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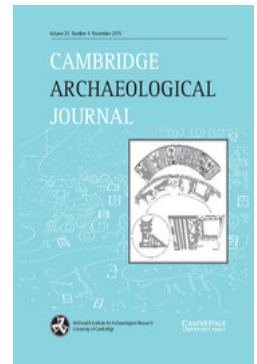
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Knowing, Learning and Teaching— How Homo Became Docens

Anders Högberg, Peter Gärdenfors & Lars Larsson

This article discusses the relation between knowing, learning and teaching in relation to early Palaeolithic technologies. We begin by distinguishing between three kinds of knowledge: knowing how, knowing what and knowing that. We discuss the relation between these types of knowledge and different forms of learning and long-term memory systems. On the basis of this analysis, we present three types of teaching: (1) helping and correcting; (2) showing; and (3) explaining. We then use this theoretical framework to suggest what kinds of teaching are required for the pre-Oldowan, the Oldowan, the early Acheulean and the late Acheulean stone-knapping technologies. As a general introductory overview to this special section, the text concludes with a brief presentation of the papers included.

Introduction

Homo sapiens is the only extant species that systematically educates conspecifics. In so doing, we help and encourage our children to gain extraordinary knowledge and skills. This enables them to do remarkable things like perceiving complicated patterns that help them categorize things in the world and learning connections between events that help them perceive causal structures. Much of this is achieved via teaching. Other species are able to learn through imitation and facilitation, but proper teaching seems to be absent. The intergenerational cultural transmission of skills, concepts and facts by teaching is unique to humans. So something has happened during the evolution of *Homo sapiens* that also made us *Homo docens*.

Without learning, there could be no teaching. Learning increases human knowledge and thereby stimulates what Haidle *et al.* (2015) have termed an expansion of human cultural capacity, contributing to the unique human socio-cognitive niche construction (Odling-Smee *et al.* 2003; Whiten & Erdal 2012). There are many kinds of learning, but social learning has been a significant behaviour adaptation of hominins throughout prehistory (Heyes 2012a). Renfrew *et al.* (2009, xiii) identified cultural learning as what makes

Homo special and underlined the importance of studying why and how the sapient minds learned to learn more extensively than in any other species. Others have focused on related areas like learning and environmental adaptation (Shennan & Steel 1999), human ecology, information storage and cultural learning (Bentley & O'Brien 2013; Henrich 2004), evolution of modern thinking and increased working memory (Coolidge & Wynn 2009), the emergence of the social brain (Dunbar 1998; Gowlett *et al.* 2012), co-evolution of hominin tool-making teaching and language (Morgan *et al.* 2015), human evolution in the light of extant non-human tool users (Whiten *et al.* 2009), neuroarchaeology and cognition (Stout *et al.* 2015; Stout & Khreisheh, this issue), the successive development of a uniquely long period of human childhood, allowing imaginary play to expand (Nielsen 2011; Nowell 2010; this issue), stone tools and the evolution of human cognition (Nowell & Davidson 2010), to mention a few of many areas (for overview, see e.g. Beaune *et al.* 2009; Renfrew *et al.* 2009). However, while a multitude of aspects of evolution and learning have been examined, surprisingly few studies are devoted to investigating teaching and the specific roles teaching might have had in human evolution (but see Gärdenfors & Högberg submitted; Kline 2015).

In this text we suggest that the evolution of human cooperation and cultural learning (Heyes 2012a, b) may crucially rely on one important mechanism: the ability to teach. Other species are able to learn through copying or facilitation (Whiten *et al.* 2009), but the process of advanced intergenerational transmission of knowledge by proper teaching is unique to humans (Gärdenfors & Högberg submitted). The evolution of teaching should thus be understood differently in comparison to other forms of social learning, e.g. emulation or imitation.

We bring forward teaching as a bridging activity in what Sterelny (2012, 8) describes as ‘positive feedback loops’ between social complexity and individual cognitive capacities. Teaching goes beyond other forms of social learning and becomes a way to organize society to facilitate intergenerational transmission of knowledge. Our suggestion is that putting teaching instead of learning in focus will change the perspective from the ways individuals learned technological skills to the ways society arranged for technological skills to be taught.

In this text we elaborate on this theme by discussing different aspects of knowledge on the basis of the concepts ‘knowing how’, ‘knowing that’ and ‘knowing what’. We also discuss different kinds of teaching, linking them to cognitive evolution. Our starting point is that human evolution should be thought of as multi-linear (Steward 1955) and multifactorial (Shennan 2002)—a diverse set of on-going processes (Haidle *et al.* 2015) forming co-evolutionary factors that over a long time have resulted in the *Homo docens* as we see ourselves today.

Most teaching is informal

When thinking about teaching in present-day society, activities in modern classrooms naturally come to mind. In contrast to informal learning in traditional cultures, such formalized teaching is a comparatively recent phenomenon and hence not our focus here. A number of ethnographic studies show that informal teaching is traditionally an integrated part of everyday activities (Greenfield *et al.* 2000). In informal learning children are taught, by adults or peers, the conditions of their work and behaviour through playful participation (Kamp 2001). Even though it can be organized in various ways (d’Errico & Banks, this issue), most researchers agree that play has a vital role in children’s learning. For example, in a study looking into childhood in Inuit societies, Park (1998) emphasizes that children mimic and imitate adults in tasks like hunting, care-taking and household activities, and in so doing the children actually enact the life of the

grown-ups (Lombard, this issue). This kind of play is both playful diversion and preparation for integration into society’s social and material activities.

Recognizing that teaching is not to be thought of as formal education, we here focus on the evolution of cognitive capacities required to teach and to be taught. Riede (2006, 63) points out that stone-tool production skills in prehistory would largely have consisted of routine procedures, practised repeatedly from an early age and thus deeply embodied in the Palaeolithic people. Fully acknowledging this, we argue that a focus on teaching will elucidate what is hidden in what Riede calls ‘routine procedures and practices repeated’ in forms of social interaction.

Knowing how, knowing that and knowing what

Cultural learning is usually defined as processes that are ‘thought to enable cumulative cultural evolution, i.e. the non-genetic inheritance of information in a way that allows individual and group phenotypes to achieve a progressively better fit with the demands of the social and physical environment’ (Heyes 2012a, 2181). Building on discussions of the role of social learning in human cultural evolution, Heyes (2012a) has extended the Associative Sequence Learning model. Using imitation as an example, she shows that a task a learner observes must be translated into individual actions to be understood in such a way that the task can be performed by the learner. This is made possible ‘by direct, excitatory connections between visual and motor representations of actions’ (Heyes 2012a, 2185). A learner who observes a sequence of actions, for example the production of a stone tool, generates a mental image of the sequence. Commencing to perform what has been observed, the learner creates an understanding of ‘what it feels like to execute the action’ (Heyes 2012a, 2185). It is the relation between observations and the experience of execution that results in social learning.

The neuro-psychological differentiation between visual and motor representations of actions links well to the commonplace epistemological distinction between ‘knowing how’ and ‘knowing that’ (Ryle 1945). In archaeology, and especially within the French school of technological *chaîne opératoire* studies (Pélégriin 1990), these concepts, normally referred to as ‘knowledge’ and ‘know-how’ (see Högberg 2009), are important (Tostevin 2012). ‘Knowing how’ depends on muscular embodied memory. It is tacit knowledge that is acquired through practical experience (Apel 2001), hence linking to motor representations. ‘Knowing that’ is communicative, something that can be transferred from one person to another

through language, by speech, signs, gestures, sounds, etc., hence linking to visual and other sensory representation (Heyes 2012a).

The distinction between the two kinds of knowledge basically corresponds to the Aristotelian distinction between *epistēmē* (scientific knowledge) and *technē* (skill, art or craft). Current philosophical debate (Fantl 2012) concerns whether the two kinds are independent—a position called anti-intellectualism—or whether ‘knowing how’ can be reduced to ‘knowing that’—a position called intellectualism (see e.g. Stanley 2011). Heyes (2012a) takes this debate further and suggests that neither independence nor reduction is sufficient to understand how these concepts link to processes of social learning. Instead, she emphasizes that it is not visual *or* motor representation of actions that is important for learning, but the *connections* between them. These connections do not emerge by themselves—social learning is needed. It is important to notice that the more advanced the learning gets, these connections require different forms of teaching to be achieved (Gärdenfors & Högberg submitted; Haidle *et al.* 2015).

Here, we also want to distinguish a third kind of knowledge—‘knowing what’. ‘Knowing what’ concerns the ability to categorize objects, for example to know what kind of tool an object is and what kind of work it is associated with, or what kind of disease somebody is suffering from. ‘Knowing what’ is central in *planning* a technological activity such as stone knapping: you must know what your goal product is before you start the production process. This kind of knowledge is framed, not just by technology and skills, but by culture. ‘Knowing what’ is socialized and materialized, something discussed by Lemonnier (1992) as ‘the social representations of technologies’.

The division of knowledge into ‘knowing how’, ‘knowing what’ and ‘knowing that’ can be compared to the three different kinds of long-term memory proposed by Tulving (1985):

- (1) *Procedural* memory, which allows the organism to remember the connections between stimuli and responses of different kinds. This kind of memory corresponds to ‘knowing how’;
- (2) *Semantic* memory, which allows agents to cognize actively about categories and objects. Semantic memory is closely related to pattern recognition. This kind corresponds to ‘knowing what’;
- (3) *Episodic* memory, which allows agents to remember individual events and the order in which they have occurred. This kind corresponds to ‘knowing that’.

Tulving claims that the order in which memory types are presented here corresponds to the order in which

they have emerged in evolution and that episodic memory is well developed only in humans. This would explain why ‘knowing that’ is so central for humans. Tulving’s thesis entails that ‘knowing how’ and ‘knowing what’ are more fundamental forms of knowledge than ‘knowing that’.

Given the connection between different kinds of knowledge and the long-term memory system, it follows that the different kinds of knowledge amplify each other. Tulving’s (1985) thesis about the evolutionary progress in cognitive development indicates that it is possible to identify and analyse archaeological contexts relevant for the study of teaching and learning (see Haidle 2010 for discussion) in terms of the three kinds of knowledge.

The connection between episodic memory and human abilities to learn is also emphasized by Donald (2012). His ‘mimesis hypothesis’ states that a specific form of cognition (and a corresponding culture) mediated between those of the common ape-ancestor and modern humans (Donald 1991). In brief, Donald proposes that while ape culture is based on associational learning (along behaviourist lines), early *Homo* evolved a new form of cognition. The basis for this was that the body could be used volitionally to repeat earlier actions; to *rehearse* a given skill by matching performance to a goal. Donald (2012) expands the mimesis hypothesis and emphasizes that a key feature of the human memory system is our ability to *voluntarily retrieve* a particular memory. To distinguish modern human learning from non-human animal learning, he points out that ‘nonhuman animals can learn skills with appropriate conditioning, but their performance can be retrieved only by external cues that elicit conditioned responses. Voluntary recall, as in self-triggered conscious retrieval, the kind of recall needed to practice a skill, is absent’ (Donald 2012, 275). This implies that there can be no rehearsal without voluntary recall of previous performance. This assumes a ‘capacity to self-trigger a specific procedural memory. The ability to initiate and guide the selective internal cuing process that triggers such a memory is called “autocuing”’ (Donald 2012, 276). Autocuing depends on episodic memory, within the realm of ‘knowing that’.

As we have pointed out, ‘knowing how’ depends on practice and muscle memory, i.e. the embodiment of a technology to become skilful. This notion thus fits well with what is called *embodied cognition*, that is, that an agent’s thinking is not only confined to the brain but strongly influenced by the activities of the body (Rosch *et al.* 1992). For Donald (2012), ‘knowing how’ is more. Beyond muscle memory, it represents the ability to recall tasks performed and the cognitive capacity to use recall to approve skill by rehearsal.

As such, 'knowing how' links to gradual evolution of abilities to understand causal relations, thus referring back to visual representation (Heyes 2012a).

Riede (2006, 65) emphasizes that the actions of prehistoric tool-makers should be seen as 'tightly constrained by the transmission history of the cultural lineage in which they are situated' (see Tostevin 2012 for similar critique). This connects directly to the idea that cognition is *situated*, that is, knowledge and learning is intimately bound to history and physical, social and cultural contexts (Lave & Wenger 1991). As Boivin (2008, 138) has stressed, the course of human evolution is 'therefore a process not only of human decisions, choices and ideas, but also of material forces with which humans are surrounded, and with which they engage'. Shennan (2002, 65) also points out that these processes are made up of individuals managing their lives in the light of the cultural (i.e. social and material) traditions they are part of, whose cumulative actions, conscious or not, produce evolutionary patterns.

Odling-Smee *et al.* (2003, 260) have stressed that 'much of human niche construction is guided by socially learned knowledge and cultural inheritance'. To make this happen, society must be organized in ways to make knowledge transition possible. Transmitting skills from one generation to another is done in a context and is hence dependent on its application in the world (Nonaka *et al.* 2010, 165). However, the more complex societies become during hominin evolution, the less sufficient individual learning is, and the higher the demands on transmitting knowledge via teaching become.

Teaching and cognitive evolution

In this section we present different forms of teaching that connect to different forms of knowledge and learning. Before that, we must briefly present social learning that does not require teaching. Tomasello (1999) distinguishes between learning by *emulation*, where the learner observes the outcomes of the model's actions and tries to reach the same outcome (goal-oriented copying), and learning by *imitation*, where the learner observes the sequence of the model's actions and tries to perform the same actions (process-oriented copying) (see also Tehrani & Riede 2008; Zentall 2001). In both examples, the learning individual observes the behaviour of a second knowledgeable individual (the model), while the model does not adapt its behaviour to make it easier for the first individual to learn. Hence, no proper teaching is taking place.

A central question is what skills and what knowledge can be learned by imitation or emulation only, and what require some form of proper teaching. In archaeological studies on social learning, the distinction between copying and proper teaching is rarely done (see, e.g., Morgan *et al.* 2015). For example, MacDonald (2007, 398) concluded that 'descriptions of how children learn to use and manufacture hunting weapons indicate that teaching is unimportant relative to observation and practice'. Referring to the discussion above on different kinds of knowledge, it is obvious that the way teaching in this example is opposed to 'observation' (copying) and 'practice' ('knowing how') is not adequate (see Lombard, this issue). Many human skills, let alone human knowledge systems, are so complicated that they cannot be learned by imitation or emulation only (Tehrani & Riede 2008, 318).

In this section we discuss teaching in three grades:

- (1) *Helping and correcting*: the teacher interferes with what the learner does;
- (2) *Showing*: the teacher draws attention and demonstrates something to the learner;
- (3) *Explaining*: the teacher clarifies by communicating concepts and making the learner perceive patterns.

These three types build on each other in cognitive development (see Gärdenfors & Högberg submitted) and they require different complexity in the interaction between 'knowing how', 'knowing what' and 'knowing that'.

Helping and correcting

A teacher may help learning by scaffolding the environment so that the learner learns quicker than they would otherwise have done; the teacher's intention simply being to provide that the learner exhibits correct behaviour (Caro & Hauser 1992). The selection and transport of hammer-stones to nut-cracking working areas by adult chimpanzees (Carvalho *et al.* 2008) is an example where learning is facilitated; young chimps only have to choose a hammer-stone from the selection brought to the site by the adults.

Another form is approval or disapproval of the learner's behaviour (Castro & Toro 2004). For example, if the learner is about to eat a poisonous plant, the teacher may show disapproval of this and thereby it is to be hoped that the learner will learn to avoid that kind of food.

As mentioned earlier, there are elements of teaching involved also in play since adults and other peers influence what is allowed in play (Lillehammer *in press*). Such behaviour can be interpreted as a form of teaching by approval and disapproval.

Showing

A basic level of teaching is to draw attention to something that is relevant in the learning situation. The teacher's intention in so doing is that the learner focuses on a particular object, action or feature. If the learner directs their attention to the intended goal, *shared attention* is achieved. In order to reach *joint attention*, the learner must also see that the teacher attends to the same thing, something that involves a form of mind-reading on the part of the learner. Following Mundy and Gomes' (1998) terminology, the teacher initiates joint attention and the learner responds to joint attention. In stone knapping, joint attention is, for example, involved when the teacher points to a suitable platform area on a core and then detaches a flake. When successful, the learner understands that the teacher showed a suitable platform area and illustrated this by detaching a flake.

Demonstrating is a more complex way of showing. It involves showing somebody else how to perform a task or how to solve a problem. Among humans, it is a ubiquitous form of teaching and children begin to demonstrate at an early age (Strauss *et al.* 2002). When demonstrating, the teacher's intention is that the learner exhibits the right actions in the accurate sequence. Highlighting initial and final states of an action helps the learner in segmenting the sequence of actions as well as in understanding the preconditions for the initiation of the action and the properties of its final result.

Demonstrating builds on advanced mind-reading of both the teacher and the learner. It presumes that the teacher understands that the learner does not know and that the learner perceives that something is to be learned. This kind of teaching also requires that the teacher and the learner jointly attend to the demonstration. When the learner tries to imitate the demonstrated action, the teacher responds with approval or disapproval and, if necessary, with renewed demonstration.

Explaining

Human thinking is organized around concepts—this is central to 'knowing what'. When explaining, the teacher communicates a concept with the intention that the learner perceives a particular pattern that pertains to an object or an action (Gärdenfors 2014). For more abstract concepts, the intention is that the learner mentally represents the relevant patterns.

It is not necessary for concepts to be communicated by words. Before speech is available (in evolution or in development), an iconic gesture can also be used. Explaining concepts relies on increased mind-reading, since it presumes that the learner under-

stands that the teacher is intentionally using a gesture or a sound as a *communicative sign*, that is, that the gesture or sound is used to 'stand for' something else (Zlatev *et al.* 2005).

An important type of teaching, based on communicating concepts, is when a learner is taught *sub-goals* in a technological hierarchy, i.e. essential technological actions that must be completed before the next stage in production can start (Haidle 2010; Stout 2011). The more complex a technology becomes, the more sub-goals are involved (Mahaney 2014).

The main point in relation to teaching is that sub-goals cannot be perceived directly from the action sequence. They are therefore difficult, or impossible, to teach by showing. They must be explained by teaching how to perceive the relevant patterns in the abstract sub-goal structure. The sub-goals are not perceptually available when the process starts, but they have to be kept in mind by the learner as variables that need to be coordinated within a structured sequence linking sub-goals to each other.

In the following section, we provide archaeological examples of how the kinds of teaching may be used for understanding what was required for a specific technology. But first we present a schematic illustration of how the different kinds of knowledge and teaching are linked (Fig. 1).

Archaeological examples of teaching

In this section, we will present different kinds of teaching and their cognitive requirements by briefly discussing pre-Oldowan, Oldowan, early Acheulean and late Acheulean technologies. These examples will add concreteness to our earlier, more theoretical discussion. For more detailed analysis of the Oldowan and late Acheulean technologies, see Gärdenfors and Högberg (submitted).

The oldest known knapped stones are from the unique 3.3-million-year-old site of Lomekwi 3 in West Turkana, Kenya (Harmand *et al.* 2015). Here Pliocene hominins pre-dating early *Homo* combined core reduction with battering activities using local raw materials. The Lomekwi knappers had an emerging understanding of fracture properties in stone knapping. Cores are rough, mostly made out of heavy and large-sized cobbles or blocks. By using passive hammer (block-on-block) and bipolar techniques, large irregular flakes were detached from one striking platform onto a single surface. The knappers were able to 'deliver sufficient intentional force to repeatedly detach series of adjacent and superposed unidirectional flakes' (Harmand *et al.* 2015, 313). However, the cores are irregular and technological attributes show that

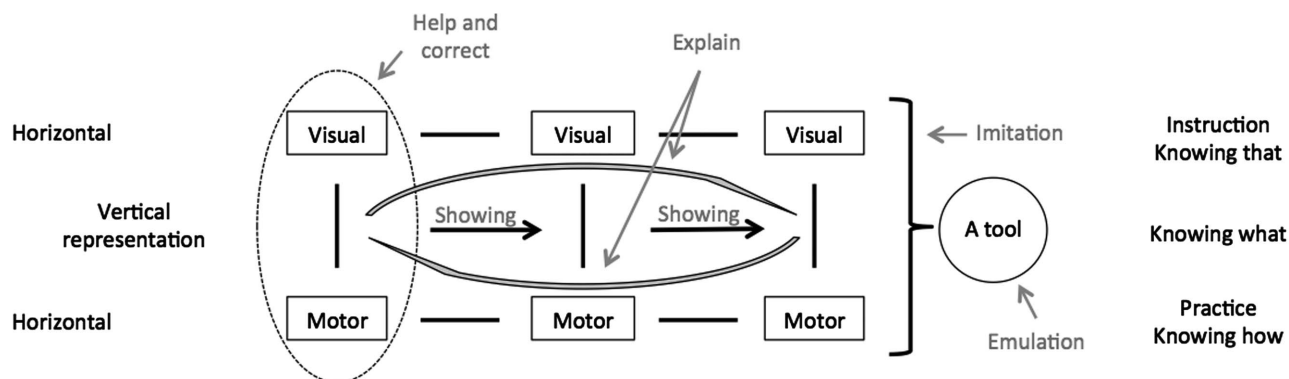


Figure 1. Schematic illustration of how the kinds of knowledge (black) and teaching (grey) discussed might link together. The horizontal line of visual and motor representation from Heyes (2012) links to instruction ('knowing that') and practice ('knowing how'). Heyes' vertical representation links visual and motor representation. The tool that is the result of the actions performed materializes 'knowing what' (Boivin 2008). Non-intentional teaching is emulation, trying to copy the tool, and imitation, trying to copy the perceived process. A simple form of teaching is to help and correct in a single vertical representation of visual and motor action (dotted line). A more advanced form of teaching is showing. Here the vertical representation of action sequences is in focus, teaching that one action leads to another if performed in a sequence. Explaining is a yet more complex form of teaching, focussing on how to perceive patterns. The vertical representation is of action sequences, here taught as part of a pattern of inter-related sub-goals.

the knapping actions were poorly controlled (Harmand *et al.* 2015). To learn to produce this kind of lithic assemblage, helping and correcting is enough.

The Oldowan is the earliest known stone-tool technology associated with *Homo*. It is normally characterized as based on flake production from simple cores. Both flakes and cores were used as tools (Torre 2011). The techniques used in the Oldowan were knapping with a hammer stone using direct percussion or bipolar percussion with an anvil (Braun *et al.* 2008). Refitting analyses demonstrate that *core maintenance* was practised (Delagnes & Roche 2005). Core maintenance is achieved by detaching flakes in a way that makes it possible to strike further flakes from the same core, that is, keeping the core active in a toolkit without immediately exhausting it (Braun *et al.* 2008).

Oldowan technology can be learned through imitation, including rehearsal, and showing. By drawing attention and demonstrating, the teacher intends to make the learner understand action sequences involved in the technology. Here, demonstration is required when the teacher shows the learner how to detach a series of flakes, at the same time maintaining the core to facilitate future flaking.

In terms of morphology, the Acheulean hand-axes show extraordinary stability over time (Hodgson 2015). At the same time, in a long-term perspective, one finds a distinct refinement in symmetry (Isaac 1982). Early hand-axes are generally thicker and less symmetrical than the more elaborately shaped later Acheulean hand-axes (Stout *et al.* 2014). Even

though comparisons over large geographical areas indicate noteworthy differences, a dominant chronological pattern towards more symmetric and standardized tools from the early to late Acheulean is evidence for an increasing preference over time for particular proportions (Gowlett 2011).

Acheulean hand-axe technology requires advanced levels of intra-generational transmission of knowledge (Shipton 2013). The production process builds on a reduction strategy that maintains the three-dimensional bifacial shape throughout the production process. The actions performed are made up of entangled sequences of techniques and methods that, in part, repose on knowledge of specific concepts, that is, 'knowing what'. The production sequences cannot be learned by imitation (Mahaney 2014), they must be taught. This involves the teacher breaking down the sequences into sub-goals and explaining these in order to convey the specific concepts the learner must know to master the technology. The teacher must adopt a holistic view of the complete production process, and be able to teach the process in such a way.

A number of theoretical models have been suggested to explain the difference between early and late Acheulean hand-axe production technology. These models, relating to differences in cognitive capacities, typically deal with complexity of techniques and methods involved, or aspects of symmetry and the ability to produce a bifacial tool by visualizing and processing a three-dimensional image (see Hodgson

Table 1. Teaching and knowledge linked to stone-tool production within archaeological technologies. The numbers 1–5 are here used as illustrations of stages in hypothetical action sequences.

Teaching type	Knowledge taught	Cognitive understanding	Industry
Helping and correcting	–	Single isolated actions	Pre-Oldowan
Showing	Rudimentary action sequences Core maintenance	One action leads to another action	Oldowan
Showing	Sophisticated action sequences Three-dimensional bifacial reduction	One action leads to another To reach the goal these actions needs to be performed in a sequence: 1→2 2→3 3→4 4→5	Early Acheulean
Explaining	Sophisticated action sequences Three-dimensional bifacial reduction Relevant patterns	One action leads to another Explaining that to reach the goal the actions needs to be performed in a sequence of sub-goals: 1→2→3→4→5	Late Acheulean

2015 for a recent review). Recognizing the importance of these models, Gärdenfors and Högberg (submitted) expand on them by focusing on the cognitive capacities necessary to perform *platform preparation* in particularly crucial phases of the production process.

Platform preparation represents a significant difference in learning between early and late Acheulean hand-axe production (Stout *et al.* 2014). The teacher must explain to the learner how platform preparation isolates and alters the platform in the area from where a flake is to be removed. The learner must therefore be able to envisage the pattern that constitutes an appropriate platform. When this is understood by the learner, the teacher must show how to prepare the platform to get it right, and how to apply force to the piece so that the intended type of flake can be detached. This involves explaining the concept of a platform as well as the temporal patterns involved in the action hierarchies necessary to prepare it. And different phases in the tool production require different approaches to how a platform is set up. Consequently, the production process is a multivariate construct (Gowlett 2011).

In Table 1 we summarize our discussion of different types of teaching. Since the different forms of teaching presume different levels of mind-reading, Donald's (2012) concept of autocued rehearsal is important for understanding how this might have evolved. In a large-scale experimental study, Morgan *et al.* (2015) tested how different social learning mechanisms could be used to transmit Oldowan stone-knapping techniques. They conclude that cultural reliance on Oldowan tools generated a selection mechanism that favoured teaching (Morgan *et al.* 2015, 3). Our discussion of 'showing' by drawing attention and demonstrating to learn to understand rudimentary action sequences and their interaction with autocued memory increases our understanding of how social learning might have worked for the Oldowan knap-

pers and how it differs from pre-Oldowan technologies. As mentioned earlier, Stout *et al.* (2014, 577) have noted the importance of effective platform techniques in the transition from early to late Acheulean. Here, recall and rehearsal, in combination with cognitive abilities to understand concepts and how these relate to actions performed in patterned sequences with sub-goals in action hierarchies, illustrate the suggested development from early to late Acheulean hand-axe production.

Conclusion

The ability to translate intelligence, imagination and social interaction into technology must be regarded as having had an essential impact on human evolution. The way technology has been transmitted between generations is thus essential for our understanding of human development. Renfrew *et al.* (2009, xiii) see the question of how *Homo* minds 'learned to learn' as essential for our understanding of human cognitive evolution. Here we have moved from *learning* to an investigation of how increasing levels of *teaching* have contributed to the unique human social-cognitive niche construction (Whiten & Erdal 2012).

As a grounding for our analysis, we discussed different forms of knowledge—'knowing how', 'knowing what' and 'knowing that'—and showed their connections to different forms of learning and long-term memory. This led us to identify three basic types of teaching: helping and correcting, showing, and explaining.

As an application of the theoretical framework, we have presented an analysis of which types of teaching are necessary for some Palaeolithic stone-knapping technologies. The conclusion is that there is a strong correlation between the complexity of the technology and the complexity of the required teaching.

The articles in this section

This special section brings together articles by an international, interdisciplinary group of scholars and experts interested in the implications of social learning and education for understanding human evolution. The focus is on teaching in an evolutionary setting and what evidence archaeology can bring forward that is relevant to when and in what forms teaching occurred in the *Homo* lineages. Interdisciplinary aspects of learning, teaching, language, cognition, neuroscience, stone-tool production, visual cultures and hunting technologies are brought together and discussed from a wide range of perspectives.

The articles originate from the workshop 'How did *Homo sapiens* become *Homo docens*? On the evolution of social learning and teaching', held in November 2013 at Stellenbosch Institute for Advanced Study (STIAS), Wallenberg Research Centre, at Stellenbosch University, South Africa. The two main questions in focus at the workshop were the following:

- (1) What are the implications of how teaching emerged for our understanding of human evolution?
- (2) How can we understand teaching during the Early Stone Age?

A uniting theme throughout the section is to analyse aspects of how to develop an interdisciplinary understanding of education throughout prehistory and what is meant by understanding and knowing in different contexts and eras. The goal is to analyse what forms teaching may have taken throughout the deep time of the *Homo* lineage and to suggest theoretical perspectives and methods to talk about teaching and learning in an archaeological framework.

Along the lines as we have discussed above, **D'Errico** and **Banks** argue that the emergence of teaching cannot be understood if it is only associated with the origin of our species. A perspective that goes beyond *Homo sapiens* is needed. They distinguish between spatial, temporal and social dimensions of teaching. The spatial dimension concerns how easy it is for the learner to copy the teacher, depending on the distance between them. Here d'Errico and Banks include gesture moulding (when teacher and learner are in bodily contact) and explanation-complemented action where verbal (or gestural) explanations are added to the bodily actions. The temporal dimension concerns, for example, whether teaching consists in a single information transfer event or in repetitive or sequential information events. Finally, the social dimension deals with, for example, whether the teaching is horizontal transmission, describing transfers that take place between individuals of the same gener-

ation, or vertical transmission, in which information is passed from parent to offspring. Their approach combines concepts and analytical tools from a variety of disciplines into an operational framework that can be used to identify and study potential means and mechanisms of transmitting cultural information. In so doing they provide a basis for an evolutionary perspective on teaching that relies on material culture recovered from archaeological contexts.

Increasing reliance on skill-intensive subsistence strategies appears to be a hallmark of human evolution, with wide-ranging implications for brain size, life-history and cognitive adaptations. In the article by **Dietrich Stout** and **Nada Khreisheh**, methods from neuroscience are discussed. The authors describe how Palaeolithic tool replication experiments offer a new avenue for establishing empirical links between technological behaviours, neurocognitive substrates and material culture recovered from archaeological contexts. In modern humans, skill teaching and learning are facilitated by cognitive capacities for complex imitation, joint attention and pedagogy, as well as affective dispositions favouring pro-sociality and enhanced self-regulation. These cognitive and life-history parameters describe a human technological niche that relies on efficient intergenerational reproduction of increasingly complex foraging techniques, in particular the production and effective use of tools. Stout and Khreisheh conclude that the archaeological record provides a valuable source of evidence for tracing the emergence of this modern human condition, but research will require commitments of time and effort to address the complex skills properly.

The following two articles discuss different aspects of material culture in relation to teaching and learning. Stone Age hunting technologies are considered by **Marlize Lombard**, and the Upper Palaeolithic visual cultures manifested by cave art from southwest Europe are discussed by **April Nowell**. Hunting techniques and cave art are central topics in studies of human evolution. Here this central evidence of prehistoric material culture is discussed from the perspective of teaching and learning.

Human hunting represents one of the most difficult foraging activities. It is a skill-intensive pursuit with an extended learning process. Stone Age hunter-gatherers used complex strategies and technologies to outsmart and pursue their prey. Lombard discusses aspects of how such strategies and technologies were grounded in extensive knowledge that facilitated context-specific solutions during different phases of weapon production and hunting. She concludes that, apart from subsistence behaviour, Stone

Age hunting technologies also inform about a suite of associated skills, behaviours and levels of cognition. In her article, Lombard provides an overview and broad timeline of the ‘evolution’ of hunting technologies associated with the southern African Stone Age record and presents ethnographic hunter-gatherer examples of teaching and learning associated with hunting. In so doing, she situates the archaeological and ethnographic data within a theoretical framework of teaching and learning evolution.

During the Upper Palaeolithic, southwest France and northern Spain were sites of locally situated Pleistocene visual cultures that were both quantitatively and qualitatively different from the symbol-using cultures that came before them. Nowell discusses children’s phenomenological experience in these visual cultures and their embodied participation in communities of practice as a process of both ‘seeing to learn’ and ‘learning to see’. She starts from the premise that children are not born picture-users, but in the process of developing a pictorial competence, she argues that children must have been able to hold in their minds both a picture and its referent simultaneously, as well as understanding the nature of the relationship between a representation and its referent. The very special visual cultures have in this sense influenced the children’s evolution, making them both symbolists and materialists. Upper Palaeolithic children learned to move fluidly between three-dimensional and two-dimensional worlds and to perceive a fourth dimension of time through motion from still images. These abilities not only permitted, but also forged, new ways of imagining and acting in the world.

The evolution of language is a disputed topic. As regards the evolution of teaching, it is important to understand the role of linguistic communication in the relation between teacher and learner. The last article in this special section focuses on the evolution of language. On the basis of recent studies, **Rudolf Botha** discusses conceptual bridges that span the ontological gap between the behaviours and capacities of modern humans and those of the earlier hominins. Focusing on studies that draw inferences about the social use of language by hominins from data about the linguistic behaviour of modern hunter-gatherers and other modern people with traditional cultures, Botha elaborates on source-critical factors involved in these studies. In particular, he discusses uniformitarian assumptions, maintaining that knowledge of processes operative in the past can be inferred by observing processes in the present. He argues that the linguistic, behavioural and cultural differences between earlier hominins and modern humans discourage an appeal

to uniformitarian assumptions to warrant the inferential step from ethnographic data about the linguistic behaviour of modern hunter-gatherers to conclusions about the linguistic behaviour of non-modern hominins.

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