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Teaching and the Life History of Cultural Transmission in Fijian Villages

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Abstract Much existing literature in anthropology suggests that teaching is rare in non-Western societies, and that cultural transmission is mostly vertical (parent-to-offspring). However, applications of evolutionary theory to humans predict both teaching and non-vertical transmission of culturally learned skills, behaviors, and knowledge should be common cross-culturally. Here, we review this body of theory to derive predictions about when teaching and non-vertical transmission should be adaptive, and thus more likely to be observed empirically. Using three interviews conducted with rural Fijian populations, we find that parents are more likely to teach than are other kin types, high-skill and highly valued domains are more likely to be taught, and oblique transmission is associated with high-skill domains, which are learned later in life. Finally, we conclude that the apparent conflict between theory and empirical evidence is due to a mismatch of theoretical hypotheses and empirical claims across disciplines, and we reconcile theory with the existing literature in light of our results.

Key words Cultural transmission · Human evolution · Teaching · Learning · Childhood

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Humans rely on cultural learning much more than any other animal species. Other animals primarily adapt to local environments through a variety of forms of individual learning. Each individual organism must acquire most of the knowledge it needs to thrive in the local environment on its own. In some species, social cues and even forms of scaffolding or teaching may facilitate the proliferation of local traditions (Caro and Hauser 1992; Hoppitt and Laland 2008; Thornton and Raihani 2008). However, they are limited to behaviors that individuals could learn on their own; there is no evidence of cumulative cultural change across generations, except perhaps for bird song. Humans acquire vast amounts of information from others by imitation, teaching, and other forms of cultural learning, and this leads to the cumulative evolution of complex local adaptations that no individual could learn on his or her own (Boyd et al. 2011).

Over the past several decades a number of researchers have developed a rich body of theory that analyzes the conditions under which natural selection will favor such a reliance on cultural learning, and how cultural learning should be structured (Boyd and Richerson 1985; Enquist et al. 2007; Feldman et al. 1996; Kameda and Nakanishi 2003; McElreath and Strimling 2008; Rendell et al. 2010; Rogers 1988; Wakano and Aoki 2007). Of particular interest here, this theory makes predictions about when individuals should learn from their parents as opposed to learning from others, and when teaching would be adaptive. We first review the theory on when to learn socially, and from whom, and then detail the predictions relevant to the current empirical study.

When to Learn from Others

A substantial amount of work (Boyd and Richerson 1988, 1996; McElreath and Strimling 2008; Perreault et al. 2012) indicates that natural selection favors social rather than individual learning when the behavior of others is a more accurate predictor of the best behavior in the local environment than alternative non-social cues. This will be true under at least two conditions. First, models show that when environmental cues vary in quality so they are only sometimes good indicators of the most adaptive behavior, selection can favor a psychology that causes individuals to learn selectively. Specifically, the most adaptive strategy is to learn individually when environmental cues provide clear guidance, but to learn from others when environmental cues are of low quality (Boyd and Richerson 1988; McElreath and Strimling 2008; Perreault et al. 2012). Second, other models assume that individual trial-and-error learning allows individuals to make small improvements cheaply, but not big ones. In these models, selection favors cultural learning, combined with occasional marginal improvements through individual learning (Boyd and Richerson 1985, 1996). In both cases, modest amounts of individual learning are sufficient to allow a population to accurately track changing environments, and thus the behavior of others provides useful information about the best behavior in the local environment. Qualitatively, this body of theory suggests that selection can give rise to an evolved psychology that includes both a strong intrinsic motivation to imitate others as well as motivations to independently discover and adopt novel adaptive behaviors.

Researchers have also addressed to whom learners should attend, when they do learn socially. Several different factors are likely to be important. First, a variety of cues may allow learners to identify models who are more likely to be behaving adaptively; successful individuals, widely copied individuals, older individuals, individuals whose behavior is more common, and individuals who resemble the learner in relevant dimensions are all examples (Boyd and Richerson 1985; Henrich 2009; Henrich and Broesch 2011; Henrich and Gil-White 2001). Second, the commonness of a behavior among models can provide a cue about which behaviors are best (Henrich and Boyd 1998; Nakahashi et al. 2012). Finally, it may be more costly to copy some individuals than others. Social learning takes time and requires access to the model individual, which means that it will usually be least costly to copy parents, family members, and others who are observed in the course of normal activities (Henrich and Broesch 2011).

When to Teach

One body of work evaluates when teaching is favored by natural selection (Cavalli-Sforza and Feldman 1981; Hoppitt et al. 2008; Thornton and Raihani 2008). Here *teaching* is defined as behavior that (*a*) is contingent on a naive observer being present, (*b*) is costly to the model, at least in the short term, and (*c*) facilitates or speeds up the acquisition of behavior by the learner (Caro and Hauser 1992). This definition includes a wide range of behavior from explicit instruction to the model providing subtle cues that he or she intends the behavior to be copied. Looked at this way, teaching is cooperative—more accurate learning benefits the learner but costs the model. Thus, teaching can evolve only when the teacher can recoup fitness costs, contingent on the pupil's improved learning (Hoppitt et al. 2008). If the model and the learner are related, then inclusive fitness benefits can favor teaching (Cavalli-Sforza and Feldman 1981), so all other things being equal, more teaching is expected among relatives than non-relatives. There may also be direct fitness benefits to offset a teacher's costs. Learners can compensate teachers through deference (Henrich 2009; Henrich and Gil-White 2001) or through reciprocity, or teachers may reciprocally teach each other's offspring. Such reciprocal arrangements may be especially effective when the cost of teaching increases only slightly as the number of learners increases—and going from one to two pupils does not double the teacher's cost, for example.

Predictions about teaching depend critically on the costs to teachers and the benefits to learners. Researchers have argued that communication generally (Sperber and Wilson 1995) and cultural learning specifically (Gergely and Csibra 2006, 2011) is very difficult without ostensive cues provided by the model that narrow the range of possible inferences that learners can make. If this is true, very low cost teaching will yield very large benefits, and therefore we should expect such subtle teaching under a wide range of circumstances. Even low relatedness owing to viscous population effects may have been enough to endow humans with a psychology motivated to engage in subtle teaching directed toward any naive learner in their social group. For the same reason, indirect reciprocity could have easily supported the evolution of subtle, low-cost teaching. On the other hand, explicit instruction is often time-consuming and may require substantial modification of the teacher's behavior. For such high-cost types of teaching, the theory predicts that an evolved psychology should limit the behavior to close relatives, or to contexts in which the learners or their relatives provide the teachers with direct fitness benefits that compensate for the costs the teachers incur.

A common view in ethnographic work is that teaching is rare, if not uniquely Western (see Hewlett et al. 2011 for recent review). In contrast, evolutionary reasoning predicts that teaching should be common because our species' ability to adapt depends on faithful cultural transmission and teaching can be a powerful tool for increasing fidelity. We argue this conflict results from a mismatch of definitions: anthropologists typically equate teaching with Western-style instruction or schooling, whereas evolutionary theorists define teaching in terms of adaptive costs and benefits, with a broader behavioral profile (for applications to teaching in non-human animals, see Caro and Hauser 1992; Hoppitt et al. 2008). In this paper we adopt the evolutionary approach to the study of human teaching and show that it leads to a more sophisticated understanding of teaching's role in cultural learning.

When to Learn from Parents versus Others

This body of theory makes predictions about when selection should favor learning from parents (aka vertical transmission) and when it should favor learning from others ("oblique" and "horizontal" transmission). The following factors tend to favor learning from parents.

Cultural Variation in Fertility

When cultural variation causes variation in number of offspring (Aoki et al. 2011; McElreath and Strimling 2008), children who copy parents have a greater chance of acquiring cultural variants that increase family size than do children who copy randomly chosen adults. To see why, consider the following simplified example: Suppose that there are two culturally transmitted behaviors, and that mothers with one behavior produce three offspring, while mothers with the alternative behavior produce only one. Further suppose that children learn from their mothers and that the two behaviors are equally common. Three quarters of the children are in large sibships, and thus children who copy their mother have a 75% chance of acquiring the behavior that leads to large families. Children who copy random adult women have only a 50% chance. This effect will cause selection to favor cultural transmission when cultural variation has a substantial effect on variation in fertility, and the same variants do not have negative effects on other fitness components. (For example, cultural variants that lead to high fertility might also lead to high mortality.)

Low Levels of Cultural Variation

Cultural learning depends on access to models. If young children typically spend much more time with members of their family than with other adults, it will usually be cheaper for younger children to copy their parents and other members of the immediate family. Older children and adolescents typically interact with a wider range of adults, and it thus becomes less costly to copy non-family members. Because non-parental adults provide a large sample, adaptive considerations suggest that, all other things being equal, children can benefit by being open to imitating such individuals. This predicts a two-stage model of cultural learning (Henrich and

Broesch 2011; Hewlett et al. 2011; see also Aunger 2000). First, children learn from their parents and other members of their immediate family. As they get older, children compare what they have learned to the behavior that they observe among other individuals. If there is evidence that the novel behaviors are better, learners adopt them—vertical transmission first, then horizontal and oblique transmission. However, sometimes non-parental adults will provide no new information. There may often be little cultural variation among individuals in small-scale societies (Hewlett and Cavalli-Sforza 1986). The same may be true in larger societies that have reached cultural equilibrium. When new beneficial ideas are rare—for instance, because of rapid environmental change—imitating non-parents may provide big benefits (McElreath and Strimling 2008), but once they have spread through a society, learners can get them from their parents. These considerations predict that vertical transmission will be the norm in societies with limited cultural variation or for domains in which alternative cultural variants are equally attractive, and that a two-stage process will be common in societies or in domains with much cultural variation. The empirical record suggests that both patterns exist: vertical transmission is common in cross-species or cross-domain reviews (e.g., Hewlett and Cavalli-Sforza 1986; Shennan and Steele 1999), but there is evidence that oblique transmission is important in particular domains, such as ethnobotanical knowledge (Reyes-García et al. 2009; see also Hill et al. 2009; Kaplan et al. 2000).

When Models Are Motivated to Deceive Learners and Conceal Information

The models and learners may often have divergent interests, and this means that learners may need to evaluate what models are trying to teach them (Sperber et al. 2010). For many traits this is not a problem because learners can observe models "practicing what they preach." If a learner observes a model frequenting a particular fishing ground, then the learner can be reasonably certain that the model thinks that location is a fruitful one. More generally, if models can be seen exhibiting individually costly behavior consistent with a particular belief, then learners can reasonably infer that the model is not trying to deceive the learner (Henrich 2009). If a learner observes a model expending considerable effort to reach his preferred fishing grounds, this might be better evidence of the model's true belief in the location's value. Nonetheless, there are also situations in which detecting deception is difficult; some kinds of cultural learning depend on the testimony of models (Jaswal et al. 2010; Koenig and Harris 2007), and models may be motivated to lie to learners in order to increase their own fitness. Because parents' fitness depends on their offspring's success, parents may be the most willing and trustworthy models. This is true for other close relatives to a lesser extent. In contrast, especially attractive models may require learners to pay for access with resources, labor, or deference, as is often true of apprenticeships (Coy 1989).

Present Study

As part of a long-term study of life in rural Fijian villages, we performed a series of interviews designed to evaluate specific hypotheses about the roles of teaching and non-vertical transmission in cultural learning based on the theory outlined above. We tested three predictions about the distribution of teaching as a type of cultural learning.

1. *Teaching is most common among closely related kin, and least common where no genetic relatedness exists, all else being equal*. As a result, teaching should be more closely associated with vertical transmission than with oblique transmission.
2. *Domains that are more difficult in terms of skill—but not in terms of strength—should be associated with higher rates of teaching*. The adaptive value of teaching depends on how much the learners gain from tutelage—the gains from teaching should be greater for tasks that are more difficult to master.
3. *A domain's importance will be positively associated with frequency of teaching*. Teaching should be most frequent where its impact on fitness is the greatest. As a proxy for impact, we use a measure of a domain's importance to achieving success and respect in village life.

   We also tested three predictions about the distribution of vertical, horizontal, and oblique pathways of cultural transmission based on the body of theory discussed above.
4. *Vertical and horizontal transmission will be negatively associated with the age at which a domain is first learned, whereas oblique transmission will be positively associated with start age*. According to the two-stage model of cultural learning, learning that takes place early in life is likely to be based on models that are easily accessible, including parents and close kin. In contrast, domains learned later on may be learned from a broader array of acquaintances.
5. *Low-skill domains will be associated with lower start ages, whereas high-skill domains will be associated with higher start ages*. The two-stage model of cultural learning suggests that basic skills are learned early in life, and later updated when a learner's access to models and experiences expands. Low-skill domains will not require updating and so will be associated with early learning ages. In contrast, high-skill domains may be learned later in life to begin with, and may be continuously updated throughout the life span, resulting in later reported learning ages.
6. *Domains requiring greater skill—but not greater strength—will be associated with higher levels of oblique transmission*. Domains for which there is less variation within a population—low-skill domains—can be learned from nearly any adult model so are likely to be learned from those close at hand, primarily parents or close relatives. In contrast, there is likely to be greater variation in competence for high-skill tasks, so they are better learned from particular models, perhaps experts.

Methods

We collected data about children's day-to-day lives, ways of learning, and expected work contributions to their households. Here we give a detailed explanation of the field site and interview methods for three interviews: Domains of Success, Child Learning Interview, and Difficulty Ranking Task. All participants were recruited based on a random sampling of adults drawn from a demographic database; participants did not receive direct compensation for these interviews.

Ethnographic Context

Data presented here were collected during 2008–2011 in three Fijian villages on Yasawa Island, located in the northwestern corner of the Fijian Islands. These villages are sustained by a primarily subsistence economy, with 23% of calories coming from the market economy (Henrich et al. 2010a), and only 2 of 84 adults in Teci and Dalomo villages in 2010 reporting work in wage labor. Wage labor is more common in Bukama village, which lies about 30 min' walk from the island's only resort. Both men and women sometimes emigrate for jobs in the tourist industry, or other forms of wage labor.

Political units are composed of interrelated patri-clans, governed by a council of elders and a hereditary chief, and life is organized by a complex web of kinship relations and obligations. Each village has its own dialect. There are no local markets, broadcast television, automobiles, or public utilities in these villages, whose populations are about 100–250. Radios are common and cell phones have become increasingly prevalent since 2009, though a lack of a reliable source of electricity, unreliable service, and the difficulty of purchasing additional minutes limits their usage. Despite the introduction of British-style formal schooling in the early 1900s (see White 2007), Fijian childhood in these relatively traditional villages remains quite different from childhood in the Western world, making for a valuable cross-cultural comparison of cultural learning. This paper focuses on Fijian adults' explanations of how children learn skills and behaviors that are important to success in a traditional Fijian village, including who they learn from, at what ages, and how. For additional ethnographic detail, readers should refer to the supplemental materials from Henrich and Henrich (2010b) and Henrich and Broesch (2011).

In this and many other Fijian villages, social interactions including those relevant to cultural learning are shaped by the relative social status and kinship relationships of the actors (Brison 1999; Nayacakalou 1975; Ravuvu 1983; Sahlins 1962; Toren 1990). As in many of the traditional societies mentioned above, relationship norms structure interactions so that subordinates do not dominate an interaction or set its terms by direct questioning (Arno 1990; Nabobo-Baba 2006). This is a recurring pattern in Polynesia (e.g., Borofsky 1987; Ritchie and Ritchie 1979). Many village rules about hierarchy do not apply to infants and very young children, who are thought to be incapable of comprehension. According to Hocart's study in the Lau region of Fiji, infants are said to be "without minds," and young children are "watery-souled" (Hocart 1929:146). As a result, Hocart reports that children are not expected to learn *tabu* (taboos) such as the ban on interaction with parallel cousins until the age of 7. In present-day Yasawan villages, adults say children should learn this tabu by 12–13 years of age (see ESM, pp. 1–2).

As is typical in the Pacific (Ritchie and Ritchie 1979) and across the world, Fijian parents are not expected to actively instruct very young children (see also Ochs and Schieffelin 1984), children are not encouraged to ask questions, and they are expected to contribute to household chores from the age of 7–8 (see "milestones" in the ESM; see also Bock 2002; Lancy 2008; Lancy and Grove 2011, cf. hunter-gatherer groups: Hewlett and Lamb 2007). In traditional villages in Fiji, legitimate ways of learning include learning (*a*) by listening either to an established elder's telling or chatting *(talanoa)* or to rules as frequently repeated by parents (Nabobo-Baba 2006), and by experience, either (*b*) as a helper who is sometimes corrected (Ritchie and Ritchie 1979), or (*c*) individually, through pseudo-experimental trial-and-error (Nabobo-Baba 2006). Participants in our interviews occasionally mentioned schooling as a means of learning, and most children in the village attend primary school somewhat regularly between the ages of 7 and 14. Most adults in the population have completed primary school or have some secondary school education. However, as elsewhere in Fiji, parents in these villages seem to think of schooling mainly as a means for gaining future employment through fluency in English, rather than for success within traditional village life or as a goal that is valuable in itself (Brison 2007; Veramu 1992), so villagers generally rate more-educated individuals as having less knowledge of important domains of work within the village (Henrich and Broesch 2011). Children must still fulfill an economic role in the household, with priority apparently given to chores over homework (Dakuidreketi 2006; Veramu 1992). This suggests that though formal schooling is admired by many in Fiji, growing up in a Yasawan village is still quite different from growing up in a typical "Western, educated, industrialized, rich, democratic" society (see Henrich et al. 2010b for comparisons between "WEIRD" societies and others).

Domains of Success Interview

To document which domains are the most important for success in village life, we conducted interviews with a randomly selected sample of adults (n=72), drawn from three villages on Yasawa Island—Teci, Dalomo, and Bukama. In this interview, we asked participants: (Q1) "What are the areas of skill, knowledge or success that make one a well-respected member of the community here?" We also asked participants (Q2) to tell us the most important areas of life for a boy to learn, and (Q3) the same for a girl. Finally, we asked (Q4) how children learn these skills, and (Q5) what aspects of life parents teach to their children. We use data from this interview in three ways, and review each below. The interview script and additional results are published in Henrich and Broesch (2011). This interview was completed in Teci and Dalomo villages in 2006–2007, and Bukama village in 2009.

First, we used answers to Question 1 make a list of target domains for our Child Learning Interview. This interview was completed in Teci and Dalomo village in 2006–2007, and in Bukama village in 2009. From the list of domains participants mentioned, we selected all those domains that must be learned, eliminating inherited traits (e.g., chiefly status), personality attributes (e.g., kindness), or formal/governmental institutional domains (church and schooling). We eliminated personal attributes because Yasawans view some aspects of personality as biologically inherited (see Moya et al., in prep), and we are focused here on socially learnable domains. We also eliminated domains that were so general as to make it infeasible to ask questions about stages of learning, or degree of difficulty (for instance, *sasamaki*, a term which means "cleaning" in general and encompasses a number of more specific chores). To the remaining list, we added two domains we knew to be high skill, and that not every villager is expected to master: captaining a boat (*kavetanitaki ni boto;* males) and traditional medicine (*wainimate vakaviti;* females, includes mostly ethnobotanical medicines). Our final list includes eight target domains. For males, the remaining domains are farming (*laulau;* horticulture including cassava, yams, and fruits), traditional house-building (*tara sue*), and diving (*riu*). For females they are reef gathering (*vivili*), mat-weaving (*tali loga*), and cooking (*vakatoko*).

Second, we used responses about which domains are most important for boys and girls to learn (Q2 and Q3) in order to calculate an "importance to success" variable for each of our target domains. We calculated *importance* as the total number of times a given domain was mentioned in response to Q2 and Q3 (see Table 1). The mean importance score is approximately 27 and the standard deviation is 9.3; the highest possible score is 72. Traditional medicine and boat captaining were never mentioned, so they received scores of zero. We suspect that participants neglected to list these domains because only a few men and women in the village master them, so they are not prerequisites for achieving success even if mastering them might be sufficient to command respect among villagers (see Henrich and Broesch 2011).

Finally, we coded responses to Question 4 in terms of the process by which children learn. We coded for 5 possible learning processes: (1) hearing/listening (*rogoca*), (2) seeing/observing (*tolavia/raica*), (3) doing/practice (*cakava, vuli tara, vakatovotovotaka*), (4) imitating (*muria*), and (5) being taught. Terms coded as *being taught* include Fijian terms that translate as "taught" (*vakavulica*), "told" (*tukuni vua, talanoataki*), "corrected" (*vakadodonutaki*), or "shown" (*vakaraitaki vua*). Of 72 participants, 75% (n=54) named at least one learning process. Many participants listed more than one learning process, for a total 101 listed learning processes. Some participants described specific learning processes for particular domains, rather than replying generally about all domains. We developed the Child Learning interview with a focus on documenting this type of domain-specific variation in the processes, sources, and life history trajectory of cultural learning.

Child Learning Interview

In a structured interview in 2009, we asked a random sample of adults in Teci and Dalomo villages (n=44; 21 male) questions about how boys and girls learn different skills that are crucial to success in village life, from whom they learn, and at what age. We asked specifically about the eight target skills from the Domains of Success interview. We also asked about the expected ages for a number of developmental milestones, as well as more open-ended questions about what sort of work children should do for the household, and at what ages (see ESM).

We present several types of data from this interview. First, participants were asked eight questions in the format "How does a boy/girl learn to do X?" where X is one of the target domains. The question is intentionally vague, so participants could name a process of learning (see/hear/do/imitate/teach), a source or pathway of transmission (parents/grandparents/friends/elders), or both. Participants were not compelled to answer in terms of social learning, but most did. Participants could have provided no, one, or more than one pathway of transmission and/or process for each domain about which we asked. Three participants never suggested any pathways of transmission so were dropped from these analyses. We collected 293 responses about transmission pathways for the target domains. The minimum number of responses about pathways for any domain in our sample was 34 and the maximum was 38. For responses about processes of learning, we collected 105 instances. The minimum number of responses about process for any domain in our sample was 9 and the

Table 1 Target domains of success, the number of participants who listed each domain as important, and the gender category to which the task typically belongs

Domain	Importance	Gender
Farming	65	M
Weaving	53	F
Cooking	51	F
Diving	23	M
House-building	19	M
Reef gathering	8	F
Traditional medicine	0	F
Captaining boat	0	M

maximum was 17. To code processes of learning, we used the same coding scheme as in the Domains of Success interview. To transform data on sources of learning into data on pathways of transmission, we coded learning from parents and grandparents as "vertical" transmission, learning from peers or siblings as "horizontal" transmission, and learning from more distant relatives, elders, villagers, experts, and others as "oblique" transmission. Because horizontal learning was so rarely reported, we did not distinguish between learning from siblings and from other peers.

For both the process and pathway data, we calculated the frequency of our focal variable (e.g., vertical transmission) over all relevant responses (e.g., all responses mentioning any source of learning), per domain. This created the *pathway* variables: frequency of vertical, oblique, and horizontal transmission, and the *process* variables: frequency of transmission through seeing, hearing, doing, imitating, or by teaching. For data on the rates of teaching by kin category, we calculated the number of times teaching was mentioned in conjunction with that kin type, divided by the total number of times that kin type was mentioned as the source or pathway of learning in conjunction with any process of learning, for each domain.

We also asked, for each target domain: "At what age should a boy/girl begin to learn to do X?" We use these data as "start age" estimates for the target domains. In a separate open-ended question, we asked: "What type of work should a boy/girl do for the household? At what age should they begin?" Participants provided as many domains of work as they pleased, along with an age estimate. We use these data as "start age" estimates for 10 additional domains. We also asked participants about whether there is anything that parents "should directly teach" *(e dodonu me vakatavulica ga)*, whether there is anything boys and girls must learn from peers, and whether there is anything that boys and girls must learn from adults other than their parents (see ESM). The question on teaching was asked using a Fijian translation for "teach" (*vakavulica*) that is roughly equivalent to the everyday use of the word in English. Literally, *vakavulica* translates as "cause to learn it." This meaning is achieved by using a causative particle, *vaka,* and the transitive form of the base that means "learn" (*vulica*). In contrast, the response "learn by doing" is *vuli tara,* translating literally as "learn-do." We used the Fijian intensifier "directly" (*ga*) in order to encourage participants to focus on the act of teaching rather than the expected general influence of adults on children's learning. This treatment of teaching is meant to parallel what anthropologists mean by teaching.

Difficulty Ranking Interview

We used responses from the Child Learning interview to create an inclusive list of domains to be learned, including the eight target domains and any categories of work listed in response to the open-ended question about types of work children should do for the household. We then asked randomly selected adult participants (n=16) to rank these 25 tasks according to difficulty in terms of (*a*) skill and (*b*) strength. Since these participants are not familiar with pen and paper rankings, we used a stack of index cards with task names printed on them and guided participants through a series of forced pair-comparisons for each successive domain. The end result is a linear ranking from most difficult to least difficult. Participants were then asked to look over the entire ranking from "high difficulty" to "low difficulty" and were permitted to make changes. Finally, we recorded the ranks on a paper data sheet. The index cards were shuffled between tasks, and the order in which participants did the skill and strength difficulty rankings was counterbalanced. We use the mean skill and physical difficulty rankings per domain in our analyses, reverse-scored so a larger number indicates higher difficulty, with a possible range of 1 to 25.

All three interviews were translated and back-translated by research assistants who are native speakers of Standard Fijian. The interviews were administered with the help of these research assistants. Some of the terms used for the difficulty ranking task were in the local Teci dialect of Fijian, which differs from Standard Fijian. The first author coded responses to the Domains of Success and Child Learning interviews using both the original Fijian responses as well as English translations done by research assistants. She resolved discrepancies in translation using Gatty's (2009) Fijian to English dictionary when necessary.

Results

We combined data from the Domains of Success, Child Learning, and Difficulty Ranking interviews to test key predictions drawn from theory on the evolution of teaching and social and cultural learning. First, we focus on predictions about the prevalence and strategic use of teaching. Second, we examine the roles of vertical and oblique transmission with respect to the two-stage model of cultural learning.

Teaching

We found substantial variation in reports of teaching across the domains we studied. In the Child Learning interview, across all eight target domains, we found that teaching was listed as a learning process on average 42.6% of the time, ranging from 21.4% for boat piloting to 66.6% for mat weaving. This is roughly equivalent to the cross-domain average for learning by "seeing" (43.3%), which was the most common process of transmission listed for boat piloting (78.6%), farming (tied with "doing" at 41.7%), house-building (52.9%), and traditional medicine (tied with teaching at

44.4%). In our Domains of Success interview, in which we only asked *generally* how children learn important skills or knowledge, participants named teaching as a process less often (17.8%) and were more likely to list "seeing" (33.6%) or "imitating" (22.7%). Learning by doing was also a common response (18.8%). These results demonstrate that teaching rates are variable across domains, even if teaching is generally rare.

We also asked participants whether there are things parents must teach their children directly. The most common response, made by 42 of 44 participants, translates as the "customs/ways of the people of the land" (*i tovo/i valavala vakavanua*) and refers generally to knowledge of ritual traditions, and respectful behavior expected from those living in a Fijian village. Participants could name more than one domain, and the next most common response was "ways of dress" (*sulusulu, n*=13). All other responses were named by fewer than 10 participants: to speak well (*vosavosa vinaka; n*=8), school-related behaviors or habits (*vuli, n*=5), church or religious beliefs (*lotu, n*=5), hairstyles (*kotikoti, n*=4), knowledge of kinship or relatives (*veiwekani, n*=2), and "to listen," which sometimes implies both listening and obeying (*rogoca*, *n*=2). In a follow-up question in the same interview, many participants said that if parents did not teach these things to their children, the results could be social conflict, drug use, and even jail time. None of the target domains was mentioned even once in response to this question, despite the relatively high reported rates of teaching when we asked specifically about how each domain is learned. This illustrates the importance of using a variety of interview approaches.

To test hypothesis 1, we examined the relationship between the frequency of vertical, horizontal, and oblique transmission and the frequency of teaching, using linear regressions on data for the target domains (Table 2). Frequency of teaching is measured as the number of times teaching was mentioned over the total number of transmission process mentions. As predicted, we found that domains that are more likely to be transmitted vertically are also more likely to be taught (Fig. 1a), and that domains that are more likely to be transmitted obliquely are less likely to be taught (Fig. 1b). We found no effect for horizontal transmission on teaching rates—this is expected given the rarity of horizontal transmission for the target domains.

We also examined whether relatedness between teacher and pupil is positively associated with rate of teaching. We found that parents were the most likely to teach, with teaching mentioned 74.3% of the time that parents were listed as a source of social learning (*n*=250). Elders were the next most common teachers (50%, *n*=85), followed by grandparents (43%, *n*=53), and experts (33.3%, *n*=59) and peers (33.3%, *n*=36). Formal schooling (*n*=7), villagers in general (*n*=6), siblings (*n*=2), uncles (*n*=2), and other individuals (*n*=3) were never associated with teaching (Fig. 2). In calculating these figures, we treated responses with no mention of pathway as missing data. Only parents were positively associated with teaching at a statistically significant level (χ^2=16.98, *p*=0.00). We also tested for an overall effect of genetic relatedness on the rate of teaching across all kin types. Three levels of relatedness are represented in the kin types participants offered: *r*=0.50 (parents), *r*=0.25 (siblings, grandparents), and *r*=0, or background relatedness (elders, experts, peers, villagers in general, school, others). Testing across these kin types (*n*=9) using a linear regression, we did not find that relatedness predicts teaching rates (Coeff. = 44.15, *p*=0.35, R^2=0.13). The results do not change qualitatively if we cluster our

Table 2 Results of linear regressions predicting teaching rates for each domain (n=8) from rates of transmission by a given pathway within each domain. Bootstrap standard errors are based on 10,000 repetitions

IV	Coeff.	p	R^2	Bootstrap SE
% vertical transmission	0.38	0.03	0.59	0.13
% oblique transmission	−0.32	0.05	0.51	0.14
% horizontal transmission	−0.41	0.31	0.17	1.95

analysis according to the transmission pathway for each kin type, or if we control for pathway of transmission using dummy variables.

For hypothesis 2, we tested whether high-skill domains were positively associated with teaching, using linear regressions on data for the target domains. Because small sample sizes render p values unreliable, we also calculated the bootstrapped Standard Errors. We found that neither skill difficulty nor strength difficulty ratings alone predict a greater role for teaching (Table 3). However, when we control for the pathway of transmission by including the rate of vertical transmission in the models, the coefficient for skill difficulty dramatically increases in size, and the p values become marginally significant. In addition, the bootstrapped SE suggests our findings are statistically significant, and the regression accounts for 77% of the variation. As expected, controlling for transmission pathway does not alter the results for models of physically demanding tasks, and none of the results we present here change qualitatively if we control for rate of oblique transmission rather than vertical transmission. Controlling for domain importance does not change the outcome of the models. However, boat piloting is an outlier in the skill difficulty model, and removing boat piloting improves the model results (see caption, Table 3). This may be because, like learning to drive a car, learning to drive a boat requires automatizing a number of

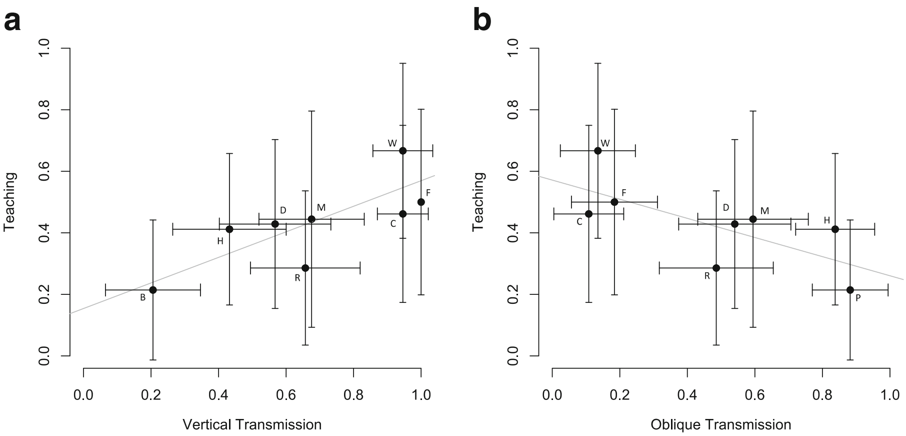

Fig. 1 **a** Results of a linear regression predicting rates of teaching from rates of vertical transmission. **b** Results of a linear regression predicting rates of teaching from rates of oblique transmission. Data for both graphs are based on 8 domains, and bars represent standard error. Letters indicate particular domains. B=boat piloting, H=house-building, D=diving, F=farming, R=reef gathering, M=Fijian medicine, C=cooking, and W=weaving

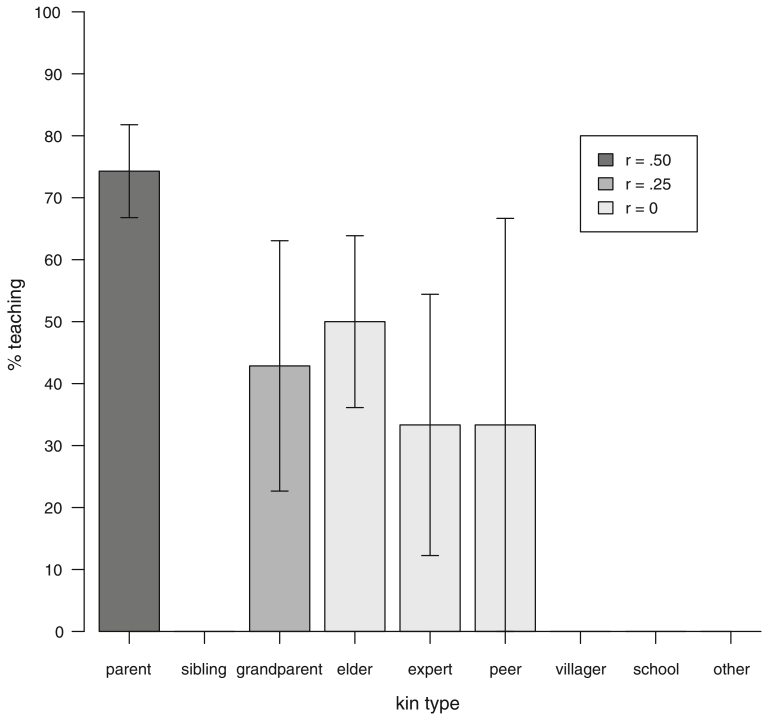

Fig. 2 Rates of teaching, for each kin type. Typical genetic relatedness (*r*) for a kin type is indicated by shading. Bars represent standard error

complex, embodied routines. Thus actually learning to drive the boat requires hours of practice, whether or not certain principles are taught.

For hypothesis 3, we investigated whether the importance of a domain is associated with higher rates of teaching, using linear regressions based on data for our target domains. As predicted, we found that the importance of a domain to success in village life is a strong predictor of rates of teaching (Table 3). Controlling for importance does not improve the regression models testing the effects of skill difficulty on teaching rates.

Life History and Pathways of Transmission

We now evaluate three additional hypotheses based on the two-stage model of cultural learning. Here, we use logistic regressions with individual-level data on the target domains to test whether the age at which a domain is first learned affects the probability of its being learned through a particular pathway of transmission—vertical, oblique, or horizontal (Table 4). As predicted by hypothesis 4, we found that domains that are learned later in life are less likely to be transmitted vertically and more likely to be transmitted obliquely (Fig. 3). Horizontal transmission remains rare compared with oblique and vertical transmission and has a weak negative association with start age. Responses that included no information about transmission pathway were treated as missing data, so 3 participants were dropped and responses from 41 participants were included. We calculated bootstrap standard errors using 10,000 repetitions.

Table 3 Results of linear regressions predicting teaching rates per domain (n=8) from skill and physical difficulty per domain, and from the domain's importance to success. Bootstrap standard errors are based on 10,000 repetitions. Without boat piloting in the sample, the regression of teaching on skill difficulty improves (r=0.01, SE=0.007, p=0.11; n=7)

Independent Variables	Coeff.	p	R^2	Bootstrap SE	β
skill difficulty	0.00	0.50	0.08	0.02	0.28
physical difficulty	−0.00	0.97	0.00	0.01	−0.01
importance to success	0.00	0.04	0.54	0.00	0.73
skill difficulty	0.01	0.10	0.77	0.04	0.43
% vertical transmission	0.41	0.01		0.19	0.85
skill difficulty	0.01	0.56	0.57	0.02	0.18
importance to success	0.00	0.06		0.00	
physical difficulty	0.00	0.65	0.61	0.04	0.14
% vertical transmission	0.39	0.04		2.52	
physical difficulty	−0.01	0.43	0.60	0.07	−0.26
importance to success	0.00	0.04		0.01	0.81

To test hypothesis 5, we used linear regressions to examine the effect of skill and physical difficulty on the age at which children begin to learn a given domain (Table 5). We found that later start ages are associated with tasks requiring greater skill, but not with tasks requiring greater physical strength (Fig. 4). We used estimates of starting age (n=499) for 18 domains of learning, including our eight target domains. We also calculated bootstrap standard error using 10,000 repetitions.

Finally, we used logistic regressions to test hypothesis 6, on the effect of skill and physical difficulty on the probability of the target domains being transmitted through a given pathway (Table 6). We found that vertical transmission is common for tasks of all skill levels, but less so as task difficulty increases. In contrast, oblique transmission is unlikely for low-skill tasks and becomes more likely with increasing task difficulty. Horizontal transmission is common for low-skill tasks but quickly becomes rare as task difficulty increases (Fig. 5). Participants could and often did

Table 4 Results from logistic regressions predicting rates of transmission by a given pathway within each domain (n=8) from the age at which each domain is first learned. DV=dependent variables and IV=independent variables. Bootstrap standard errors are based on 10,000 repetitions. Both bootstrap SE and p values are clustered first by domain (n=8) and then by participant (n=41)

Dependent variables	OR	p	Pseudo R^2	Bootstrap SE
Probability of vertical transmission	0.83	0.00	0.08	0.03
(clustered by domain)		(0.00)		(0.04)
(clustered by individual)		(0.00)		(0.04)
Probability of oblique transmission	1.16	0.00	0.07	0.04
(clustered by domain)		(0.00)		(0.05)
(clustered by individual)		(0.00)		(0.06)
Probability of horizontal transmission	0.91	0.05	0.02	0.04
(clustered by domain)		(0.01)		(0.04)
(clustered by individual)		(0.02)		(0.04)

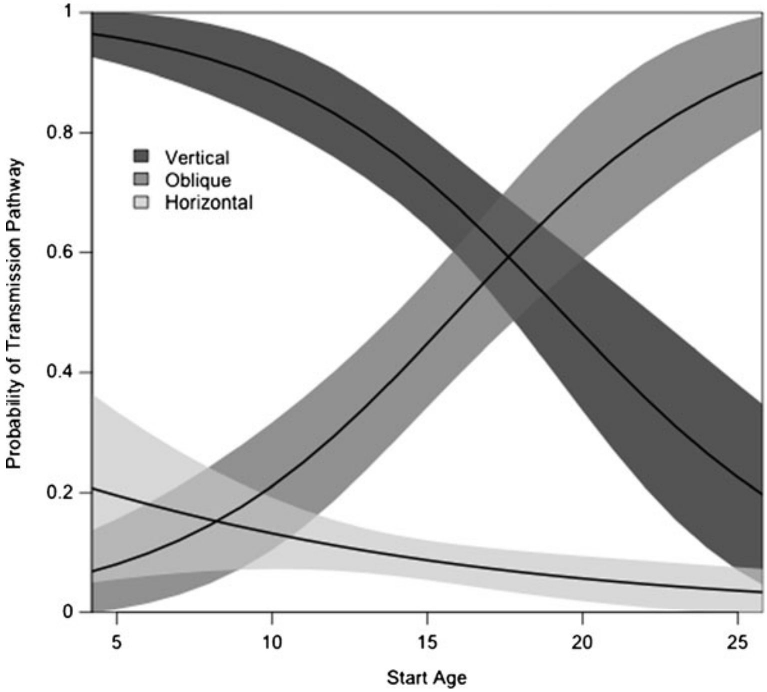

Fig. 3 Results of a logistic regression predicting the probability of transmission by three possible pathways from the age at which individuals start to learn a task, clustered by individual. Pathways are distinguishable by shading, which represents 95% confidence intervals

name more than one pathway of transmission per domain. This suggests that multiple pathways of transmission are often active for a single domain, and that the pathways are not mutually exclusive. As a result, the probabilities for all three pathways do not sum to 1. Three participants did not provide any information on transmission pathways, so the analysis was based on 293 responses from 41 participants. To correct for non-independence of data, we clustered our analyses first by domain and then by individual. We calculated bootstrap standard error using 10,000 repetitions.

Table 5 Results for linear regressions predicting skill and strength difficulty of each domain from the age at which each domain is first learned. Bootstrap standard errors are based on 10,000 repetitions. Bootstrap SE and *p* values are clustered first by domain (*n*=8) and then by participant (*n*=41)

Dependent variables	Coeff.	*p*	R^2	Bootstrap SE
Skill difficulty	0.59	0.00	0.23	0.05
(clustered by domain)		0.00		0.15
(clustered by individual)		0.00		0.06
Strength difficulty	−0.01	0.89	0.00	0.05
(clustered by domain)		0.97		0.18
(clustered by individual)		0.86		0.04

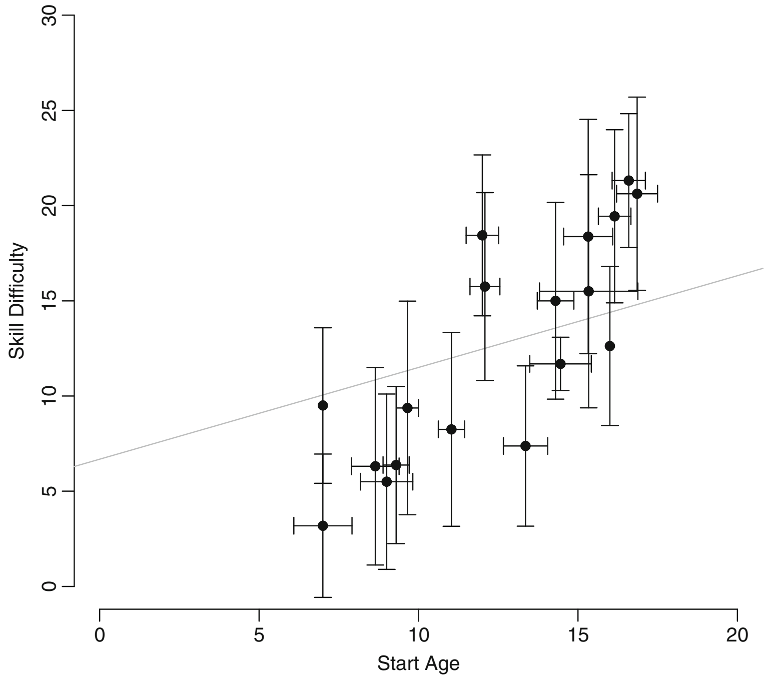

Fig. 4 Results of a linear regression predicting skill difficulty for each domain (n=18) from the age at which individuals start to learn them. Regressions are based on 499 start age estimates, but we plot only the mean of each domain here. Bars represent standard error

Discussion

Teaching Is Important

Our efforts illustrate the value of bringing specific evolutionary hypotheses to bear on the question of teaching. We found that teaching is more common than the existing ethnographic literature would (qualitatively) suggest—for instance, in discussions of "the absence of teaching" outside Western societies (Lancy and Grove 2010; see Hewlett et al. 2011 for review). Our findings are based on interviews about cultural learning in a fishing and horticultural village in the Yasawa region of the Fijian Islands. This region of the world contrasts with Western societies in that teaching is not a privileged way of learning, though there are formal schools. Our findings are in this sense surprising. Across village "domains of success," 43% of responses about process of transmission elected teaching. However, our findings are reconcilable with the existing literature on teaching, especially when considered in the light of the evolutionary hypotheses we test. We found teaching was more common in domains that were more important to success in village life. Because our investigation was already limited to areas that villagers deemed important to success in village life, this may help to explain our generally high rates of reported teaching across domains. In addition, our rates may be higher than those in the existing literature on human teaching because we used a broad definition of teaching, including Fijian terms for being told, being shown, being corrected, and the literal translation of "teach." This approach focuses on the adaptive function of teaching—to facilitate learning

Table 6 The results of logistic regressions predicting the probability of transmission by a given pathway within a domain from the skill and strength difficulty of each domain. Bootstrap standard errors are based on 10,000 repetitions. Both bootstrap SE and *p* values are clustered first by domain (*n*=18) and then by participant (*n*=41)

IV	DV	OR	*p*	Pseudo R^2	Bootstrap SE
Skill difficulty	Probability of vertical transmission	0.96	0.17	0.01	0.01
	(clustered by domain)		0.62		0.05
	(clustered by individual)		0.17		0.01
Skill difficulty	Probability of oblique transmission	1.16	0.00	0.07	0.01
	(clustered by domain)		0.00		0.05
	(clustered by individual)		0.01		0.01
Skill difficulty	Probability of horizontal transmission	0.79	0.00	0.19	0.03
	(clustered by domain)		0.00		0.21
	(clustered by individual)		0.00		0.03
Strength difficulty	Probability of vertical transmission	0.97	0.13	0.01	0.02
	(clustered by domain)		0.61		0.12
	(clustered by individual)		0.10		0.02
Strength difficulty	Probability of oblique transmission	1.05	0.02	0.01	0.02
	(clustered by domain)		0.52		0.08
	(clustered by individual)		0.01		0.02
Strength difficulty	Probability of horizontal transmission	0.96	0.22	0.01	0.03
	(clustered by domain)		0.63		0.23
	(clustered by individual)		0.22		0.03

in others—and is more like that used by researchers in animal behavior (e.g., Hoppitt and Laland 2008) than those used by either psychologists or anthropologists.

In the Child Learning interview we asked specific questions about how particular domains are learned, and as a result we obtained a number of different rates of teaching. In response to a more general question about how children learn in our Domains of Success interview, participants were much less likely to talk about teaching—82% of the learning processes named by participants were something other than teaching, which accounted for only 18% of responses. This replicates the qualitative claims in the anthropological literature on the rarity of teaching, using roughly the same methods on which claims about the "absence of teaching" are based. This suggests that our new findings on the importance of teaching are due to a more refined methodology rather than some unique feature of our field site. The discrepancy between reported rates of teaching for specific domains versus learning in general highlights one source of disagreement between theory and empirical research on teaching—while the theory focuses on the specific conditions under which teaching is adaptive and should therefore be common, the empirical record consists mostly of general claims made at the level of entire cultural groups.

Our data on teaching shows that its frequency is predicted by several factors. First, the identity of the potential teacher matters: vertical transmission is strongly associated with teaching, and parents are especially likely to teach. These findings are consistent with evolutionary predictions based on inclusive fitness and kin selection, despite the fact that we did not find a statistically significant main effect of relatedness on teaching rates. This may be because the open-ended nature of our questions resulted in only seven kin types being mentioned, and a significant effect is unlikely

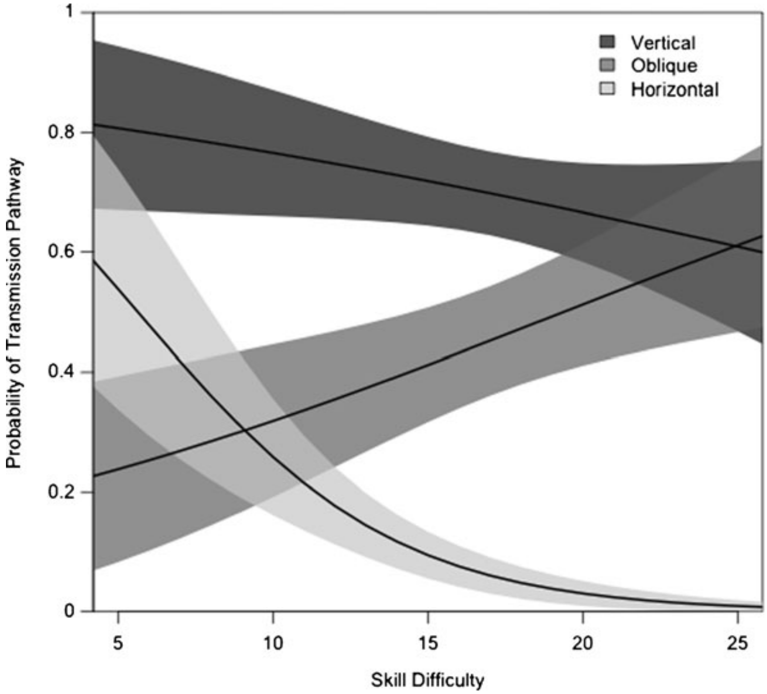

Fig. 5 Results of a logistic regression predicting the probability of transmission by three possible pathways within a domain from each domain's skill difficulty (n=8), clustered by individual. Pathways are distinguishable by shading, which represent 95% confidence intervals

with such a small sample size. Alternatively, relatedness effects may in reality be small compared with the effects of proximity to available teachers, domain skill level, age of the pupil, and the importance of the domain. A study that more specifically targets questions of who teaches whom, or one that includes the costs incurred by teachers, might clarify this result. We focused instead on open-ended questions about "how" children learn in order to allow participants to indicate that children learn-by-doing or through other non-social means.

We found evidence that tasks that are more difficult in terms of skill but not in terms of strength are more likely to be taught, controlling for transmission pathway. We also found that importance of the domain for success is a strong predictor of rates of teaching. These findings suggest that teaching should be most common in domains that are important for every child to master, and that are also difficult to learn. In short, teaching should be most prevalent in domains that have the greatest impact on the pupil's evolutionary fitness.

Non-Vertical Transmission Is Important

We found that domains for which learning begins early in life are more likely to be vertically transmitted, whereas domains for which learning begins later in life are more likely to be transmitted obliquely. Horizontal transmission was rare for our focal domains such that we were unable to distinguish peer versus sibling transmission, but children are expected to learn a number of social norms—such as style of dress and speech—horizontally (see ESM). This general pattern supports what has been called the two-stage life history of learning (Henrich and Broesch 2011; Hewlett et al. 2011), or the more general view that as patterns of social interaction change over the lifespan, so do sources of social and cultural learning, and the resulting patterns of cultural variation (Aunger 2000). This finding is important because it resolves the apparent contradiction between theory, which suggests that non-vertical transmission should be common, and the empirical record, which documents that in non-Western, small-scale societies, everything is learned from the parents. It also supports a more complex interpretation of the existing literature, suggesting that when people are asked "Whom did you learn X from?" they are likely to list the person they first learned from, without mentioning the people from whom they later learned additional skills. This explains why early research found such a strong role for parents—it is likely that participants were thinking only of early learning experiences. By asking about societal norms and by including skills that are acquired later in life—such as traditional medicine, piloting a boat, and house-building—we were able to circumvent this issue and get a broader view of cultural learning across the life history.

We found that domains learned later in life were also more difficult in terms of skill, but not in terms of physical strength. This impacts the study of the life history of cultural learning in several ways. First, it suggests that the long juvenile period is not primarily an adaptation for learning high-skill tasks, since the most difficult tasks in terms of skill are learned the latest in life. Alternatively, high-skill tasks may come with many prerequisite skills, and those skills might be learned during the juvenile period. This does not rule out the juvenile period as an adaptation for learning other aspects of a complex cultural world, however, because our questions focused on tangible tasks such as horticulture, gathering, manufacturing artifacts, and other household work. On the other hand, it complicates the debate about whether skill or strength constrains children's subsistence efforts. It may be that for a given task, strength rather than skill limitations prevent a child from being as efficient as an adult (e.g., in reef gathering: Bird and Bliege-Bird 2002; Bliege-Bird and Bird 2002). However, this may be the case only because high-skill tasks are not attempted in early and middle childhood, so the skill constraint is demonstrated through *which tasks* children attempt rather than their performance in any particular task. Also, this explanation ought to apply equally to high-strength tasks—a trend which our data do not support. Finally, the delayed onset of learning complex skills, paired with the finding that such skills are more likely to be transmitted obliquely, suggests an alternative interpretation. If high-skill tasks are best learned from experts, and experts are rare and hard to approach, high-skill tasks may be learned later in life not only because of children's cognitive constraints but also because of social constraints in children's access to experts.

Conclusions

Overall, our findings support predictions made by theories of cultural evolution and the two-phase approach to the life history of cultural learning. We found that teaching was a strategic component of cultural transmission and was spontaneously offered by interviewees as one process of learning among many. We also found that patterns in the frequency of teaching can be explained by evolutionary reasoning—teaching is more common among kin, and when the expected benefits to the pupil are high. And we found that vertical transmission is important, but not the only means by which key domains are learned. In fact, high-skill domains or domains learned late in life are learned primarily from non-parents. Given these findings, future research should focus on examining the trade-offs between the cost of teaching and the benefits that may be derived by the teacher—including kinship benefits or prestige deference exchange. In addition, researchers should focus on how different pathways of transmission correspond to changes in social interaction networks throughout the life history, and how these changes may affect the likelihood of teaching. Since teaching is in theory a cooperative problem (Thornton and Raihani 2008), further progress might be made in studying the social norms which promote or discourage teaching and other information-sharing behaviors (see Henrich 2009). Further, anthropologists and psychologists can benefit from the literature on teaching in non-human animals, and on research into the cognitive bases of teaching, both of which use evolutionary theory to classify different types of teaching. Since both these fields lack a thorough cross-cultural perspective on the range of teaching behaviors and the variety of situations in which humans do teach, ethnographers have a great deal to offer in return. This would lead to a richer, more accurate picture of cross-cultural variation in teaching and the life history of cultural transmission.

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