Evolutionary and Genetic Bases of Education: An Adaptive Perspective

Juko ANDO
(FACULTY OF LETTERS, KEIO UNIVERSITY)

The present article attempts to verify the Homo educans hypothesis that human education is not a by-product of evolution, but a direct outcome of natural selection, based upon recent evidence, including findings on non-human teaching as a precursor of human education, empirical findings on the beginnings of human teaching (e.g., the teaching of rules even by 20-month-old children), a life history theory of childhood and old age, consideration of Geary's (2002) theory of the motivational bias of educational content and the structure of intelligence (single-general vs. multiple-specific issues), and findings on human behavioral genetics in the context of the ontogeny of education. Human education can be defined as "learning based on triadic interaction". A new integrated discipline on education, the "evolutionary science of education", is anticipated.

Key Words: active teaching, education, evolution, triadic interaction, behavioral genetics

"Der Mensch ist das einzige Geschöpf, das erzogen werden muß" (Man is the only being who needs education; Kant, 1803/1960). This famous sentence is usually understood as a declaration that education is so specific and idiosyncratic to human beings that there is a complete division between humans and all other species. Education is likely to be designed not by natural selection, but by the rational and intentional plans of human intelligence. Even after the recent achievements of comparative and evolutionary studies of cognitive and learning abilities, there have been very few attempts to explain education or teaching behavior from an evolutionary perspective.

Kant's passage in his Education (1803/1960) does declare, however, the very idea that education is an evolutionary outcome; his statement represents a working hypothesis that education is specific to humans as a biological species, and that Homo sapiens acquired, in the process of evolution, biological conditions that enable people to conduct teaching behavior. It is easy to imagine that education, however it is defined, would be an adaptive and highly beneficial behavior for humans' lives. Most of the social rules that people need to live an autonomous life, as well as the knowledge and skills needed for job performance, have to be taught and acquired through formal and

---

Figure 1 (a plus b):

**Figure 1a** Adaptation in Nonhuman Animals

**Figure 1b** Adaptation in Human Beings

[Note] Nonhuman animals adapt directly to natural environment, whereas human beings adapt to the natural environment through culture and have to adapt to school in order to adapt to culture.
informal processes of instruction and learning. Because human beings adapt to the natural environment through culture, they cannot survive in the natural environment if they cannot adapt to human culture (Figure 1).

On the other hand, other animal species directly adapt to the natural environment by using innate behavioral strategies and individual learning, as a result of which they can survive and reproduce. Even social animals that construct communities can acquire behavioral patterns for survival and reproduction by individual and observational learning, not by teaching. In humans, however, intentional teaching facilitates learning, as well as individual and observational experiences. It seems that humans are strongly motivated to teach others.

Nevertheless, after evolutionary theory has been established, why has the evolutionary basis of educational or teaching behavior not been discussed? This may be because teaching behavior has been considered to be a by-product of other abilities specific to humans, such as the manipulation of symbols (including language and numbers), communication skills, observational and imitative learning (modeling), theory of mind, and empathy (Kruger & Tomasello, 1996; Premack & Premack, 1996, 2004; Strauss & Ziv, 2004). Thus, it is likely that education has been considered as a cultural product, in the same way as police, insurance, and money systems, all of which are necessary for human life but which are not direct biological phenomena. The fact that there were no precursors of teaching behavior even in chimpanzees, the closest primates to Homo sapiens, has supported this idea.

Since 2006, however, a series of historical findings has emerged indicating the existence of active teaching in species relatively distant from Homo sapiens (i.e., tandem-running ants, meerkats, and pied babblers; Thornton & Raihani, 2008). These findings indicate that education itself can be understood as a direct evolutionary outcome. If so, it is possible to refer to hereditary and adaptive mechanisms underlying teaching behavior. Because human behavioral genetics has indicated that there is a substantial genetic component in individual differences in almost all aspects of human behavior (Turkheimer, 2000), it might be plausible to provide an integrated understanding of genetic variations in human ability in the context of the evolutionary basis of education.

The purpose of the present article is to discuss the ontogenetic and phylogenetic basis of education in terms of the working hypothesis—using concepts from genetics and adaptation—that human education is an evolutionary product.

The distinction between proximal and ultimate causes is essential to understanding evolutionary phenomena (Tinbergen, 1963). Although actual educational activities are often regulated by proximal reasons, such as a teacher's method of instruction and a student's specific motivations and interests, the aim in the present analysis is to describe educational phenomena in terms of ultimate factors.

1. What is evolution?

The core concepts of Darwin's evolutionary theory (the theory of natural selection) are variation, heredity, and competition, with adaptation as an integrated concept of the first three. Organisms usually bear many more offspring than there are parents, and not all of these individuals survive. Among a variety of individual differences in various phenotypic characteristics (variation), those individuals that possess characteristics that are more appropriate (adaptive) for survival and reproduction in a certain environment will tend to be selected by competition. If these adaptive characteristics are transmitted by genes (heredity) and continue to be selected from generation to generation, the number of individuals with these characteristics will gradually increase in a population, and finally all the members of a species will come to share them. This kind of temporal change of genetic conditions is what is referred to as “evolution”.

It is known today that the unit of evolution is neither an individual nor a species, but a gene. The organism evolves in the direction that makes as many gene copies as possible to deliver the gene to relatives; that is, it evolves in the direction that maximizes inclusive fitness (Hamilton, 1964). Because genes are transmitted to biological relatives, evolution occurs to benefit these relatives, and especially biological offspring; this is called kin selection. At a behavioral level, altruistic behavior has developed to help individuals rear as many offspring as possible. Additionally,
in the case of social animals, because altruistic behav-
ior toward individuals—even those with no direct kin-
ship—would increase the chance of a gene surviving in
turn, reciprocal altruism has developed. In humans,
reciprocal altruism has systematically developed from
personal-level features such as kindness and friend-
ship to social systems such as economy, law, and
insurance. Teaching behavior and educational sys-
tems are also important reciprocal altruistic behav-
iors in humans.

2. Evolution of education: Teaching in nonhuman animals

The question of whether there is teaching behavior in animals other than humans has long been discussed. Until quite recently, in terms of Caro and Hauser's (1992) operational definitions of teaching in nonhuman animals, the answer was “no”. Caro and Hauser (1992) proposed the following three criteria;
(1) An individual, A, modifies its behavior only in the presence of a naive observer, B.
(2) A incurs some cost, or derives no immediate bene-
fit.
(3) As a result of A's behavior, B acquires knowledge
or skills more rapidly or efficiently than B would have
otherwise, or B would not have learned at all.

The only exception that Kant mentioned in Education (1803/1960) was bird songs. Kant wrote, “.... as far as we know, no animal needs, for none of them, learn anything from their elders, except birds, who are taught by them to sing.” (Kant, 1803/1960, p. 5; author's italics). It is known that male Bengalese finches learn and copy species-specific and individual-specific fea-
tures of the songs of their parents or even biologically unrelated individuals, and create their own songs for females, thus maximizing their mating chances (Okanoya, 2004). This case, however, does not meet Caro and Hauser's (1992) criteria for teaching.
(1) An individual, A, modifies its behavior only in the presence of a naive observer, B.
(2) A incurs some cost, or derives no immediate bene-
fit.
(3) As a result of A's behavior, B acquires knowledge
or skills more rapidly or efficiently than B would have
otherwise, or B would not have learned at all.

The reason why such a highly intelligent species
does not show direct active teaching is that its mem-
bers cannot establish triadic interactions among two
individuals and an object (Tomonaga, Tanaka, Matsuzawa, Myowa-Yamakoshi, Kosugi, Mizuno, Okamoto, Yamaguchi, & Bard, 2004). Chimpanzees' way of learning “culture” is basically dyadic. Their learning is between an individ-
ual and an object (individual learning), or between an individual and an adult's behavior (observational learn-
ing). Figure 2a illustrates this. On the other hand, in
humans, when infants reach the age of about 9 months,
they start to engage in triadic exchanges based upon
the formation of a referential triangle of infant, adult,
and the object of which they share attention. This is
called the “9-month revolution” (Tomasello, 1995).
According to this formulation, human education can
be defined as learning based on triadic interactions
among a teacher, a pupil, and the learning material. A
teacher demonstrates to a pupil a dyadic interaction
with an object in order to facilitate the pupil’s imitation;
the teacher uses instructions, explanations, evalua-
tions, and encouragement. The pupil usually follows
the teacher's instructions in order to learn how to
interact with the object, and sometimes asks for teach-
ing and evaluation. (See Figure 2b)

Since 2006, however, three studies have been pub-
lished with results that meet Caro and Hauser's (1992)
three criteria and therefore verify the existence of
active teaching in nonhuman animals, specifically in
tandem-running ants (Franks & Richardson, 2006), meerk-
ats (Thornton & McAuliffe, 2006), and pied babblers (Rai-
hani & Ridley, 2008).

For example, Thornton and his colleague reported
Teaching in meerkats, Suricata suricatta (Thornton &
McAuliffe, 2006). Meerkats feed on various kinds of animals (e.g., scorpions) that are difficult to handle and potentially dangerous to their young pups. When the pups are younger, "helpers"—older group members, not the pups' parents—kill or disable the prey before provisioning the pups (criterion 1). Interestingly, the helpers adjust the frequency with which they kill or disable mobile prey and gradually introduce the pups to live prey, depending on the pups' age. In this case, the adults incur costs through giving the pups mobile prey that might escape (criterion 2), but the pups' handling skills improve as a result of practicing handling live prey (criterion 3).

These findings are significant for three reasons. First, "teaching" animals are not necessarily species closely related to humans (i.e., nonhuman primates). Second, teaching behavior does not necessarily require higher-order cognitive and social abilities such as a theory of mind. Third, parents are not necessarily the only ones who play the role of teachers for their offspring. The fact that, contrary to Kant's view, teaching behavior is observed in nonhuman animals indicates that human teaching might not be a secon-

3. Evolutionary basis of human education

3.1. Beginning of teaching

For most educational and developmental psychologists, the working hypothesis that education is a direct evolutionary outcome that emerged under selection pressure may sound too strong. The most common view of the origin of education attributes basic mechanisms of teaching to a theory of mind (Premack & Premack, 1996, 2004). Tomasello and his colleagues (Tomasello, Kruger, & Ratner, 1993) postulated that, in the development of general cultural learning in humans, children could learn something by instruction only when they reach the age of about 4 years, that is, only after a theory of mind is accomplished, indicating that the child at this stage can internalize the teacher's behavior and instructions. Before the age of 4 (and after the 9-months revolution), children learn culture only by imitative learning. They can understand an adult's intentions by perspective-taking (e.g., joint attention and social referencing), but cannot understand the adult's mental state by intersubjectivity, which is considered a prerequisite for instructed learning.

Compared with studies of learning, there have been fewer studies of the development of teaching. However, the most common idea is still that the emergence of teaching is accompanied by the ability to understand the other person's mental state. Strauss and her colleagues (Strauss & Ziv, 2004; Strauss, Ziv, & Stein, 2002) were the first researchers to claim that education is a natural cognition. In their review of teaching behavior, however, they claimed that even though the ability to teach is not necessary learned by being taught as such, it appears when an individual knows that the partner does not know. This skill develops after the age of 3, and teaching behavior itself develops as the child grows up.

However, if teaching has an evolutionary basis as its origin, leading to an innate motivation to teach others, and does not need to be based on highly
cognitive abilities such as theory of mind, it can be assumed that teaching emerges at a much earlier age.

Akagi (2004) successfully demonstrated this phenomenon. In his experiment, toddlers from 12 to 23 months of age saw an adult experimenter who pretended to fail a task in which a round plate had to put into a round hole. As the toddler watched, the experimenter forced the plate into a square hole. Active teaching by not only staring at the experimenter’s face but also by pointing at the round plate was observed in about 60% of toddlers over 20 months of age.

There are two important points to be noted from the results of Akagi’s (2004) study. First, acquisition of active teaching at a behavioral level occurs much earlier than 4 years, indicating the possibility that children can teach if they know that the partner is not doing the right thing, even if they don’t know what the partner does or does not know. Second, unlike the typical case in nonhuman animal teaching, the content of teaching is not related to food but to rules.

Ando (2008a, b) studied the content of teaching between infant twin siblings. Parents of twins from 17 months to 4 years old were asked to report as many as possible of the actions that occurred between their twins. Twins are obviously exactly the same age and have small within-pair differences in their experiences. This situation does not easily seem to lead to teaching behavior from one twin to the other. However, twins have established a long-term stable social relationship with each other, and it seems that all kinds of social interactional behaviors appear at a very young age in twins. Therefore, if teaching is an evolutionary outcome and is based upon some kind of innate motivation, it should be observable in the everyday life of twins by their parents.

Of the 1643 parents who participated in the Tokyo Twin Cohort Project (Ando, Nonaka, Osaki, Sato, Fujisawa, Suzuki, Yamagata, Takahashi, Nakajima, Kato, & Ooki, 2006), 533 responded to the questionnaire, reporting 209 cases of active teaching. These cases were categorized broadly into three groups: (a) symbols, which consisted of teaching kana syllables, numbers, names of things, and so on; (b) procedures, which consisted of teaching how to make origami, dance, fasten shoe-laces, and so on, and (c) social rules, which consisted of the inhibition of wrong-doing, teaching rules of play, and teaching places to put things.

The first teaching behavior, which was reported to have occurred when the twins were 20 months old, was directing where to sit down; the second, at 22 months, was to say “no” when a co-twin tried to perform a prank. Both of these are related to social rules.

Figure 3 shows developmental changes in the frequencies of these three domains. The numbers increase as the twins grow older. The earliest and biggest domain is social rules; symbols appear after 2.5 years of age. There are two jumps, from 2.5 to 3 years and from 3.5 to 4 years. The former may correspond to language acquisition and the latter may correspond to acquisition of a theory of mind. These findings replicate those of Akagi (2004), who reported that active teaching appears even in toddlers aged 1.5 years, and that the earliest content of teaching is social rules, not food.

From an evolutionary point of view, the finding that the contents in humans’ teaching at an early age are social rules and symbols is important, because social rules and symbols are what the human brain creates to adapt to culture. Through this process, people can adapt to, and survive in, nature (see Figure 1).

3.2 Developmental features of human teaching in terms of life history theory

In the evolution of education, there are two outstanding human stages in terms of life history theory (Bogin, 1999; Sprague, 2004): childhood and old age.

---

Figure 3 Developmental Changes in Active Teaching of Social Rules, Procedures, and Symbols in Young Twin Siblings
In humans, a new life stage, childhood, occurs between weaning and autonomous locomotion and feeding, accompanied by the cutting of adult teeth. Childhood ranges from the age of around 3 to 7 years. This stage is characterized by a moderate growth rate (slower than in infancy and adolescence), dependency for feeding, a mid-growth spurt, and cessation of brain growth by the end of the stage (Bogin, 1999, p. 55). It is assumed that the childhood stage may have originally evolved as a means by which parents and kin who are in the juvenile period could provide the offspring with food, freeing the mother from the demands of nursing and the inhibition of ovulation related to continuous nursing. This decreases the interbirth interval and increases reproductive fitness (Bogin, 1999, p. 190). The later juvenile stage is characterized by sexual and social maturation to prepare for adult life. Because of the insertion of childhood before the juvenile stage, humans have a much more extended learning period than is found in other primates.

Old age is another evolutionarily interesting life stage, because in humans, it extends for much longer than in other primates (Shultz, 1924), although it does not contribute to reproduction. A possible explanation for this is the "grandmother hypothesis", which postulates that older people help mothers avoid nursing and therefore help to increase reproductive fitness. In addition, this hypothesis implies that the opportunities that grandmothers or others of the older generation offer in terms of active teaching of children are also increased.

Thus, life history theory can provide explanations of the mechanisms underlying the evolutionary embedding of teaching activities in different generations and the unfolding of these activities according to human development over the span of a lifetime. Although the discussion here is very elementary, it offers the further possibility of connecting life history theory with theories of development, lifelong learning, adaptive expertise (Hatano & Inagaki, 1986), and even the design of educational systems.

### 3.3 Evolution of educational content.

Educational content appears to be a very non-natural and non-evolutionary issue. It is decided on by parents, teachers, school systems, and governments, all of which have preferences, value judgments, and ideologies that change with the times. It is also possible, however, that the content of material to be taught is evolutionarily regulated. As introduced in section 3.1 above, the earliest examples of infant teaching are rules that are arbitrarily made in, say, a game setting (Akagi, 2004) or a family (Ando, 2008a, b). This content is different from those of other animals, whose teaching is related mainly to foraging and food. This is probably because the human is an animal that uses a high level of cooperation based on reciprocal altruism. It is therefore quite important to share social rules among members of a human group. Cosmides (1989) showed experimentally that human reasoning is biased toward sensitivity for detecting those who cheat the social contract rules, indicating that this kind of reasoning bias has an evolutionary basis. It is therefore reasonable to assume that humans are motivated to teach a domain of social rules that is much stronger than other domains, even in infancy.

Geary (2002, 2005), who is, as far as the present author knows, strongly inclined to establish an evolutionary basis for educational phenomena, proposes a new discipline, evolutionary educational psychology, as "the study of the relationship between folk knowledge and accompanying inferential and attributional biases as these relate to academic learning in modern society" (Geary, 2002, pp. 327-328). His idea is that natural selection resulted in an evolved motivational disposition to gain access to, and control of, resources for survival and reproduction, such as social, biological, and physical modules, which leads to folk psychology, folk biology, and folk physics respectively, as well as other evolved domains (e.g., numbers and counting). Children are innately motivated to engage with information and activities associated with these kinds of folk knowledge as primary abilities, such as number-counting and arithmetic ability. Scientific, technological, and intellectual advances have emerged from these kinds of folk knowledge, but this resulted in a gap between folk knowledge and the theories and knowledge base of the associated sciences and disciplines (e.g., formal counting systems, Arabic arithmetic, algebra) as secondary domain abilities. Therefore, in order for students to close this gap, school education emerged. This "multiple domain view" is one of the most plausible hypotheses from an evolutionary point of
view for explaining the emergence of various academic disciplines taught in educational systems. According to this view, there are knowledge fields at the primary level that require few, or even no, teaching and are spontaneously learned and acquired (e.g., natural language).

Although different views of multiple domains (e.g., Gardner's multiple intelligence theory, 1983) or modules (e.g., the Swiss army knife analogy by Cosmides & Tooby, 1994) assume that each domain has a specific biological and evolutionary basis adapted to its own purpose, the idea of general intelligence has also been well developed in psychology since Spearman (1904). Mithen (1996) speculates that the Neanderthals' intelligence consisted of three major domains: technical, natural history, and social, and that linguistic and general intelligence were at their emerging stages. On the other hand, in Homo sapiens, a general intelligence that integrated different kinds of specific domain became dominant.

The single general vs. multiple specific issue of intelligence is one of the most controversial topics in the history of psychology. It is quite similar to the wave vs. particle debate with respect to light; the answer is "both". Human intelligence works in quite a general manner, but it is still, at the species level and at the individual level, biased toward learning some specific things more easily than others. Everybody can learn almost everything if there is no concern about the level of achievement of their resulting performance. The human mind is not a blank slate (Pinker, 2002). There are differences in the difficulties encountered in learning and teaching from domain to domain and from individual to individual that cannot be ignored. These differences are what make human education so difficult.

4. Ontogeny of education

4.1 Genetic individual differences in the human mind

If human education is regulated by evolution, which is, in turn, characterized by variation, competition, heredity, and adaptation, then the role of individual genetic differences in education is another important issue for discussion. The findings of human behavioral genetics have been summarized in the following three laws (Turkheimer, 2000):

1. All human behavioral traits are heritable.
2. The effect of being raised in the same family is smaller than the effect of genes.
3. A substantial portion of the variation in complex human behavioral traits is not accounted for by the effects of genes or families.

Figure 4 shows the relative proportions of genetic, family (shared) environmental, and non-systematic individual-specific (non-shared) environmental effects on individual differences for various human psychological (i.e., cultural in a broad sense) traits (calculated from raw data in Shikishima, Ando, Ono, Toda, & Yoshimura, 2006). This figure illustrates the above three laws: (a) substantial genetic contributions (30% to 70%); (b) no shared environment, except in the case of verbal intelligence; and (c) a substantial non-shared environment (usually more than 50%).

4.2 Genetic and environmental effects in education

From an educational point of view, the above three laws can be interpreted as follows:

1. Individual differences in all cultural attainments reflect differences in adaptive strategies acquired through formal and informal educational situations

---

(i.e., learning by triadic interaction) by individuals with different genetic dispositions who are trying to adapt to a cultural environment according to their own genetic condition.

(2) Family is not the place to teach and learn social rules and cultural contents systematically, independent from genes (except in the case of academic achievements, as discussed below).

(3) Behavioral attainments in educational processes are also the outcomes of processes of adaptation to situations just for now, for here, for this, and “for me”.

Laws permit exceptions, and academic education is one case. Academic achievements usually show substantial shared environmental effects (a summarized review is given by Ando, 2007). General intelligence (g or IQ) also shows a significant shared environmental effect until adolescence (McGue, Bouchard, Iacono, & Lykken, 1993), as is replicated in the present author’s data (see “verbal intelligence” in Figure 4). Because laws 1 and 2 imply that, in general, familial transmission of cultural behavior occurs mainly by genes (stochastically, because of polygenicity), academic matters and other issues related to academic performance are a special domain in an evolutionary sense; they require not only genetic transmission but also non-genetic (i.e., environmental) inheritance in families by intentional and non-intentional teaching, observational learning, and so on.

Three important points should be mentioned regarding the genetic and environmental features of individual differences in academic achievement. First, shared environmental effects on academic achievement may disappear in adulthood and old age. This is because evidence shows that, for general intelligence, shared environmental effects disappear in adulthood (McGue et al., 1993), and general intelligence and academic performance are highly correlated. That means that, contrary to parents’ common anticipation that they need to invest in current education for their children’s future, educational investments work only contemporaneously (in the here and now).

Second, from a behavioral–genetic perspective, genetic regulation of intelligence works in a single-general way, not in a multiple–specific way. Genetic factors for different cognitive abilities overlap substantially and, quite often, can be integrated as a unity (Kovas & Plomin, 2006; Shikishima, Hiraishi, Yamagata, Sugimoto, Takemura, Ozaki, Okada, Toda, & Ando, in press). The situation in academic performance is quite similar. Academic performance in various subjects (Wainwright, Wright, Luciano, Geffen, & Martin, 2005), and even behavioral and psychological processes related to academic performance (e.g., study hours, effective learning strategies, motivational processes, and perception of teachers’ attitudes: Ando, Murayama, Yamagata, Shikishima, Takahashi, Ozaki, & Nonaka, 2008), can be explained by a single genetic factor that is highly correlated with general genetic factors of intelligence (e.g., Bartels, Rietveld, Van Baal, & Boomsma, 2002; Luo, Thompson, & Dettman, 2003; Wainwright et al., 2005). This implies that “fitness” (in an ontological sense) to adapt to the formal educational content or strategies in an education system, at least in societies with modern school systems, is dependent mainly on genetic general intelligence, because general intelligence is the latest biological device in evolution that has no specific domains to adapt and, therefore, must be so “fluid” that it should be “crystallized” (Horn & Cattell, 1966) by educational experience.

General intelligence, however, is not the only genetic dimension of human diversity. Genetic personality structure cannot be integrated into a single factor, but instead has multiple, usually three or five, dimensions (Ando, Suzuki, Yamagata, Kijima, Maekawa, Ono, & Jang, 2004; McCrae, Yamagata, Jang, Riemann, Ando, Ono, Angleitner, & Spinath, 2008; Yamagata, Suzuki, Ando, Ono, Kijima, Yoshimura, Ostendorf, Angleitner, Riemann, Spinath, Livesley, & Jang, 2005). Just as a color printer can produce an incredibly rich variation of hues with only three colors (cyan, magenta, and yellow) plus black, human behavioral variation could be made genetically infinite by various degrees and combinations of at least three personality dimensions e.g., neuroticism, extraversion, and psychosis (Eysenck, 1947; novelty seeking, harm avoidance, and reward dependence (Cloninger, 1986); behavioral activation system, behavioral inhibition system, and fight-flight-freeze system (Gray, 1991)); plus general intelligence.

It can be imagined that this possible genetic infinity in human variation has enabled us to adapt to an incredibly wide range of environments through the use...
of a great variety of cultural resources and tools. If human education is an adaptive process in a biological sense, it can be assumed that genetic resources other than general intelligence must play important roles in educational settings. This issue also needs to be explored.

Finally, although the above three laws of behavioral genetics depict the general or main effects of genes and the environment, existence of a genotype × environment (GE) interaction is another law (for a summary reference, see Rutter, 2006, pp. 178-220). An example of a genotype × environment interaction in educational settings was provided by Ando (1992) in an aptitude-treatment interaction (ATI) paradigm. The Ando (1992) study indicated that genetically more intelligent students learned grammatical rules better in a grammar-Japanese translation-oriented instruction, whereas genetically less intelligent students learned better in a communication-oriented instruction. As it is well established that aptitude-treatment interactions are universal but unstable because interactions usually occur in higher-order ways (Cronbach & Snow, 1977; Namiki, 1997), the genotype × environment interaction may not be very stable.

Recently, Hiraishi and his colleagues (Hiraishi, Yamagata, Shikishima, & Ando, 2008) provided a possible model of an underlying mechanism of genotype × environment interaction from an evolutionary perspective, called the internal environment hypothesis. By using the twin method and direction of causation (DOC) model, they showed that individual differences in general trust (i.e., the trust - lack of trust dimension), which is regarded as an adaptive strategy in modern society and is genetically influenced, are adjusted by extraversion and agreeableness, which are also genetically influenced. Their idea is that individuals try to adapt to inner environments (such as their own personality traits) as well as to outer environments. This is a possible mechanism by which genetic variations in personality and intelligence are maintained in a population; it also explains why, from an adaptive perspective, the genotype × environment interaction occurs. If this kind of mechanism were found universally (even if it were unstable) in educational settings in a broad sense, in which individuals with different genetic dispositions adapted differently to different learning/teaching conditions, different subject matter (secondary domain), and different cultural fields, then education could be regarded as a process of regulation of this kind of adaptation.

5. Conclusions

The present article has outlined some evolutionary and genetic bases of human teaching and education. The term “teaching” was used in a relatively narrow and concrete sense, and the term “education,” in a broader and more abstract sense, but the two terms cannot be clearly distinguished and are sometimes compatible. The article also discussed the origin of human teaching compared to that in non-human animals, the general formulation of education (learning by triadic interaction), its developmental processes and contents from a phylogenetic point of view, and the roles and functions of genetic variation in human education. The coverage was so wide that, in the present author’s opinion, a new discipline, such as “evolutionary pedagogy” or the “evolutionary science of education,” needs to be established as an integral science to explain educational phenomena from an evolutionary perspective. The cultural evolution of education, which deals with historical changes and regional differences in content and systems, was not discussed at all in the present article. It will be an important research field in this new discipline.

The evolutionary science of education resembles “learning science” in several ways. Both are directed toward the biological basis of learning and teaching, and acknowledge the importance of learning out of school. However, there are significant differences between them. Learning science literally focuses on learning by learners, whereas the evolutionary science of education is directed toward learning by a triadic interaction among teachers, learners, and objects. In learning science, evolutionary explanations appear to be just one of the mechanisms related to learning, and there is no explicit distinction between proximal and ultimate causes, whereas in the evolutionary science of education, evolutionary explanation is the core principle of the theory and attention is directed at ultimate causes. Learning science emphasizes domain-specific knowledge, whereas the evolutionary science of education focuses on both domain-specific and
general abilities. The evolutionary science of education is focused on life history theory and behavioral genetics, but learning science is not. Education is just an applied field for learning science, but it is a central target to be explored in the evolutionary science of education.

The present author's working hypothesis for the evolutionary science of education is that education is not a secondary by-product for something other than survival and reproduction, but rather is a direct outcome of evolutionary needs to survive and reproduce. Therefore, education is not a field in which basic theories are applied, but rather it is a field that could be explained by evolutionary theory. Human beings are characterized as "Homo educans" in the essential sense of the phrase. This statement is not an ideology, but rather a scientific hypothesis to be verified.

References


Geary, D. C. (2002). Principles of evolutionary edu-


Shikishima, C., Hiraishi, K., Yamagata, S., Sugimoto,


Acknowledgements

I thank Kazushige Akagi, Nobuyuki, Kutsukake, Kazuo Okanoya, Masaki Tomonaga, Kai Hiraishi, Osamu Sakura, Keiko Fujisawa, and Taro Nishimura for their helpful comments and information.

The research reported in the paper were supported by Grants-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) (no. 13309014, 18330140), Human Frontier Science Program, and Brain Science and Education (Type II) from Research Institute on Science and Technology for Society (RISTEX), the Japan Science and Technology Agency (JST).