations. The content of mental models will include attributional biases, expectancies, and other social-learning mechanisms that can influence evaluations of future goals and behavioral persistence in attempts to achieve these goals.

In other words, Bandura's (1993, 1997) model of self efficacy is consistent with an evolutionary perspective, but with different points of emphasis regarding children's academic motivations and corresponding self evaluations. One difference regards my prediction of domain-specific biases associated with folk domains and a much weaker motivational bias for academic learning, such as mathematics. Further, the core of the self schema—an evolved bias to remember and organize knowledge about one's self—is predicted to be referenced in terms of one's standing vis-à-vis peers and, importantly, more so for traits that have an evolutionary history than for culture-specific knowledge and abilities. The former include physical abilities and attractiveness, social influence, and family status (Geary, 2010). These are predicted to be universal and to influence the development of self schemas and self evaluations, whereas success in culturally specific activities, such as mathematics, is predicted to be less central to emerging self evaluations, and indeed this is the case (see Harter, 1998).

From an evolutionary perspective, the valuation of academic achievement and the relation between achievement and self esteem

is predicted to be highly variable across- and within cultures, and heavily influenced by peers' valuation of academic achievement. From a social-learning perspective (Bandura, 1986), many children will imitate parents and teachers who engage in academic activities (e.g., reading); many will come to focus on these activities because they provide access to culturally valuable resources, such as a job; and, many will come to enjoy these activities in their own right, developing a mastery orientation. Children and adolescents will also develop a sense of academic self efficacy in cultures with formal schooling. These outcomes also follow from an evolutionary perspective that includes evolved modes of cross-generational knowledge transmission.

Another notable difference in the social learning and evolutionary perspectives concerns the specificity of predictions: For instance, with successive grades, academic content will increasingly diverge from its evolved foundation, and thus academic learning is predicted to become more difficult and any motivation to engage in this learning is predicted to decrease, as it is also the case (see Eccles et al., 1993). Social living also becomes more complex and nuanced as people mature into adulthood, but motivational disengagement from social life is predicted to be far less common than disengagement from academic life. These differences follow logically from an evolutionary perspective, but less readily from a strictly social learning one.

Conclusion

Debate over whether children's ease of learning and their learning motivation are influenced by evolved biases or by cultural factors results in a false dichotomy. Humans have evolved to

create culture—a system of shared ideologies and rules for social behavior that enable the formation of large cooperative groups—and children and adults have evolved learning and motivational mechanisms that support the cross-generational transfer of culturally useful knowledge. The mechanisms include child-initiated play, observational learning, and adults' use of stories to teach cultural knowledge. An evolutionarily-informed educational psychology is needed because we are at a point in human history where the store of cultural knowledge and the array and complexity of evolutionarily novel abilities needed to function in modern societies has outstripped the capacity of evolved learning and motivational mechanisms. Schools emerged in these societies to address the limitations of these mechanisms and to formalize the cross-generational transfer of knowledge.

Evolutionary educational psychology is the study of how children's inherent learning and motivational biases influence their ability and motivation to learn evolutionarily novel academic abilities and knowledge in school. An evolutionary approach has the potential to answer key questions in instruction and learning, such as why many children need explicit instruction to learn word decoding and text comprehension but do not need such instruction to produce and understand natural language, and why many children value peer relationships more than they value academic learning. Equally important, the mechanisms I outline here and elsewhere (Geary, 2005, 2007, 2008) provide a means for generating hypotheses about children's academic motivation and their ease of learning in school, as well as equally important hypotheses about the effectiveness of alternative instructional methods. I outlined the basic argument for reading, but it also applies, in theory, to all other secondary domains.

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