Journal of Philosophy of Education
The Journal of Philosophy of Education Society of Great Britain
pesgb

Journal of Philosophy of Education, Vol. 51, No. 3, 2017

Three Views on Expertise: Philosophical Implications for Rationality, Knowledge, Intuition and Education

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INTRODUCTION

An important aspect of education is transmission of knowledge. Not only has knowledge been a central topic in philosophy, at least since Greek antiquity, but in recent years, it has been a prominent issue in the study of expertise. Reflecting on expertise has led to new insights about several long-standing philosophical questions beyond epistemology, including the nature of rationality and intuition. The aim of this article is to discuss three views of expertise that have something important to say about these philosophical issues. While two of these views come from philosophy (Dreyfus and Dreyfus, 1986, hereafter D&D; Montero and Evans, 2011, hereafter, M&E) and one from psychology (Gobet and Chassy, 2009, hereafter, G&C), they all address similar philosophical questions, albeit with rather different conclusions. The article first briefly reviews the issue of defining and identifying expertise and the philosophical debate around knowing-how and knowing-that. After presenting the key assumptions made by the three views on expertise, it compares them along six philosophical dimensions: rationality, knowledge, intuition, introspection, deliberation and artificial intelligence. In the discussion, the article draws conclusions for education.

Philosophy and education share a common interest in knowledge. While philosophy has enquired on the nature of knowledge and its truth value, education has focused on the transmission of knowledge through teaching. Obviously, different philosophical answers will lead to different educational practices. For example, whether knowledge is best characterised as knowing-how or knowing-that—a question to which we will return often in this article—will have different implications for education, including the kind of representations used by teachers and the likelihood that knowledge acquired about one topic (e.g. geometry) will transfer to another one (e.g. physics).

Before discussing the extent to which expertise sheds light on the philosophical issues we have just highlighted, we need to define the term ‘expert’. The definition is actually trickier than seems the case at first blush, as was already noted in Plato’s *Charmides*, where it was argued that distinguishing

Published by John Wiley & Sons Ltd, 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA.

a fake physician from a true one would challenge even a wise person. This issue is made more poignant when it is realised that there exist surprisingly many *fake experts*—individuals who are thought to be experts while in fact they do not have the required skills and/or qualifications. Examples include bogus doctors (around 10,000 in the US only!), a Defence Minister and an Education Minister in Germany who had plagiarised parts of their PhD, and a conman who sold fake weapon detectors (actually £15 gadgets used to find golf balls) for £10,000 each, earning more than £55 million and causing thousands of deaths in Iraq (Gobet, 2016b).

In contrast, there are domains of expertise where identifying experts is not problematic, such as chess and tennis. In such domains, superior performance can be replicated in the laboratory and thus the status of the expert confirmed. It is thus worthwhile distinguishing between two kinds of expertise (Gobet, 2016b): performance-based expertise (*p-expertise*) and reputation based expertise (*r-expertise*). Fortunately for our analysis, the three views we will discuss focus on p-expertise, drawing examples mostly from chess, where an objective and widely-used measure of skill is available.

KNOWING-HOW AND KNOWING-THAT

Traditionally, philosophers have adopted a position known as intellectualism: explicit knowledge (aka knowing-that or propositional knowledge) is the primary form of knowledge, and tacit knowledge (knowing-how) derives from it. In other words, knowing-how can always be translated into propositions. An important exception to this dominant view was Ryle (1946, 1949), who argued that knowing-that and knowing-how are not the same kind of knowledge, in that it is not possible to reduce knowing-how to knowing-that. In addition, knowing-that does not necessarily deliver the same skills that knowing-how does. Thus, one can know-that without knowing-how in a particular domain, as Ryle illustrates with chess: 'We can imagine a clever player generously imparting to his stupid opponent so many rules, tactical maxims, "wrinkles", etc., that he could think of no more to tell him; his opponent might accept and memorise all of them, and be able and ready to recite them correctly on demand. Yet he might still play chess stupidly, that is, be unable intelligently to apply the maxims, etc.' (Ryle, 1946, p. 5). Ryle's proposal has led to much debate in philosophy. Critiques have disputed the epistemological value of differentiating between knowing-how and knowing-that (e.g. Stanley and Williamson, 2001; White, 1982) and claimed that the concept of knowledge-how is ill-defined (e.g. Snowdon, 2004). Crucially, the question of knowing-that and knowing-how is central to the study of expertise. It will play an important role in the three views discussed in this paper.

PRACTICAL APPLICATIONS OF PHILOSOPHY TO EDUCATION

Before going into the subject matter of this paper, it is worth briefly reviewing two examples showing that philosophical analysis can illuminate applied issues related to education. The first example examines the meaning of knowing-how. To answer questions about vocational and professional

education, Winch (2010) studied professional bricklaying qualifications in eight countries of the European Union. A first important conclusion is that *know-how* contains a fundamental ambiguity in English. 'A knows how to F' has two possible meanings: (a) A can carry out F, and (b) A can provide an account of how F is carried out. This ambiguity is not present in French (*savoir faire* vs. *savoir comment faire)* and in German (*können* vs. *wissen wie)*.

A second important conclusion is that it is essential to understand how initially providing instruction in the form of propositional knowledge is related to practice (Winch, 2009). This has implications for the distinction made by Ryle between knowing-how and knowing-that, and in particular suggests that the importance of knowing-that is not fully appreciated in many forms of knowing-how, such as making judgements.

The second example deals with the discrepancy between what is expected by an industry and what actually happens. Boyd and Addis (2010, 2011) interviewed senior managers and bricklayers and identified clear divergences between the sort of knowledge that the industry assumed to be essential and what was observed in real life. The industry emphasised technical and factual knowledge, but working practices relied much more on non-factual knowledge (e.g. the proper way to deal with people).

THREE VIEWS ON EXPERTISE

There exist many approaches accounting for various aspects of expertise in philosophy, psychology and other social sciences. The three views discussed in this paper have been selected because (a) they discuss the philosophical concepts identified in the introduction; (b) they discuss at length the same domain, chess, the domain of expertise that has been most researched and discussed in academy; and (c) there has been cross-discussion between the authors of the central ideas defended in these papers. It should be noted at the outset that these views use different types of evidence to support their claims. D&D mostly use references to the philosophical literature, thought experiments, anecdotal evidence and the reader's intuitions on the way human expertise works. M&E use similar sources, but also refer to experimental data from psychology. Finally, G&C draw evidence from experimental data in psychology and from computer simulations.

Dreyfus and Dreyfus's (1986) View on Expertise

Hubert Dreyfus's interest in human expertise stems from his phenomenological critique of the symbolic approach in artificial intelligence, in particular the research programme carried out by Newell and Simon (1972), Minsky (1977) and McCarthy (1968). A key argument of his book *What Computers Can't Do* (1972) was that humans do not use discrete symbols and rules (i.e. propositional knowledge) to perceive and make decisions but rather do this holistically. The holistic nature of human cognition is, according to Dreyfus, particularly apparent with experts. This conclusion naturally led to another book, *Mind over Machine* (Dreyfus and Dreyfus, 1986),

co-authored with his brother Stuart, in which they developed a five-stage theory of expertise (see also Dreyfus and Dreyfus, 1984, 1996, 2005). Targeting the then widely held opinion that expert systems would equal or even better human performance (e.g. Feigenbaum and McCorduck, 1983), the book concludes that expert systems will at best perform at the level of human non-experts: while human experts act intuitively and use context-bound and embodied knowledge, experts systems employ discrete, context-free and disembodied rules, just like non-experts. In other words, while human experts use knowing-how, expert systems are stuck with knowing-that and thus cannot act in the fluid and natural way that characterises human experts' behaviour.

Dreyfus and Dreyfus (1986) identify five stages of expertise. In the first stage, 'novices' learn domain-specific facts, features and actions through instruction. They use rules independently of the context, in a rigid manner. It is only after considerable concrete experience with a particular domain that the second stage is reached. In that stage, 'advanced beginners' start using situational elements that incorporate meaningful information about the context. In the third stage, 'competent' individuals become more efficient and start organising decision-making procedures in a hierarchical way. However, the kind of planning used is still largely conscious and deliberate. In the fourth stage, 'proficient' individuals now perceive some features as salient and pay no attention to others. They are able to categorise and grasp problem situations intuitively, but they must still think analytically when making decisions about their future actions. In the final stage, 'experts' display a fluid and intuitive behaviour not only for understanding the problem situation, but also for deciding what actions to carry out next. When tasks are ordinary, 'experts don't solve problems and don't make decisions; they do what normally works' (Dreyfus and Dreyfus, 1986, pp. 30–31).

Montero and Evans (2011)

Montero and Evans (2011) provide both a critique of Dreyfus's theory and propose their own view on expertise, based on McDowell's (1994, 2007a, 2007b) theory of rationality. Contrasting with D&D, M&E argue that experts follow rules consciously, and that this represents rational action. Two types of rules are considered. The first type is not particularly interesting philosophically: in a game such as chess, experts know the rules of the game and, if required do so, can state them explicitly. The second type of rules—heuristics rules—are at the centre of the know-how/know-that debate. Two classes of heuristics are considered, and both are assumed to be known explicitly and used consciously. First, there are basic heuristic rules (e.g. 'Control the centre' in chess); these are often not very predictive, because they might conflict with each other. Second, there are specific, advanced heuristic rules (e.g. 'When White carries out a minority attack in the Exchange Variation of the Queen's Gambit Declined opening, the Queen's rook should be placed on b1, not c1'). These heuristics are both powerful and also subject to exception: 'Although Grandmasters

can usually beat International masters or weaker players without ever relying on anything beyond heuristics, it is times where specific heuristics are flouted which decide who wins in games between Grandmasters' (M&E, p. 182).

A key assumption of M&E's view is that experts are rational, in the sense that they can consciously justify their decisions. M&E's emphasis on conscious rationality suggests that they are sceptical about the importance of intuition, and this is indeed the case. According to M&E (p. 189), 'the psychological data on the relative importance of intuition for players of different strengths is mixed'. They argue that intuition, when present, is *rational*—the processes leading to the intuition can be articulated—as can be seen in M&E's following example: 'I saw that the position was a Dragon Sicilian Yugoslav Attack, and so I instantly saw that sacrificing on the h-file would lead to checkmate, as it inevitably does in those kinds of positions' (p. 191).

In line with their view of human rationality and the rule-following character of human cognition, M&E also argue that experts have reliable access to their thoughts, and they 'see no reason to think that chess players are radically mistaken about what goes on in their minds during games' (p. 188).

Gobet and Chassy's (2009) View on Expert Intuition

Gobet and Chassy (2009) use the template theory of expertise (Gobet and Simon, 1996) to theorise about expert intuition, focusing on chess and nursing. While developed originally to account for chess data, the theory, which is implemented as computer programs (Gobet, 1997; Gobet and Simon, 2000), is a general theory and accounts for the development of expertise in domains such as games, science, engineering and sports, and has been applied to other aspects of cognition such as the acquisition of language and concept formation (Gobet *et al.*, 2001; Simon and Gobet, 2000).

Referring to Simon's (1982) theory of bounded rationality, G&C assert that human rationality is strictly limited. That is, attention can be heeded to just one thing at a time, the capacity of visual short-term memory is limited to four items, and searching through the problem space of possible states is slow (perhaps ten positions in a minute in chess). These limitations apply both to novices and experts.

Two features help experts circumvent these limitations. First, when making decisions, they carry out a highly selective search; this is made possible by efficient, albeit narrowly focused problem-solving methods and heuristics. Second, they simplify decisions by acquiring large amounts of knowledge, learning how to apply previously successful solutions to new problem situations. Following Simon and Chase's (1973) work, it is proposed that a large part of this knowledge is stored as 'chunks', which are units both of perception and meaning that are built recursively. The presence of chunks allows experts to perceive stimuli as groups of objects rather than individual objects. When some patterns are often present in the environment, they may

lead to the acquisition of a template (schema), which originally is built on a chunk (the 'core' of the template). A template is a more complex structure than a chunk, for it also possesses one or several 'slots', where variable information can be encoded.

In line with the assumption of bounded rationality, learning is assumed to be relatively slow: 8 seconds to create a new chunk, and 2 seconds to add information to an existing chunk. The construction and use of chunks and templates is not exclusive to expertise, but is underpinned by basic mechanisms that are also used in many other domains, including concept formation and the acquisition of language (Gobet, 2016a; Gobet and Lane, 2010).

As the result of practice and study, chunks and templates may be associated with possible actions, such as what move to play or what plan to follow in chess. Thus, we have what Newell and Simon (1972) term 'productions': a condition linked to an action. An example of such a production could be: 'Given an open line, put a rook on it'. An important class of actions includes instructions about where to move one's eye and thus direct attention (De Groot and Gobet, 1996). Thus, G&C assume a close interaction between knowledge and perception: template theory 'includes mechanisms detailing how perception determines what will be learned, on the one hand, and how learned knowledge determines what will be perceived, on the other' (Gobet and Chassy, 2008, p. 161). Intuition is explained mostly by the idea that recognised patterns activate productions that provide relevant information from long-term memory, and by emotions that act as an alert system.

APPLICATION OF THE THREE VIEWS TO PHILOSOPHICAL KEY THEMES

We are now in a position to discuss what each of the three views says about the key philosophical themes we have mentioned in the introduction. The reader should note that there is some overlap between these themes; for example, the discussion of 'rational intuition' pertains both to rationality and intuition.

Rationality

The question of rationality is answered bluntly by Dreyfus: experts are *arational*, in that they are not able to defend their actions rationally. '[T]he master may make moves that are entirely intuitive and contrary to any preconceived plan. In such instances, when asked why he did what he did, he may be at a loss to reconstruct a reasoned account of his actions because there is none. (. . .) Nothing about the position need be nameable and thinkable as a reason for acting' (Dreyfus, 2005, pp. 54–55). The essence of expertise is to act intuitively without much, if any, deliberation. It is individuals at the novice, advanced beginner and competent stage who use deliberation and analytic thinking and thus could justify their actions. However, these individuals are not experts.

M&E's motivate their own position by first criticising D&D's theory. They note that, whilst D&D argue that experts rarely rely on attention and deliberation, there is actually considerable empirical data showing that experts, for example in chess, carry out much look-ahead search (e.g. De Groot, 1978). M&E actually take the opposite position to Dreyfus: experts are always able to provide rational justifications for their actions, and expert intuition in fact depends on reason. This position is similar to that advocated by McDowell (1994) in his theory of rationality.

G&C adopt a middle ground position. Experts are not arational or fully rational, but they show a rationality that is limited, in that they occasionally make minor and every so often even major mistakes (for evidence, see Gobet, 2016b). For example, in the case of chess, full rationality entails a systematic search of all logical possibilities, and minimaxing. This is not possible due to humans' limits in short-term memory, learning rates and speed in generating new positions. Experts therefore show high selectivity in their search behaviour, made possible by their knowledge, both tacit and declarative. This selectivity allows them to rapidly focus on favourable options whilst ignoring irrelevant ones—a point powerfully emphasised by D&D. Whilst this runs the risk of missing optimal moves, it is highly adaptive, as decisions can be made rapidly if necessary. In line with psychological research on expertise, G&C propose that some of experts' decisions are made intuitively, using pattern recognition, while others depend more on conscious analysis and enumeration of possible moves and countermoves. According to Gobet (2012), there is a difference between how experts *decide* and *justify* actions. With the former, experts use a combination of tacit knowledge, declarative knowledge and look-ahead search. With the latter, they rely on conscious rules and validations based on conclusions from analysis.

Since part of experts' decision-making is intuitive and relies on perceptual cues that are unconscious or at best difficult to verbalise, they cannot always justify their decisions. Thus, they do not display rationality in the sense of D&D and M&E. Importantly, they do not display either the kind of (full) rationality often discussed in the social sciences, defined as the ability to make the best possible decisions for achieving one's goals, given one's knowledge. Rather, they display bounded rationality (Simon, 1956, 1982).

Knowledge

To what extent do experts follow rules? D&D argues that experts do not do it: they just act intuitively. Thus, they defend a pure version of knowing-how. In fact, according to D&D, rule-following is a characteristic of *non*-experts. M&E criticise this view, arguing that it is inconsistent with the fact that experts use both basic and advanced heuristic rules. For them, the use of heuristics (i.e. rules) is the essence of expertise—a pure version of knowing-that.

As with other dimensions, G&C's view avoids extremes. With D&D, it agrees that some knowledge is intuitive; with M&E, it agrees that some

knowledge is rule-based. GC also discuss two possibilities rarely considered in the knowing-how/knowing-that debate in philosophy. In line with much research in psychology (e.g. Fitts, 1964), they assume that some rules initially encoded declaratively later lead to the creation of procedural knowledge that can be used unconsciously. They also argue that the creation of productions using perceptual patterns means that some unconscious rules are created without ever being conscious (a possibility not discussed by M&E). In fact, at least two psychological theories of expertise (chunking theory and template theory) consider that such productions are critical for the acquisition of expertise. Automatic visual pattern recognition has the advantage over explanations depending on language of explaining how expertise can develop in visuo-spatial domains where it is difficult to code the information verbally.

Intuition

Intuition plays a central role in D&D's view of expertise: for them, expertise *is* intuition. While intuition characterises expertise, deliberation typifies non-expertise. As noted above, a key feature of intuition is that it is arational. Again, M&E take issue with this view and argue that intuition is rational and that it is possible for experts to justify their actions consciously. G&C tend to agree with D&D on the question of intuition. In fact, one of the criteria of their definition of intuition (Gobet and Chassy, 2008, p. 130) is that experts cannot verbalise why they have made their choice and what steps they have taken. In addition, they point out that emotions, which mostly are unconscious, affect experts' decisions in important ways (Benner *et al.*, 1996; Tikhomirov and Vinogradov, 1970), enabling rapid decisions to be made. G&C also emphasise the importance of pattern recognition, and thus perception, in expert decision-making. As stated by de Groot and Gobet (1996, p. 1), '. . . the two areas of thinking and perception are hardly ever separable, and in many cases even indistinguishable. "Pure" thinking—human information processing without any perceptual intake in the process—is extremely rare. In problem solving tasks, the problems are necessarily presented in perceivable form; but in most cases they are also operated upon perceptually'.

Introspection

A related issue is whether experts have full access to their own thinking. D&D argue that this is not the case, given the intuitive nature of decision-making. M&E imply that experts do, given that they can justify their decisions. G&C adopt an intermediate position. Some thinking is accessible to consciousness. For example, in many domains, asking experts to think aloud when making a decision generates protocols that provide fairly reliable evidence about their thinking processes. Indeed, a subfield of expertise research has used precisely this method, which has sometimes yielded surprising results, for example with chess players. However, the method has limits, in particular with visuo-spatial domains or with domains in which actions occur rapidly (Gobet, 2009). In addition, there is

sometimes a disconnect between conscious thought (as inferred from verbal protocols) and actual actions, even with experts. For example, Bilalić *et al.* (2008) recorded the eye movements of chess experts trying to find the best move in a novel position. The position had two solutions: one familiar and non-optimal, and one unusual and optimal. All players found the familiar solution, and were asked to find a better one. Players said they did so. However, the eye-movement recordings showed that players kept directing their gaze towards the elements of the board position that were relevant for the familiar solution and not those important for the optimal solution. This dissociation between the actual location of attention and what players thought they were looking at means that, at least in some cases, experts are not able to access the contents of their thoughts correctly, with the consequence that *post hoc* rationalisations affect the reasons they provide for their decision.

Deliberation

D&D argue that experts rarely use attention and deliberation; when they do so, they do not behave like experts but revert to the behaviour of individuals that are only at the competent stage. Thus, as mentioned several times, deliberation is seen as a sign of lack of expertise: 'the enemy of expertise is thought' (Dreyfus, 2007, p. 354). More specifically, they negate the importance of look-ahead search in chess, or even that it takes place. But obviously, chess players spend long minutes thinking in competitive games; so, what do they do during this time? D&D explicitly rejects the possibility that they carry out look-ahead search: 'While most expert performance is ongoing and nonreflective, when time permits and outcomes are crucial, an expert will deliberate before acting. But (. . .) this deliberation does not require calculative problem solving, but rather involves critically reflecting on one's intuitions' (Dreyfus and Dreyfus, 1986, pp. 31–32).

M&E criticise D&D's position, and based both on the psychological literature and personal recollections of the second author (Evans), who is a chess master, state that attention, deliberation and look-ahead search are important. However, they make it clear that recursively calculating the consequences of possible moves supplements rather than replaces heuristics. Thus, 'merely learning a grandmaster's repertoire of heuristic rules may not turn a competent player into a grandmaster not because the grandmaster never relies on heuristic rules when deciding on a move, but rather because in addition to heuristic rules, calculating out the consequences of moves and intuition and [sic] plays a role' (Montero and Evans, 2011, p. 182).

G&C also criticise D&D's negation of chess players' search behaviour, given the overwhelming empirical evidence for it in the verbal protocols analysed in De Groot (1965) and later studies (e.g. Charness, 1981; Gobet, 1986, 1998; Saariluoma, 1995). They note that, while deliberation and search are important, they are closely intertwined with perceptual processes. Thus, in most cases, it is not possible to speak of pure deliberation, as perceptual pattern recognition is closely linked to search behaviour, among other things explaining its selectivity.

Artificial Intelligence

Knowledge plays a central role in expert systems, which encode the knowledge used by human experts in order to solve problems (e.g. diagnosis or troubleshooting) at the level of human experts. In order to be used, human knowledge must first be elicited and formalised. As this subfield of artificial intelligence has led to applications in education (e.g. intelligent tutoring systems), it is worth discussing it here.

As noted earlier, D&D (see also Dreyfus, 1972) attack the assumption that experts' knowledge can be formalised using declarative rules. In their view, expert systems are bound to fail, as their knowledge is not embodied, experiential and situated. Thus, even sophisticated knowledge-elicitation techniques can capture, in the best case, only the knowledge of competent individuals.

Since M&E assume that most heuristics are accessible to consciousness—else, it would not be possible for experts to justify their actions—they must agree that expert knowledge can be coded and used by expert systems. Thus, the assumption of rationality also means that expert knowledge can be easily communicated to fellow humans.

As with many other dimensions, G&C adopt an intermediate position. With Dreyfus, they agree that some knowledge is intuitive and procedural, and thus cannot be communicated as propositions explicitly. With M&E, they agree that some knowledge is declarative and can be coded as propositions, and thus can be used by computers. Where they are more optimistic than D&D with respect to formalisation of expert knowledge, is about the possibility of artificial systems learning procedural knowledge (what we called productions earlier) given the right kind of input (e.g. masters' games). In principle, it should be possible to achieve this with the programs used to implement template theory.

DISCUSSION

As it should be clear by now, there are substantial differences between the three views discussed in this paper. These differences are summarised in Table 1. However, the aim of this paper is not to directly compare the views with the goal of finding a winner (see Gobet, 2016b, for a more adversarial approach); rather, it is to evaluate to what extent they raise questions about central themes in philosophy, and what philosophical light they shed on education.

While the striking disagreement between the three views raises important questions about the nature of expertise and knowledge, there is nothing particular about it. The presence of fundamental disagreements between experts is common in academia, including 'hard' sciences, as we are reminded by historians and philosophers of science. (Think, for example, about the debates surrounding the nature of life in biology.) It is in fact an issue actively researched in social epistemology, and known as *epistemic peer disagreement* (e.g. Gutting, 1982). Part of the disagreement can be explained by the differences in values between the three views; for example,

Table 1. Summary of the key attributes of the three target theories

	Dreyfus and Dreyfus (1986)	Montero and Evans (2011)	Gobet and Chassy (2012)
Rationality	Arational	Rational	Boundedly rational
Knowledge	Knowing-how	Knowing-that	Both
	Holistic	Decomposable	Both
	Unsconscious	Conscious	Mostly Unconscious
Intuition	Critical	Not critical	Critical
Introspection	Impossible	Possible	Mostly impossible
Deliberation	Not important	Relevant, but not critical	Critical
Artificial intelligence	Impossible	Possible	Possible, but difficult

while D&D espouse a non-mechanistic view of the world, G&C clearly adopt a mechanistic view.

Implications for Education

Of the three views, M&E's view leads to the most straightforward implications and also implies a fairly unproblematic transmission of knowledge. Assuming full rationality, in the sense of being able to justify actions, implies that (advanced) heuristics are fully accessible to consciousness, in a propositional format (knowing-that). Thus, heuristics can be used for teaching beginners and more advanced individuals. (As seen above, they can also be used for building expert systems.) Thus, once rules have been elicited from an expert, teachers can teach them explicitly, presumably using examples and exercises to verify correct learning and provide other feedback. There is no problem in identifying and transmitting such rules.

Of course, D&D argue that teaching heuristics is not possible at levels higher than the third, competent stage. (Still, one could argue that teaching rules can move somebody fully ignorant of a domain to the competent stage, which is not to be sneered at from an educational point of view.) For reaching higher stages, it is illusory to try to teach rules or propositional knowledge. According to D&D, the way forward is to put learners in context, so that practical knowledge (knowing-how) can be acquired. This approach has been extensively used in nursing by Benner (Benner, 1984; Benner *et al.*, 1996), whose efforts were directly inspired by D&D's view. The core of Benner's instructional method is to de-emphasise the role of propositional knowledge, including theoretical knowledge, and to emphasise the necessity of acquiring intuitive knowledge, including being emotionally involved with patients.

As noted earlier, G&C often take a middle ground between D&D and M&E. As can be seen for example in the many textbooks on chess strategy and tactics, some expert knowledge can be transmitted propositionally. However, their view also assumes the presence of knowing-how that is harder to transmit, not the least because it is closely linked to perceptual information.

Several consequences of G&C's view, and template theory more generally, might be mentioned here (Gobet, 2005, 2015). Given the assumption that discrete chunks underpin expert knowledge, it is possible to design instructional methods that decompose the material to teach into small slices. In addition, the way the material is segmented and its ordering can then be optimised. Finally, the hierarchical nature of knowledge implied by chunking suggests that it is beneficial to teach the material from simple to complex.

The assumption that some chunks evolve into more complex knowledge structures—templates—also affords the possibility of designing methods for facilitating their acquisition. For example, the idea that variability is key for the creation of templates suggests instructional methods encouraging a diversity of examples and exercises. These ideas can be embedded in computer-based tutors (Gobet and Wood, 1999). Ideally, learners should be put in real-life situations only after basic and complex skills are acquired through these methods.

The methods described in the previous paragraph are based on strong epistemological assumptions: target skills can be identified; knowledge can be decomposed; and simplified problems can be developed to optimise teaching. In contrast, D&D argue that these methods are not viable, because expertise is holistic and cannot be dissected into components. The only way to teach expertise is to place individuals in contextual situations in which they face real-life tasks and problems.

The contrast between M&E's view and G&C's view is instructive as well. M&E assume that learning the correct (advanced) heuristics (i.e. knowing-that) leads to expert performance, assuming the ability to carry out correct look-ahead search when necessary. By contrast, G&C argue that there is a disconnect between knowing-that and knowing-how: acquiring knowing-how requires the acquisition of a large number of perceptual patterns and productions, which is time consuming even after heuristics have been fully memorised.

There is currently considerable interest in the possibility that acquiring skill in one domain (e.g. chess) leads to benefits in other domains (e.g. mathematics) or increases in general cognitive ability (e.g. visual-spatial intelligence). Interestingly, the three views agree about the difficulty of such transfer of skill. D&D's view, because intuitive knowledge is context-dependent; M&E's view, because advanced heuristics are specific to a particular domain; and G&C's view, because knowing-how is linked to specific perceptual knowledge. Recent reviews of literature about chess, music and working memory training all concluded that transfer is indeed difficult and rare (Sala and Gobet, 2016, 2017a, 2017b).

CONCLUSION

This article has discussed three different views on expertise. Perhaps surprisingly, these views differed widely on most of the philosophical issues considered. They also led to starkly different implications for education: there is little agreement about educational issues and advice, except about the difficulty of transferring knowledge from one domain to another.

A naïve hope was perhaps to expect that theorising about expertise would lead to clear-cut answers both for philosophy and education. This was far from being the case, as could be seen for example with the wide variability of opinions about one of the recurring themes of this paper, the debate between knowing-how vs. knowing-that. There is simply no clear-cut answer. In a sense, this discussion has raised more questions than it has answered—not necessarily a bad thing.

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