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Teaching for Thinking: explaining pedagogical expertise in the development of student thinking through the skills, values and virtues of inquiry

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Abstract

Expertise in teaching is typically represented by descriptive accounts of what excellent teachers do. While this approach has the advantage of allowing us to recognise expertise when it appears, it has the disadvantage of inviting mimicry. Descriptive accounts of expertise are not optimal for creating expertise in others or for understanding why some process or strategy works. What we really need to know is what and how expert teachers think. Knowing what they think helps explain why they do what they do and this knowledge can be used to develop the understanding of the novice on their own path to expertise.

It is characteristic of expertise, particularly in cognitively complex domains, that expert knowledge is organised into schemata that collectively represent the understanding of the expert. These schemata include knowledge of the types of problems typical of the domain and how they are most effectively and efficiently solved within it. A schematic representation of the nature of expertise in the domain of teaching for thinking, however, is lacking in the literature. The lack of clear schematic structures impedes the development of new expertise and the ability to learn from existing experts. This thesis offers such a schematic representation of the nature of expertise in teaching for thinking.

Since schemata are comprised of elements and their interrelationships, the first part of the thesis outlines what key elements are constituent of the expert schema of teaching for thinking and how these elements are interrelated. The broad underpinning elements of the schema include pedagogy, epistemology, metacognition and critical thinking. The relationship between pedagogy and epistemology is significant since many thinking skills have epistemic ends based on conceptions of epistemic goods. I show that a pragmatic epistemology characterised by fallibility, a rejection of relativism, and a disconnect between truth and justification offers an effective epistemic position for the teaching of critical thinking. The relationship between metacognition and critical thinking is also significant since critical thinking in this thesis is explained as metacognitive evaluation, in which our thinking and the criteria for evaluation of that thinking are themselves objects of study—a decidedly metacognitive affair. The relationship between a variety of epistemic positions and the opportunities for metacognitive evaluation is also explained in a later section.

The explicit elements of the schema can be, and are, more easily rendered diagrammatically; these include subject area content, cognitive skills and the values and virtues of inquiry. Cognitive skills can be thought of as ‘things we do with knowledge’ (including to create new knowledge) and

include well-established skills such as justification, evaluation, analysis and synthesis. These skills make up, in large part, the type of thinking we seek to improve educationally. Since a skill cannot be improved without feedback, it is also necessary to evaluate thinking so that such feedback can be provided. As the core of the word ‘evaluate’ is ‘value’, it is therefore also necessary to come to an understanding of what we value in good thinking. For the American pragmatists, C. S. Pierce, and later, John Dewey, thinking was inseparable from inquiry. Having explained the benefits of a pragmatic epistemology in teaching for thinking early in this thesis, the connection between thinking and inquiry allows me to suggest that what makes for good thinking is what makes for good inquiry and that evaluating inquiry is evaluating thinking. The thesis outlines what we value in thinking and inquiry to allow for the establishment of a selection of criteria for evaluating thinking. In providing the schematic structure of teaching for thinking thus far, a potential means of developing a range of virtues of inquiry also becomes possible. While virtues have a significant profile in many educational institutions, the manner by which they can be developed is less overt. The thesis provides a pathway for the development of those inquiry virtues, providing a line of sight from each individual learning experience to the sort of character we wish for our students in the years to come: a pedagogical outcome of the highest importance.

Having established *a* (not necessarily *the*) schematic structure of expertise in teaching for thinking, how this knowledge can be utilised in the classroom is discussed and modelled, with a range of instantiations of the principles and understandings of the schema provided. To assist in understanding how the schema can be implemented, a model is also explained that represents the development of mastery and proficiency in and critical thinking. To further provide pedagogical guidance, an outline of how critical thinking can be understood as developmental is given, with the connection between epistemology, metacognition and critical thinking further developed and explained. In the final section, some policy and research implications are discussed.

Declaration by author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, financial support and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my higher degree by research candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

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Publications during candidature

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I dedicate this thesis to the two women who saw me through and for whom it matters

Kirsti Ellerton and Deb Brown

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Introduction

Teaching for thinking is not a new focus. Nor is it necessarily a clear one. While it is not my intention to provide a detailed history of how thinking has been understood and educationally developed, it is worth providing a very broad context for the endeavour. The western tradition of education contains a significant heritage about the nature and purpose of thinking originating in large measure from the ancient Greeks. Any thought of a respectable education that did not refer to Plato and Aristotle at the least would have been mocked up until a few hundred years ago (and still is today by some). Traditions of medieval scholasticism, many of which were developed in the light of Greek thought lost to most of Europe but held and then restored by Irish and Arabic scholars and libraries, were heavily grounded in dialogic reasoning as a tool of education. The Renaissance was not exhausted by scientific inquiry, but it was fueled in large part by empirical investigation. The inherent logic of that inquiry demanded an engagement with the world on the assumption that it was rational and knowable, and that intelligent investigation was more fruitful than accepting dogma, however strongly rationalised a dogma it might have been.

Modern educational systems, beginning in the early nineteenth century, were subject to pressures of numbers and an increasing recognition that classical methods and topics of education were slow and unproductive. Jeremy Bentham's *Chrestomathia* school, developed for the growing middle classes and designed to address the need for faster and more immediately useful educational outcomes, is paradigmatic of the view that education is for utility and a largely scientific utility at that (Bentham, 1816). Both critics and supporters of Bentham acknowledged at the time that schools were to be modelled on factory processes, and this was something of a selling point for many, but not for all. Elissa Itzkin (1978) notes correspondence from the Hazelwood School at Birmingham expressing concerns that the roles of students and masters are too restrictively defined within this model.

> Indeed, the duties of each must be made perfectly mechanical. There must be no doubt or hesitation on the part of the master or pupil; for doubt would produce delay and dispute, and consequently throw the whole machine into disorder. Hence there can be no appeal to the reasoning powers; for reasoning, never can be reduced to mechanism… every boy [sic] must conform to the average motion of the School. (*Ibid* p.313-314)

and

> It is our object to produce voluntary mental exertion; and we therefore cannot think it judicious to subject our pupils to continual restraint. We wish to teach them to educate themselves, while we direct their operations. We must teach them to think as well as act; while all that is attempted in favour of the others is to teach them the latter power. (*Ibid* p.313-314)

This seems to me a useful articulation of the conflict between the need for teaching *for* thinking and a manufactory model of education.

Teaching thinking skills—including what might be called critical thinking—is apparently universally desirable as an educational outcome; it is rare to find an educational institution that does not mention some critical skills in its list of its graduate attributes. Too often, however, critical thinking permeates the talk and spirit of syllabi but the substance of it fails to materialise. It has become the Cheshire Cat of curricula, in that it seems to be in all places, owned by all disciplines, and yet it does not appear fully developed anywhere. Despite this ubiquity, critical thinking is too often a peripheral goal of education, at least in how it is operationalised. That is not to say that thinking is not valued, but only that the pedagogical approaches to be used to develop the skills of effective thinking are varied and are themselves not typically included in the content of syllabi.[1] Such approaches include an explicit (though not exclusive) focus on epistemology (Lipman and Sharp, 1978; Siegel, 1989; Splitter and Sharp, 1995; Rollins, 1995; Siegel, 1998; Burgh, Field and Freakley, 2006; Bleazby, 2011; Golding, 2016; Siegel, 2017), promoting of the role of arguments in contextualising and instantiating thinking skills (Kuhn, 1991; Van Gelder et al., 2004; Battersby and Bailin, 2011; Bailin and Battersby, 2015, 2016b; Mercier, 2011a) and those originating in cognitive science, including metacognition (Kuhn, 2000; Van Gelder, 2005; Veenman, Van Hout-Wolters and Afflerbach, 2006; Anderson and Perlis, 2009; Wilson and Bai, 2010; Ellerton, 2015b). To the extent that development of thinking skills is achieved, it is often a by-product of instruction in discipline methodology or through teaching problem solving techniques and strategies that form part of what Thomas Kuhn calls the 'disciplinary matrix' (Kuhn, 1970, p.182). These include the typical problem forms characteristic of a discipline that students will be sure to encounter in their training. Examples include the trolley problem in ethics, force vector resolution on the inclined plane in physics, finding the roots of a quadratic equation in mathematics and so on. As these

[1] What we might call "effective thinking" is not synonymous with critical thinking. While not all effective thinking is critical thinking (thinking by association or heuristics can be very effective but is not necessarily critical), all critical thinking at least strives to be effective. I will, therefore, on occasion speak of critical thinking as effective thinking when discussing the project of teaching for thinking as a whole.

problems and their variations are grappled with, students develop in context the thinking skills necessary to solve them. At least we hope that is the case.

Disciplines are defined, in part, by the sorts of problems they solve and the kinds of methodologies they have developed to solve them. In teaching discipline-based subjects in schools, students are presented with the types of problems typical of that discipline. These problems are modelled and the students are presumed to learn from this modelling the strategies and approaches that solve them. That they use a range of cognitive skills to do this is clear, but what these skills are, and how they may be articulated and explicitly taught, is not so clear. The efficiency of asking students to solve complex and challenging problems that demand a range of cognitive, or thinking, skills without directly teaching those skills seems, at first blush, less than optimal. Indeed, there is concern that critical thinking, as a subset of thinking concerned with evaluating and improving thinking, cannot be explicitly taught (Perkins and Salomon, 1989; Bailin et al., 1999b, 1999a; Willingham, 2008). Thinking learned through developing expertise within a discipline context can also logically lead to the belief that a particular discipline is best suited for the teaching of effective thinking. In my experience in schools, it has not been difficult to find a teacher of science or history who feels an education in their subject best represents the characteristics of critical thinking. But all disciplines embed effective thinking in their methodologies of inquiry; if this were not the case, they would not be successful. Moreover, each discipline has improved in its problematising and problem solving over time as its practitioners have collectively developed new knowledge and new techniques of inquiry. Each discipline, therefore, can claim some success in developing thinking skills through simply demanding of their students that they bring such skills (defined or not) to bear on a range of problems and, through modelling and persistence, teaching them how to solve it. It is unclear if any discipline can claim supremacy in this. Willingham (2008) makes the point that relevant background knowledge is essential to think well within a discipline, and that without this background knowledge the concept of 'thinking well' is ill-defined. I deal with this in some detail in §6.1 but suffice it to say at this point that while Willingham has a logical case, teaching for thinking need not be entirely constrained to specific discipline contexts. Many philosophical questions, such as those regarding free will, rights or ethics, involve only minimal content but can demand sophisticated thinking.

The solving of complex problems that demand high-level thinking suggests that a significant knowledge base must be accessed, however, and this can easily be provided through discipline training. Investigating how thinking can best be taught therefore often involves a discussion of whether this should best happen in a discipline context (as per Holmes et al., 2015 for example), and indeed how this is conceptualised in each context (Jones, 2007). What is not clear, however, is that the thinking skills so developed would be transferable or translatable between disciplines or into daily life (Perkins and Salomon, 1989; Willingham, 2008; Battersby and Bailin, 2011). Nor is it clear that students, or their teachers, would be aware of exactly what skills they had acquired beyond the description of these skills as instances of problem solving in context (something I discuss in §5.1 and §6.2). This leads to considerations of making those skills explicit and in turn to the question of whether they themselves can be explicitly taught. What's more, if the exact nature of these skills is not well defined, arguments for explicit instruction in them are logically weakened.

Most, but not all, attempts to understand critical thinking focus on compiling a set of cognitive skills, and perhaps affective dispositions, that together are not so much definitive of critical thinking as they are descriptive of how a paradigmatic critical thinker might be said to operate. Broad-brush definitions of a critical thinker include, taking a small sample, someone who is able to correctly assess statements (Ennis, 1964), testing their own thinking using criteria and standards (Elder and Paul, 2013), thinking effectively with concepts (Elder and Paul, 2001) and uncovering "evidential relations that hold between statements" (Mulnix, 2010, p.467). It is hard to imagine discounting any of these ideas as not relating to common conceptions of critical thinking, and none of these or other researchers would likely dispute the value of each other's categorisations. Nor do they fail to elaborate on their descriptive summaries of what critical thinking involves. Hence, the current understanding of critical thinking is very broad. This does not mean that this current understanding lacks precision, as many researchers have articulated skills and affective dispositions in great detail (Facione, 1990), but there is a sense in which the net is cast so widely that our collective definitions become too diffuse to provide a sharp educational focus. The lack of a deeper and more unified understanding of critical thinking also makes the creation of a pedagogical approach to producing critical thinkers problematic. It is this problem, how to approach the pedagogy of critical thinking, that is the goal of this thesis.

One of the first tasks is to make the case that understanding critical thinking is necessary but not sufficient for understanding how to teach critical thinking; that is, it is necessary to talk about what critical thinking might be before we can talk about how it might be taught. This might not seem a controversial claim since no one would expect, say, an expert physics teacher to be ignorant of physics. However, one might reasonably expect an expert physics teacher to also be an expert in teaching students how to think about physics, and this begins to sound like critical thinking. So, we come again to the question of whether critical thinking can be explicitly taught (perhaps in curriculum time devoted solely to this end), or whether it is best done in a discipline context.

As an argument for the former, the Philosophy for Children (P4C) approach to education, developed initially by Matthew Lipman and Ann Margaret Sharp, has established itself as a successful method for the teaching of, among other things, thinking skills (Lipman, 2010, 2003, 1998; Lipman and Sharp, 1978; Splitter and Sharp, 1995). Bearing the legacy of Peirce and Dewey in terms of epistemological assumptions and educational applications, and incorporating the pedagogical imperatives of Vygotsky, P4C has developed as an established educational practice in many countries, including Australia (Burgh and Thornton, 2016). The efficacy of this approach in terms of cognitive gain for students is backed by research over a number of years (Trickey and Topping, 2004, 2006; Topping and Trickey, 2007b, 2007a, 2007c; Garcia Moriyon et al., 2005; see also Millett and Tapper, 2011).

Lipman and others have outlined what types of thinking are fundamental to success in P4C, and why this type of thinking is important. Lipman realised how daunting a task capturing what these thinking skills would be, noting that "the list is endless, because it consists of nothing less than an inventory of the intellectual powers of humankind" (Lipman, 2003, p.8). Splitter and Sharp recognised that in studying thinking that is educationally worthwhile we a talking about more than simple cognition, we are more concerned about norms of thinking, locating this problem in philosophy.

> It is this normative dimension that marks our inquiry as philosophical rather than empirical; as being concerned with how young people ought to think rather than merely with how they think. (Splitter and Sharp, 1995, p.7)

This indeed was Lipman's educational goal, to "build a system of thought" for students (Lipman, 2003, p.103). But Lipman did more than revel in the grandness of human thought; he was careful to try to articulate how we might structure this for application in the classroom. He focused on several aspects of thinking, recognising that when we talk about thinking we are talking about both thinking and thinkers, and hence he was concerned with both thinking skills and the development of dispositions. But, in Australia, P4C has had limited success in finding traction within senior schooling, being predominantly a primary school initiative due to historical circumstances (see Burgh and Thornton, 2016, 2019), though some notable attempts have been made to implement the P4C educational method of collaborative philosophical inquiry as pedagogy for older students especially the teaching of the senior philosophy syllabi in Victoria, South Australia, Tasmania, and

Western Australia (Bini et al, 2019; see also, for example, Burgh and Nichols, 2011; Sprod, 2011) and some schools that have implemented 'whole-school philosophy' (Kennedy White et al, 2019).

As an argument for the latter, that thinking can (should?) be an object of focus in a discipline context, other pedagogical frameworks and models have been developed for active focus on thinking in disciplines, including those of Robert Marzano and colleagues that include Dimensions of Learning, the Art and Science of Teaching and the New Taxonomy (Marzano, 1992, 2006, 2007; Marzano et al., 1990). These frameworks are designed so that teachers can use them in their usual discipline contexts, focusing on the cognitions that are involved in student learning in context through structured templates and activities.

But whichever approach to the teaching of thinking skills is taken, and at whatever year levels it is attempted, a key concern remains: the kind of expertise that is needed to do it well and how to develop this expertise in teachers. This thesis is intended to be the seed of further discussion on exactly this issue. It outlines and explains a candidate schema for pedagogical expertise that incorporates much of what we recognise as valuable in educating for thinking and attempts to connect these things in a coherent and useful way, incorporating not only the concepts constituting pedagogical expertise but the practical circumstances in which that expertise is applied. Everything the teacher does pedagogically becomes an object of study and the schema provides a way to capture the thinking involved and to make this thinking and its relationship to action the basis of individual reflection and collaborative professional discussion. As such it is an enabler of praxis, which must begin with understanding that is used to guide practice and is then modified in the light of that practice. Let me explain the nature of schemata in more detail.

The concept of a schema is a broad one, being understood in a variety of ways from diagrams that represent elements of a system and their relationship in a stylised way (for example, an electric circuit), to, in the context of cognitive science, a type of changeable structure representing generic concepts that are held in memory (Bartlett, 1932; Glaser, 1985; Rumelhart & Ortony , 1977; Derry, 1996). It is this latter, cognitive, use that is relevant for this thesis and to which I will refer by use of the term 'schema' hereafter.

The schema concept was introduced to cognitive science partly, but significantly, by Frederic Bartlett (1932), who moved away from understanding memory as fixed and independent of its circumstances of recall and towards remembering as "embodied, dynamic, temporal, holistic, and social" (Wagoner, 2013). In this, Bartlett shared assumptions with Dewey, Vygotsky and others about the nature of knowledge and knowledge structures, seeing them as deeply integrated with experience as opposed to being fully described by their "inner contents" (*ibid*, p.3).

So-called "literal," or accurate, recall is an artificial construction of the armchair, or of the laboratory. Even if it could be secured, in the enormous majority of instances it would be biologically detrimental. Life is a continuous play of adaptation between changing response and varying environment. Only in a relatively few cases—and those mostly the production of an elaborately guarded civilization—could the retention unchanged of the effects of experience be anything but a hindrance. (Bartlett, 1932, p. 16)

Cognitive schemata, according to Bartlett, are not static but dynamic, temporally sensitive and contextually based representations capable of modification and indeed evolution. This understanding is significant here since the development of expertise is known to involve the continual reconstruction of schematic knowledge based upon the practical implications of the expert's understanding (the *deliberate practice* outlined in Chapter One). Success or failure in the domain of expertise is a result of schemata held by the expert, and that success or failure acts as feedback to modify the schematic structures of the expert for each context in which it is recalled and used.

David Rumelhart and Andrew Ortony (1977, p.101) propose that cognitive schema have four key characteristics: (1) schemata contain variables, such that they can be instantiated in a variety of contexts and retain their integrity, (2) that schemata can contain other schemata, and be part of greater schemata, (3) the generalised concepts that are contained in a schema may be at varying levels of abstraction and (4) schemata are not composed of or represent simple definitions, they contain rather knowledge (some of which is experiential). Again, we see here the cognitive structure of expertise. Experts bring a deep understanding of the principles and concepts of their domain, including the types and nature of problems inherent in it, and apply this to solve problems in individual contexts based on their experience and knowledge—all signs they are thinking schematically.

Sharon Derry (1996) provides more detail by suggesting three basic kinds of cognitive schemata, a formulation important to both information-processing and constructivists theories of education (see Derry, 1996, pp.164-167 for an outline of these contexts). One kind, memory-object schemata, contain a range of information including basic sensory data about the world and more complex mental constructs that form the structure of conceptual understandings. Construction of this kind of schema in students' minds is often the goal for teachers across disciplines and year levels. Another kind of schema, cognitive field schemata, are called into play in particular contexts. Their role is to retrieve a selection of memory-object schemata that are considered relevant and significant for the situation at hand and make them available for the construction of a third kind of schema, a mental model schema. The mental model schema is constructed from available memory-object schemata to model the situation at hand, simulating the context and working through possible pathways to find a solution to a problem or an optimal way forward. This is represented diagrammatically in Figure 1 below.

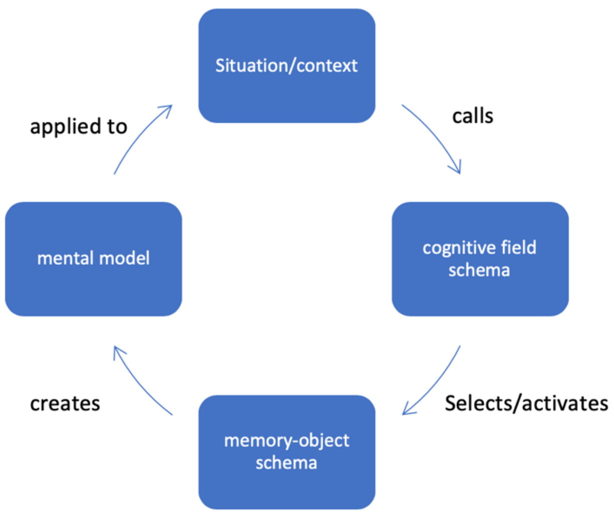

Figure 1: Cognitive schemata and their relationships

Note that while the mental model produced in this process is called a schema, it is of a different sort from other schemata (there may be a number of different mental models referring to systems, events, spacial constructs and other things, but this is not so relevant for this thesis—see Busselle, 2017 for an overview). Schemata represent how knowledge—including experiential knowledge—'hangs together' to form deeper understandings or to be useful within contexts. The literature on models is large and beyond the scope of explaining in full in this thesis, but suffice it to say, as a working definition, that models in general provide representations of phenomena in cases where the details of, and hence explanation for, a phenomenon may not be clearly observed. Mental models are models in which we create mental representations of the world and can also include abstract concepts as well as representations of objects and situations and our experiences of them. In this conceptualisation, while a mental model might be a schema, a schema is not necessarily a mental model (though it may contain other kinds of models, as many memory-object schemata clearly do—for example, the model of the solar system or of the ideal gas).

This thesis provides a candidate *schema* that establishes a starting point for the deliberate practice necessary to develop expertise in Teaching for Thinking. Within this space, a multitude of schemata are operating in the minds of teachers. Since schemata are many-layered, often being both constituted by, and constituent of, other schemata, it might seem a challenge to determine where, exactly, within that schematic structure one should focus attention to improve pedagogical outcomes. As I mention in § 2.1, *The challenge of developing schemata for thinking,* the schema is designed to be a very broad one, sitting towards the top of any hierarchy that would contain more schemata than it contributes to. This is more a statement of intent than an empirical claim, for each person has their own unique schematic structures. This uniqueness makes it difficult to identify with precision where the schema might sit for any particular educator. But it is less difficult to say, as I explain throughout the thesis, that, in terms of the potential complexity contained within the schema, there is plenty of room at the bottom.

The schema is intended to be applicable to all levels of education from early primary to tertiary education. Like all schemata, it is an organised representation of knowledge and includes, crucially, knowledge of the sort of problems inherent in a domain and how they are best solved. Schemata need not be comprehensive, detailed or have precise predictive power to be useful, rather their utility is through the provision of an understanding that can guide practice and that can be modified based on the results of that practice to improve future performance. Because schemata can be modified based on the results of practice, they are things that can, and arguably should, grow and evolve over time to reflect greater understanding and more effective practice. As such, they do not appear fully blown in the minds of developing experts but are capable of adapting and modifying to incorporating new ideas. They are the seeds of expertise as much as they are the product of it.

Expertise in teaching is typically represented by descriptive accounts of what excellent teachers do. While this approach has the advantage of allowing us to recognise expertise when it appears, it has the disadvantage of inviting mimicry. Descriptive accounts of expertise are not optimal for creating expertise in others or for understanding why some process or strategy works. What we really need to know is what, and indeed how, expert teachers think. Knowing what they think helps explain why they do what they do and this knowledge can be used to develop the understanding of the novice on their own path to expertise. [new text from here] The schema of this thesis is not a recipe for what to think, it is a beginning and a waystation of praxis. A beginning because some understanding is necessary to take practice beyond merely reflexive or habitual action and make it subject to reflection. A waystation because at any given time the expert's (or developing expert's) knowledge can be represented by some schematic structure that is subject to further development. The schema does not prescribe in detail what teachers should think, only that thinking about practice, whatever its form may take, is informed by a developing schematic understanding, the eventual shape of which is a function of the teacher's own experiences of success or failure in the classroom. To take the first characteristic of cognitive schemata outlined above, it contains variables that teacher experience and advancing understanding can provide. While the schema will be developed and explained through the first part of the thesis, it is presented below as Figure 2 to introduce the reader to its structure as an aid to developing understanding.

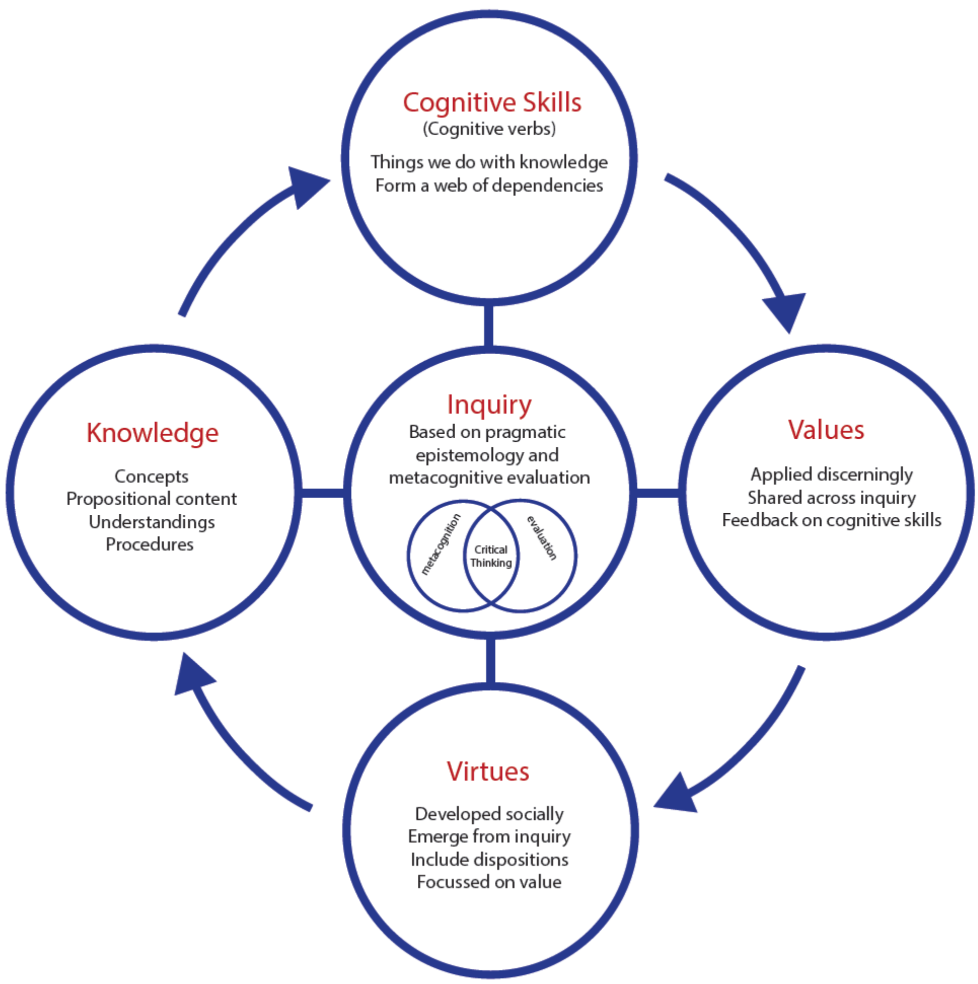

Figure 2: A pedagogical schema for Teaching for Thinking

While not all schemata are about expert knowledge, all experts do use schemata and develop their own schematic understanding as their expertise develops. The nature of expert knowledge and the benefits that knowledge brings—not just to what experts know but how they think within their domain—is the subject of Chapter One. Chapter Two explores what this means for the domain of teaching for thinking, with particular attention to expertise in teaching for thinking rather than simply teaching for learning, for these are not the same thing. While we might follow Dewey in acknowledging that "thinking is the method of intelligent learning" (Dewey, 2011, p.171), we might also follow the implication of this that there are other, less intelligent, means of learning and that these are, on occasion, to be avoided.

If we see thinking as the means to better, deeper learning (on the assumption that that is what is intelligent about it), one of the things we must think about is why this learned knowledge is to be accepted or how it is constructed. In focusing on thinking about what we are learning, our attention is on the nature of the inquiry that is producing this knowledge and the credibility or reliability of that inquiry. At core these inquiries are epistemological inquiries and hence epistemology is a pedagogical concern. The relationship between epistemology and pedagogy is developed and explained in Chapter Three. Thinking about how we think, the criteria by which we evaluate our thinking and understanding the intention behind it, requires a level of metacognition and self-regulation that are key components in becoming autonomous, life-long learners. Chapter Four shows how students can become metacognitive in the course of their learning and offers a means of understanding critical thinking linked to students being both metacognitive and evaluative.

Chapter Five uses the understanding of epistemology and metacognition as critical factors in educating for thinking to develop a schematic structure that links content and cognition to those things we value in inquiry. The schema explicitly refers to content knowledge, cognitive skills, values of inquiry, virtues of inquiry and the act of inquiry itself. It shows how feedback on student cognition can be understood and acted upon by both the teacher and the student. It also explains how using criteria for evaluating thinking leads to construction of norms of thinking, the mastery of which helps to develop particular inquiry virtues. As such, it provides a direct line of sight from the pedagogical decisions the teacher makes in the classroom at any given moment to the type of thinker and learner that the student can potentially become in future years, with each such pedagogical decision justified by a deep schematic understanding of what the teacher is doing and why they are doing it.

The schema developed through the thesis, and presented in full in Chapter Five, has some significant implications for teacher understanding, classroom practice, institutional processes and policy and research directions. In Chapter Six, I consider aspects of how the epistemological development of students can impact their ability to develop norms of thinking and to use them effectively. I then explain some concrete strategies that can be used by teachers to teach a range of skills and values and how to incorporate these skills and values in learning experience design and unit planning. Using these examples, and the schematic understanding developed earlier, I explain some key pedagogical imperatives (principles of action) that can guide teacher practice.

Some policy and research implications are considered in Chapter Seven. While there are many potential paths to follow in such an analysis, I focus on two for their relevance to practice. The first, a policy consideration, is to use Christensen's (1997) analysis of disruptive *technologies* and apply this to what I call the potentially disruptive *pedagogies* of teaching for thinking. In doing so I provide an analytical framework for how institutional change towards teaching for thinking can be conceptualised and ultimately better managed. The second, a research consideration, addresses the issue of findings in neuroscience that are given educational prominence and often used as the basis for teacher professional development. I offer a way for teachers to more intelligently address neuroscience as a discipline from a perspective of understanding their own expertise and using this perspective to frame questions targeted at providing what is important to their own practice. In a field hungry for evidence-based strategies, findings in non-educational disciplines such as neuroscience can be readily commodified and attractively packaged without necessarily adding much to teacher expertise (Busso and Pollack, 2015). The ability of teachers to discern relevant and significant information within neuroscience and to apply findings to their own pedagogical understanding is essential to properly navigate through this landscape.

As to the methodology of the thesis, it is not an empirical investigation though it does rely on empirical data to justify some of its claims. It is also not simply an analysis of what educational experts, either those who have been concerned with reconstructing education such as Lipman or empirical researchers such as Hattie, might consider a 'good' teacher. It is, rather, a philosophical analysis and synthesis of a range of pedagogical concepts (and some instantiations of these), the result of which is used to construct a schema for teacher praxis and expertise development. The schema is then used to demonstrate how teaching practice across any discipline area and for multiple age groups can be modified to solve a variety of educational problems, including finding pathways to teach the critical and creative thinking skills articulated within many national education standards.

Chapter One: The general nature of expertise

A significant goal of this thesis is to understand what it means to be an expert in teaching for thinking. To this end, it is useful to ask what might make one person better than another in teaching students to think and, moreover, to determine if there is something categorically distinct about such a person that separates them from others in their field. But this is a question that could be asked of people who excel in any field, including in teaching in general as opposed to the field of teaching explicitly for the development of thinking skills. What would make one diagnostician better than another? Why might one watchmaker be superior at their craft? What could explain the success of an outstanding sporting coach? Why is one teacher of science more successful than another? Each of these questions would clearly have answers that are to some degree context specific and couched in the language of practice. For example, the diagnostician may be very experienced in a certain family of diseases, the watchmaker familiar with a broad range of watch brands, the sporting coach themselves coached by a champion, or the teacher very knowledgeable in their subject area. But each could also be answered by an appeal to *expertise*. Since such a generic term as 'expertise' exists, we might suppose that experts have certain characteristics in common regardless of the areas in which that expertise is manifest. Therefore, before understanding expertise in teaching for thinking it will be necessary to spend some time considering the nature of expertise itself.

In attempting to understand expertise and expert performance I will begin by briefly discussing the extent to which the terms 'expert' and 'specialist' are used interchangeably and whether this interchange is justified. The synonymy of these terms is common in the vernacular, but not well addressed in the literature. Even when they are mentioned together, they are often used uncritically (see, for example, Jones and Kelly, 2013). Interrogating this relationship is a useful starting point to understanding expertise and the first part of this chapter, therefore, will involve some general discussion about expertise and specialisation before addressing the literature about expertise in general. Following this, I will review some central understandings of the characteristics of expertise and then consider these characteristics as they apply to a general and specific teaching context.

1.1 Expertise and specialisation

Consider the circumstances in which someone can be called a specialist. A general real estate business might have a specialist in commercial properties that house light industry; someone who understands the specific issues involved in buying and selling such properties. Let me call her Jill.

Presumably Jill, as a specialist, would be more knowledgeable and experienced than other members of her team in this area. A paleontologist let me call her Tilly, who is the only person to have ever studied a fossilised dinosaur skeleton representative of a particular new species, and who consequently devotes herself exclusively to the study of that species, could be considered by other paleontologists to be both *a* and *the* specialist on that dinosaur. Perhaps specialists in this sense could also be called 'experts' (a speculative claim for the moment), which seems, *prima faci*e, a reasonable substitution. To call someone a specialist is to suggest they work in a well-defined area with corresponding specialist knowledge of that area. If Jill, as a specialist in light industry sales, were to move into a business that dealt only in light industrial properties, however, she might find herself the least knowledgeable and experienced team member and hence, within that group at least, would longer be considered a specialist. Those outside the group, forming a larger collective of real estate agents, may of course consider all the team members to be specialists. Once Tilly shares her knowledge of the fossilised skeleton with other paleontologists, and allows others to study it as well, her claim to be a specialist weakens in proportion to the number of people who increase their knowledge of the fossil. If all paleontologists had equal knowledge of the fossil, then the notion of the specialist in that area disappears completely. If we treat 'expert' as synonymous, or at least broadly compatible, with 'specialist', then it seems the claim to be an expert/specialist in an area is simply one that rests on how many people in a particular group share that focus.

This tentative proposed relationship between the specialist and the expert is problematic, however. Consider that to call someone a specialist implies a focused activity that includes an intent to exclude other areas of study within a particular field from that focus. A specialist medical practitioner chooses one area over another—dermatology over oncology, for example. A specialist watchmaker may focus only on one brand, or even one model within that brand. Of course, a defense force mechanic might be told that they are to specialise in truck differentials, or a pool fencer as a specialist fencer might have inherited the family business, but in some sense a choice is still made by someone at some stage to focus on that area. Jill and Tilly both could reasonably be spoken of as becoming specialists in this manner. How striking it would be for a specialist to not be so exclusive was recently brought to my attention through a sign on the side of a commercial vehicle that advertised the driver as someone "specialising in all types of fencing". It seems this is a claim to be both a specialist and a generalist! (I grant it could mean that fencing itself is a specialty within the building industry, though the potential for the contradictory claim is still present). It is here we begin to see the problem with equating specialisation and expertise. One can imagine a field of study in which there are only a few areas in which to specialise and that there is scope and time for someone to be proficient in all of them. Such a person could be considered a specialist in each area, and therefore a generalist as well. But followed to an extreme this does seem to diminish the value attached to calling someone a specialist. It may be, for example, that someone specialises in an area so small that anyone with the inclination could master it in moments. A mechanic who specialises in inflating tires, to give an extreme example, and ignores all other aspects of the vehicle is specialised in focus, but the skills and knowledge of this specialisation would also be available to any other mechanic (and indeed mastered in moments by any layperson). Should this nominative reluctance extend to calling them 'experts'? And in what circumstances might this work or not?

On the surface, specialisation and expertise may seem easily relatable concepts, after all experts must be experts *in something* and we accept that that thing cannot be so broad as to preclude the significant depth and complexity of knowledge we inherently associate with the concept of expertise. But selected knowledge from a broader field does not imply deep knowledge as the example of the mechanic inflating tires shows, and specialisation is, therefore, not a sufficient condition for expertise. Specialists may be experts, but not necessarily so. If we understand specialists as those who work in a selected area within a field, then we come to a broader conclusion: not only is specialisation not sufficient for expertise, but it is not necessary. In other words, not all specialists are experts and not all experts are specialists. My claim here is that expertise and specialisation are independent of each other.

Let me emphasise again that the definition of specialisation I offer means that specialisation involves pursuing a selected focus in a given area, with the understanding that such a selected focus can still involve a very broad knowledge base (as any medical specialty shows).

This disconnect between specialisation and expertise is somewhat different from the relationship discussed in the literature between experienced and expert practitioners. The difference between these two concepts being that experience and expertise are not totally independent. It is generally accepted that experience is necessary but not sufficient for expertise. This relationship is explored in depth in the context of teaching by John Hattie (2004) and his findings are supported by an impressively large meta-analysis of factors influencing educational outcomes (Hattie, 2008). Hattie spends more time exploring the binary relationship between the (merely) experienced and the expert rather than the more traditional distinction of novice and expert. In doing so he challenges the notion of teaching expertise emerging simply as a function of teaching experience. In the same way, I propose that specialisation should not be seen as giving rise to expertise of and by itself and, following Hattie, that this is true of teacher specialisation as well. The specialist Physics teacher has no more claim to expertise by appeal to her specialty than her colleagues would have by appealing to their experience. Nor can the Year Seven teacher claim expertise because he specialises in that year level or the sports teacher because she specialises in futsal. Appeals to both expertise and experience as sufficient conditions for expertise are not tenable and appeals to both have no more impact than appeals to either one in isolation.

1.2 Accounts of expertise

I have already outlined how expertise and specialisation are not identical, but there is still some way to go in developing a full understanding of the phenomenon of expertise. A complete understanding of expertise is beyond the scope of this chapter, but it is essential that this understanding is developed enough to provide some guidance in developing expertise in teaching for thinking and to develop the schema that is the work of later chapters. I will therefore now provide a brief overview of some aspects of expertise.

Significant advances in our understanding of expertise have been made by Robert Glaser, K. Anders Ericsson and others by focusing on how we understand not just what experts do, but also how expert knowledge is organised, as I will explain shortly. Considering how expert knowledge is organised implies that we must also consider how experts think. I will begin this section by considering some relational aspects of expertise that were implied in the previous section but were not fully developed. I will then attempt to move how we understand expertise to a more objective footing, seeking ways in which we might understand the behaviour and success of experts in terms of organisation and utilisation of knowledge. Lastly, I will outline some significant findings in psychology and cognitive science that have informed how we view the minds of experts.

In beginning to build up an idea of what expertise is, Alvin Goldman notes that the nature of expertise is sometimes given a distinctly social flavour: “to understand expertise, it is said, we must invoke the special position experts occupy in the social environment” (Goldman, 2016, p.1). Goldman thinks this is wrong, as it does seem to allow that a person can be an expert only if others make that proclamation or would if they were appropriately informed (or even inclined) and that such a proclamation would be necessary if not sufficient for expertise. There would have to be a weakening (if not abandonment) of the idea that there is something an expert *is*. But social position is too vague to be useful. While a change in social position may be a result of attaining expertise, it does not tell us how that expertise can be achieved in any educational sense. Christian Quast takes us towards a more objective standpoint by suggesting that “…someone is an expert for a domain if and only if she is a respective authority who is competent enough to reliably and creditably fulfil difficult service-activities accurately for which she is particularly responsible" (Quast, 2016, p.2). In other words, the conjunction of reputation and competency in servicing the needs of others in ways they may not be able to pursue for themselves constitutes expertise. Goldman resonates with this view, looking to identify "what expertise *is* by reference to what experts can *do* for laypersons by means of their special knowledge or skill" (Goldman, 2016, p.1). This conceptualisation of the expert situates some degree of expertise in the person of the expert rather than solely in the reputational sphere. What one can do that is of value to other people still relies on what others value, but it is nonetheless an internal characteristic. Goldman departs from Quast, however, in denying the necessity of the conjunction above, relying only on the efficacy of the expert's capabilities and not requiring, though not rejecting, any reputational aspect. He gives the example of a newly arrived traveller who has the capability to help people but whose abilities are unknown by those around him (*ibid*, p.2). According to Goldman, this does not negate the traveller being an expert. Conversely, one could have a reputation as an expert but not be able to live up to it. Either way, it seems reputation is not all. Goldman moves along from his initial and decidedly pragmatic framing of the issue to suggest that the capability to deliver outcomes for others that they cannot achieve for themselves can also be grounded in an epistemic superiority. He suggests that "…S is an expert about domain D if and only if S has more true beliefs and fewer false beliefs in propositions pertaining to D than do most people" (*ibid,* p.2), adding also the condition that "the absolute number of true beliefs S has about propositions in D is very substantial" (*ibid*, p.3). This is an interesting addition in that it serves to remove the relative aspect of amount of knowledge, so that someone does not become an expert by simply seeking out the company of those whose knowledge is very limited. It restores the possibility that expertise is inherent rather than relational and hence gives some potential educational purpose to developing expertise.

Notwithstanding disagreements about how one defines an expert, there is significant agreement about the characteristics one can attribute to experts in terms of their performance and their cognition. To move though to a discussion of these characteristics, I will acknowledge the reasonably representative definition provided by John Hattie and Gregory Yates that experts "are individuals able to perform at the very top of an identifiable area" and that "expertise has to represent superior performance repeated over time" (Hattie and Yates, 2014, p.84). Hattie and Yates's definition is inclusive of many forms of excellence, including trades, sport and arts and presumably games as well. This is a view shared by Ericsson and Charness: "we define expert performance as consistently superior performance on a specified set of representative tasks for the domain" (Ericsson and Charness, 1994, p.731).[2] In acknowledging the definition given by Hattie and Yates I also acknowledge Goldman and Quast's requirement for successful performance without requiring Quast's reputational condition or Goldman's proportional truth claims. Hattie and Yates have simplicity on their side, but some richness seem to be lacking. Although I will need to augment their definition in time as I begin to focus on expertise in teaching for thinking, nonetheless Hattie's general work in developing teacher expertise makes it appropriate for me to take his definition as a starting point, especially considering this is a thesis with an educational focus.

1.3 The nature of expertise

The title of this section comes from a seminal paper by Robert Glaser (1985), later becoming a book of the same name (Edited by Robert Glaser, Michelene Chi and Marshal Farr 1988). In this paper Glaser formulated an understanding of expertise, or at least articulated characteristics of experts, that continues to inform current thinking and research in this area (Hattie and Yates, 2014, p.85). The characteristics of experts outlined below are taken from Glaser and Chi (opening chapter in Glaser et al., 1988) as they were among the first to so articulate them and they remain the characteristics most researches use today. I will present them in a slightly integrated form (as Glaser also originally did although mine differ slightly as my treatment is not as in-depth—see Glaser, 1985) since some seem to me more closely causally connected than others. The elements of expertise outlined below are those that must be satisfied in the thesis goal of developing expertise in teaching for thinking, and I will demonstrate how this is achieved in later chapters. Although Glaser's work, along with that of Chi, is ubiquitous in the study of expertise, it is not unique in providing insight and there is variety in the nature of expert domains that are studied. For example, while some areas of expertise clearly require high levels of cognition, others require the use of sensory-motor skills and some require both. In the area of teaching for thinking, it is the former that is of most interest.

Another distinction between areas of expertise apart from the cognitive requirements of tasks typical of a domain is that some domains contain a larger proportion of what Glaser calls "ill-structured problems" (1985). Areas with *well*-structured problems are those such as chess or those with certain kinds of diagnostic activities that can be to some extent captured by algorithms (and hence reproduced or at least represented through computation). They also include areas in which

[2] Hattie and Yates and Ericsson and Charness also note that expertise has some of the characteristics that I outline in §1.3 and elsewhere, but the definitions they give remain relational.

continual practice and the mechanism for receiving feedback on those practices are well defined, and the quality of the feedback is very high. An example of this is learning to play a musical instrument, in which the feedback for success is immediate and effective— playing an F note in an E chord on the piano, for example, is an immediately obvious error (assuming the intent is for a clean E major chord). Learning to ride a bike is a well-structured problem since the goals are clear and the feedback is unambiguous and often painfully immediate. An example of an area with ill-structured problems is that which is of concern in this thesis: the area of teaching for thinking. In teaching for thinking, and perhaps to a lesser extent to teaching in general, many problems are ill-structured in terms of quality and clarity of feedback and in terms of how the problem is understood in the first place.[3] I will explore this distinction, as well as the distinction in kinds of cognition, in more detail later in the chapter as I move from how expertise is broadly understood to how it can be understood in teaching in general and then to teaching for thinking. For the moment, however, it is necessary to look briefly and broadly at the idea of expertise to gain a general comprehension of what it is we are trying to create in teachers.

Experience and domain specificity

Glaser makes it clear throughout his work that expertise is intimately connected to practice—particularly to solving problems within that practice. It is not sufficient for someone to have only abstract knowledge and be called an expert, since "…experts know about the application of their knowledge. Their declarative information is tightly bound to conditions and procedures for its use" (Glaser, 1985, p.3). Ericsson notes also that "the superior performance of experts must be acquired by active participation in the domain" (Ericsson, 2014, R508). Experts are experts in the application of knowledge to solve problems, which implies firstly that experts are experts because of what they can *do*, and secondly, and as Goldman suggests as an explanation of that efficacy, that they are experts because of what they *know*. Let me discuss the concept of 'practice' briefly before proceeding.

Practice is the application of ideas or methods, not just the possession of theoretical understanding. So, experts must *do* something to be considered experts, but how are we to understand this action? Chess experts play chess, expert fighter pilots fly planes, expert teachers teach. But what do experts in pure number theory do? *Prima facie* it seems that such knowledge is purely theoretical and

[3] Another example of an area with ill-structured problems is philosophy, and this is an issue I will devote some time to in a later chapter when discussing the role of philosophy as a methodology for teaching how to think, a principle at the core of the Philosophy for Children project (see Lipman, 2013).

without practical application. But it seems not only unjust, but also incorrect, to deny them expertise in their areas. We might be in danger of validating the 'ivory tower' view of academia, in which those with the best theoretical knowledge are those that do the least. This is of course naïve. The expert mathematician can solve problems that others cannot, albeit problems most of us would not understand. Action in physical or social arenas that involve experts in medical diagnosis, car racing, legal practice or teaching does not exhaust problem solving or achievement. 'Practical application' need not mean demonstrating a utility apparent to us all. The sorts of problems to be solved in number theory may be beyond most of us (after all, we are not experts), and may seem esoteric, but this hardly disqualifies solving them as practice.

Expert knowledge therefore has two components. The first is knowledge about a specific domain, and the second is knowledge of how to apply that domain knowledge to solve problems within that domain. These two components are not mutually exclusive, or even always distinguishable, as Glaser's quote shows. Expertise, then, is gained through experience (i.e. practice) and that experience is gained through participation in the domain. Experts do not seem to transfer their expertise at all well to areas outside of their domain. As Hattie and Yates note: "Expertise hinges on knowledge the person has developed within the relevant context, rather than any general skills or ability" (2014, pp.85–86).[4][5] This might be surprising if we assumed that expertise was a result of some innate ability that would, through its general nature, manifest in a variety of other domains. We might think, for example, that expertise reflects general intelligence, and hence infer that someone's expertise was a result of their innate cognitive ability. What comes out of the research on expertise, however, is a striking lack of correlation between performance at the highest levels and innate ability (Ericsson and Charness, 1994, p.731). This is a point I explore in the section below on deliberate practice.

Patterns, representations and principles

Experts are also able to perceive large and meaningful patterns within their areas of proficiency (i.e. their practice). The perception of these patters "occurs so rapidly that it takes on the character of 'intuition'" (Glaser, 1985). This is a function of what Glaser calls the "representational ability" of experts who have a highly coherent and structured representation of their domain enabled by a deep understanding of the broad principles at play and how they relate to each other. Novices, on the

[4] Glaser, however, does suggest that particular tasks within certain domains may be more generalisable and hence transferable than others, suggesting applied mathematics and aesthetic design as possible candidates (1985, p.12).

[5] Though, as I will show, that context need not be particularly specialised.

other hand, make superficial connections and have shallower and less effective representations (*ibid,* p.2). Another cognitive characteristic of experts is that they group information into "chunks" for handling in short term memory. Chunking is a method of grouping information so that it is part of a larger structure, perhaps associated with a particular meaning or purpose. To use a very simple example, I might notice in a string of numbers that my birthday appears, allowing me to 'chunk' that section of the string and hence improve my capacity to remember the number in its entirety. Chunking is evident in the ability of master chess players to memorise the positions of large numbers of chess pieces on a board during an interrupted or staged game. It is telling that when the pieces are randomised, and so stripped of meaning that can be associated with them as moves or strategies with which the masters are familiar, their recollection of the positions are no better than novices (Ericsson and Charness, 1994, p.735). With no perceived pattern, there is no improvement in recall. The clear distinction between expert and novice representations of their domains is manifest in Glaser's observations of the transition from novice to expert. He notes that "in the course of developing expertise, problem representation changed from surface representations to inferred problem descriptions, to principled (and proceduralised) categorisations" (Glaser, 1985, p.13). As an example of seeking deep principles, an expert in physics can understand a problem in terms of underlying principles such as the conservation of energy or Newton's first law of motion to help both frame and therefore identify possible solutions. The novice, being much more rule-based, will seek to use equations that can match the available variables that are typically used in such problem types. The move from rule-based thinking to pattern recognition and scheme-inductive thinking is definitive of the development of expertise. Let me explain this further using an example of diagnosis in medical practice based on ideas from Peter Harasym, Tsuen-Chiuan Tsai and Payman Hemmati (2008) in a paper concerned with developing critical thinking in medical students.

In the hypothetico-deductive model of decision-making, an initial hypothesis is tested against available information. This represents the standard 'Scientific Method' approach using deductive reasoning to falsify a hypothesis (Popper, 1959). If that information does not match what would be expected by assuming the hypothesis to be true, the hypothesis must be discarded or modified. A novice working in the hypothetico-deductive mode will match what they know about certain diseases or conditions against the symptoms of the patient in question. A condition is selected from memory at random or is perhaps suggested by some of the apparent symptoms as a starting hypothesis. The symptoms of the condition are matched against those of the patient, and the hypothesis is rejected, accepted, or tentatively made pending further investigation. Critically, when working in such a manner only one hypothesis can be tested at a time. This means that diagnoses can be very slow and particularly when, in the case of the novice, hypotheses for testing are not necessarily well-prioritised, if at all.[6] The expert diagnostician, in contrast, does not think like that. Expert diagnostic knowledge is schematically organised to allow rapid access and advanced pattern recognition. The expert, presented with the same patient as the novice, calls upon various schemata—kinds of representations that can contain large amounts of information—to help in identifying what is wrong with the patient. We all use such schemata in our daily lives. If you are walking along a path and you see an unfamiliar animal, you are not necessarily completely ignorant about its characteristics. Beyond what might be immediately obvious to the eye, it is possible to have a very deep knowledge indeed about the animal. If you notice that it has hair, for example, you call up the various schemata that you use to classify organisms and you rapidly conclude that it is a mammal of some kind. Once that conclusion has been reached, you can also infer that it gives birth to live young, is warm blooded, suckles its young and has a four-chambered heart. The 'novice' naturalist may have remembered the general characteristics of the vertebrates (fish, amphibians, reptiles, birds and mammals), but would have to go through the list of their characteristics one by one until a match was found in a slow and systematic hypothetico-deductive manner. Moreover, sometimes it is just the glimpse of how the animal moved or its colour that might call up the schema — we might say "it moved in a reptilian manner", for example, without necessarily knowing exactly what we meant by that. In the same way, the expert diagnostician homes in on the cause of the problem with what seems an uncanny prescience to the novice. In effect, I might in part describe the development of schemata as helping to chunk large amounts of information by combining that information into a meaningful and coherent whole. An insight into how experts use their knowledge also allows for a better understanding of the difference I spoke about above between experts and those who are only specialists. While it makes sense to speak of expert knowledge as highly organised and effective, this is not necessarily true of specialist knowledge, which might simply be unstructured knowledge of some aspect of a domain. Jill may have knowledge that a particular type of contract is used for certain light industrial buildings, for example, but this need not be well-organised knowledge.

Another characteristic of expert practice is that experts spend considerable time in analysing problems, particularly in those domains with high cognitive demands, and sometimes more so than novices (Hattie and Yates, 2014, p.104).[7] Experts tend to spend this time in a qualitative analysis,

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[6] Worse, they could be slower because of being subject to the *availability heuristic* in which hypotheses are selected based on how much they are in the foreground of the clinician's mind, perhaps because of recent experience (see Kahneman, 2011, especially Chapters 12-13 for more on this).
[7] It might seem counterintuitive to imagine they do not, but experts are also known for their overall speed, as the next section shows.

meaning they are concerned with understanding the nature of the problem as a precursor to solving it (*ibid,* p.104). This speaks to their deep understanding of the kinds of problems characteristic of their domain and their ability to recognise them as they appear in a range of situations. It also allows them to use their schematic knowledge more effectively as the problem type and its solution are part of this knowledge structure.

Speed and efficiency

As mentioned above, experts are well known for their ability to make rapid assessments and decisions. This is, of course, not unique to experts. Humans react intuitively, and hence rapidly, to a great number of events on a daily basis (for a broad overview Kahneman and Tversky, 2000). Not only are experts faster than novices, they are more often correct. One study showed that expert (scheme inductive or pattern recognition) reasoning in medical diagnoses is not only faster but is also five times more likely to get the correct diagnosis than the (hypothetic-deductive) reasoning of novices (Harasym et al., 2008, p.349). "Expert representations (and schema instantiations) are like fast-access pattern recognitions that reduce processing load and the need for general search heuristics" (Glaser, 1985, p.13). Speed and accuracy are therefore both characteristic of expertise.

The three groupings I have outlined above, which together broadly characterise expertise, are not independent of each other. A deeper understanding of how experts operate can be achieved through an attempt to see these characteristics as manifestations of some fundamental distinctions in cognition between novices and experts. But before I explore these distinctions any further, there is one more characteristic of experts to consider. This characteristic is not as reliant on cognitive change as are the others, but it is rather a key factor in enabling the cognitive development necessary to produce those other characteristics. This characteristic also provides one of the few pathways that are open to explicitly educating towards expertise beyond the call to gain more experience through increased practice; [8] it is the ability and motivation to reflect on one's practice with clear goals for improvement using unambiguous and immediate feedback—often referred to as "deliberate practice".

Deliberate practice

[8] Decreasing the time taken to achieve expertise is a key educational concern, but it has often been identified as problematic for several reasons that I outline in the next section.

Experience does not necessarily lead to expertise. Recall that Hattie focusses tightly on the distinction between experienced and expert teachers, as well as describing the workings of novices. I type almost every day, for example, but my error rate is high and my speed does not induce awe. Any claims I make to expertise in typing are without warrant.

One attempt to understand the development of expertise and its relationship with experience suggests that expertise develops through improvements in information-processing during the acquisition of knowledge and skills over extended experience.

> This approach […] has tried to show that the basic information system with its elementary information processes and basic capacities remains intact during skill acquisition and that outstanding performance results from incremental increases in knowledge and skill due to the extended effects of experience. (Ericsson and Charness, 1994, p.726).

In this view, differences between established experts are attributed to differences in experience, and perhaps also to some extent innate talent, expressed through the efficiency of these structures as they have incrementally developed over time.

Other attempts to understand the development of expertise have relied on that very difference in innate ability as the central factor that distinguishes the expert. Howard Gardner argues for this, believing that "exceptional performance results from a close match between the individual's intelligence profile and the demands of the particular domain" (cited in Ericsson and Charness, 1994, p.726).

Ericsson, Krampe and Tesch-Romer (1993) however, provide convincing evidence that the most significant factor at play in developing expertise is deliberate practice and this position has now been widely accepted—indeed it was hinted at some time ago by Glaser and others: "Experts develop skilled self-regulatory processes such as solution monitoring, allocation of attention, and sensitivity to information feedback" (Glaser, 1985, p.14).

The word 'deliberate' with respect to practice could be misleading—after all, most practice is deliberate to some degree.[9] I deliberately teach, play tennis or drive a car. These things do not happen by accident. Deliberate practice as understood in the context of developing expertise requires, in the first case, that the practice is consciously attended to as it happens. This is not just about a conscious decision to perform a task or begin a session of practice, rather it means being aware of what one is doing and consciously and deliberately attending to the details of it. In the second case, there must be some feedback, as immediate and as detailed as possible, that speaks to the success or failure of an attempt to reach a clearly defined and understood goal. This feedback is then used to modify schematic understanding. This is not very different from how we understand learning in general. Optimal conditions for developing expertise include "the subject's motivation to attend to the task and exert effort to improve their performance. […] The subjects should receive immediate informative feedback and knowledge of the results of their performance" (Ericsson et al., 1993, p.367). John Hattie and Helen Timperley, in their paper The Power of Feedback—a title I include for its effect—write:

> When students have the metacognitive skills of self-assessment, they can evaluate their levels of understanding, their effort and strategies used on tasks, their attributions and opinions of others about their performance, and their improvement in relation to their goals and expectations. They can also assess their performance relative to others' goals and the global aspects of their performance. (Hattie and Timperley, 2007, p.94)

It is an important finding in the context of teaching that what works well in education in general is also critical in the development of expertise, for it means that what we work towards in teaching is, in part, the development of expertise.

Deliberate practice does not seem, on the face of it, to contradict the first attempt I described to understand expertise as an incremental increase in ability over time. This incremental improvement could perhaps be simply explained as driven by deliberate practice. It turns out, however, that this picture of smooth development in proportion to experience, plus perhaps some innate ability, is not supported by studies of the changes in cognitive processes that influence how experts think. These cognitive processes:

[9] It is tempting to replace "deliberate" with "deliberative" as this change would seem to better capture the reflective nature of expertise development (and also resonates with its use in in the term 'deliberative democracy'), but I will keep to the original word as that remains in use in the literature.

> reflect complex, domain-specific cognitive structures and skills that performers have acquired over extended periods of time. Hence, individuals do not achieve expert performance by gradually refining and extrapolating the performance they exhibited before starting to practice but instead by restructuring the performance and acquiring new methods and skills. (Ericsson and Charness, 1994, p.731).

What these structures are and how they differ from the structures of novices includes the schematic nature of expert knowledge mentioned above, but also reflect changes in the use of other capacities including working memory (to be explored further in the next section). That experts think just like us, only better, is no longer a tenable idea. They think in a different way, but only in the context of their domain. Outside this context, they are largely indistinguishable from the rest of us in terms of general cognition. Experts in one domain do not seem to perform any better than average in another. This means that outside their domain experts think like the rest of us.

Given that deliberate practice is a necessary component in the development of expertise, it is natural to consider for how long this need occur before making a confident claim that expertise has been achieved. There is a widely understood rule-of-thumb that a minimum of 10,000 hours or 10 years, of experience is required, but as discussed above this should be tempered by the knowledge of the need for deliberate practice.[10] Given this caveat, it turns out this claim is surprisingly accurate, though not universally applicable across the broad types of domains in which expertise is recognisable (Ericsson et al., 1993, p.393). This time factor is not a critical consideration for this thesis, though it has clear implications for the implementation of any program in the development of teacher expertise. Suffice it to say at this point that effort towards developing expertise in teachers in teaching students how to think must be substantive and sustained, and it is the purpose of the thesis to provide a framework in which this can occur.

If experts *have* expertise, then there is some *thing* that they have. And this *thing* is what allows an objective assessment of whether someone is an expert as distinct from simply being experienced or a specialist. The thing that an (non-expert) experienced practitioner has is simply experience, and the thing that a (non-expert) specialist has is simply specialist knowledge. As we have seen, neither of these, nor both together, are sufficient for expertise. The speed and accuracy of experts within their domain can be explained in part by how they access and use their knowledge. If speed is

[10] 10,000 hours has been reported as the time the best music students in an institute in Berlin had spent in deliberate practice by the age of 20 (Ericsson, 2014). The journalist Martin Gladwell in his book Outliers (2011) wrote that 10,000 "is the magic number for greatness" (p.41), and from this much of the popular myth has sprung.

linked to pattern recognition, as Glaser suggests, then to quickly recognise patterns it stands to reason that you must have patterns, or perhaps more accurately representations, internalised so that these can be called upon to match the unfolding of events in practice. Such organised knowledge is called schematic knowledge and is part of what we mean by 'expert knowledge'. The schematic knowledge of experts is developed through immersion in the problems and solutions of the domain in which expertise is sought. In the next chapter, I will identify some of the pieces need to understand expertise in teaching for thinking. In other words, I will start to form the schematic knowledge that would be indicative of expertise in this area. Before I do this, however, I need to expand on what we mean by schematic knowledge, or, more specifically, what advantages schematic knowledge gives us, in the context of what are called dual-process theories of thinking. This is knowledge that comes predominantly from cognitive science and psychology, and I introduce it here to give some insight into the value of schematic knowledge, but also to help describe its nature in the context of associate mental activities.

1.4 Dual process thinking, working memory and schematic knowledge

In this section, I will discuss models of the cognition that occurs in the brain and explain how these models can be used to explain how expert thinking differs from the thinking of non-experts. This is important as it helps to understand what the brain does as it develops and uses its expert knowledge. While it does not necessarily follow that knowing things about cognition means that we can use that information to help teach and develop expertise[11], I will show later that such knowledge as outlined below can help guide the deliberate development of expert knowledge in both students and teachers and to make the job easier overall.

It is an old idea that we discern (at least) two types of thinking—an idea rooted in both philosophy and psychology. That we have a broad duality of cognitive processes is a contentious idea, however. The key characteristics of such thinking are generally proposed to be identified with binaries such as intuitive–reflective, automatic–deliberate, effortful–effortless and fast and slow, with the use, or not, of working memory also a factor to consider. Working memory can be understood as referring to "the *temporary storage* of information that is being processed in any of a range of cognitive tasks" (Baddeley, 1986, p.34). For example, remembering someone's phone number or what cards have just been dealt requires working memory. That these binaries are often

[11] A problem with how some neuroscience is developed into professional development sessions for teachers (see Chapter Six for a fuller discussion of this).

used in discussing our thinking does not, however, logically imply that our thinking must itself be broadly binary. Some conceptualisations, such as that of Magna Osman (2004), place our thinking on a linear, one-dimensional continuum in which there is no clear categorical boundary between supposed types of thinking. Other conceptualisations, such as those of Kahneman (2011) and Evans (2011), embrace a binary model. Still others, such as Alexandra Varga and Kai Hamburger (2014), favour a description using not one but three axes of change. Figure 3 below, taken from the paper of Varga and Hamburger, summarises this nicely, with A, B and C representing the binary, linear continuum and three-dimensional models respectively (*ibid,* p.2).

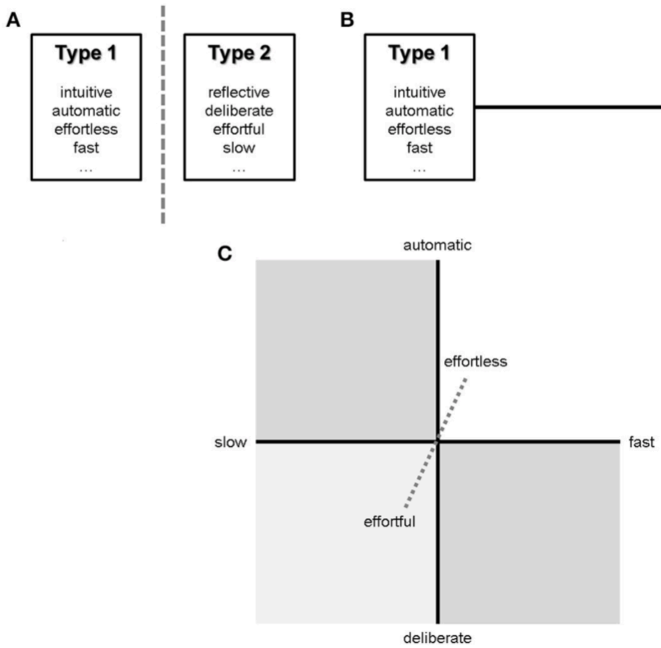

Figure 3: Competing models of cognition

Dual process thinking (type A in the diagram above) has entered popular understanding recently largely because of Daniel Kahneman's book *Thinking Fast and Slow* (2011), in which the "fast" and "slow" of the title refers to what he calls the two "systems" of thinking. This model is the most referenced of the three discussed above, with versions developed and used by a variety of researchers (Wason and Evans, 1974; Mercier and Sperber, 2011; Epstein, 2010; Stanovich and West, 2000). While I acknowledge that any of these models might claim supremacy in the future, I will focus on dual-process thinking for two reasons. The first is its dominance in the literature, and the second is because a key concern of this thesis is the relationship between expert schematic knowledge and working memory—dual process theories help explain this relationship well and provide a coherent framework for understanding how such knowledge may be used. Whether or not such a framework is an accurate representation of our cognition, it can form the basis of a model, outlined in Chapter 6, that has some utility in terms of directing our practice towards activities and outcomes we have empirical reasons to pursue. While all models are wrong, or more generously contain incorrect assumptions, approximations or idealisations, they can be useful in guiding practice and inquiry.

Modern formulations of dualistic thinking come from areas such as learning, social cognition, judgment and decision-making and in the psychology of reasoning dating back to at least William James and Sigmund Freud (Osman, 2004, p.988). Jonathan St. B. T. Evans (2011) gives a common, and reasonably inclusive, definition of these two types of thinking as:

> *Type 1*: fast, high capacity[12], independent of working memory, and cognitive ability
>
> *Type 2*: slow, low capacity, heavily dependent on working memory and related to individual differences on cognitive ability (*ibid*, p.87).

While this list of characteristics provides a simple understanding of dual-process thinking, it is also important to note that there is no definitive or standard theory that acts as a point of coalescence for other competing theories, nor that typifies what many researchers across a variety of fields hold as a working model. Rather there are a "family" of theories operating not only across but also within areas of study, for example in the psychology of reasoning (*ibid*).

A common representation of the difference between the two types of thinking, however, is that Type 1 represents an evolutionarily ancient thinking not dissimilar to that which we find in non-human animals, a thinking that is susceptible to cognitive biases and one which is not closely linked to IQ or similar measures of cognitive skills. Type 2, per the same paradigm, is uniquely human (and hence evolutionarily recent), deals with abstractions and is therefore, not surprisingly, closely linked to general intelligence (a them common through both Evans, 2011; and Stanovich and West, 2000). It is also common to associate conscious attention with Type 2 and unconscious behaviour with Type 1. Evans rejects this pairing, however, because Type 1 processing can produce outcomes of which we are clearly consciously aware (for example emotional or metacognitive states), and because Type 2 thinking may be conscious in part, but also relies on a range of inputs that are delivered by unconscious processes such as contexualisation of information or long-term memory retrieval (Evans, 2011, p.88).

[12] 'Capacity' here refers the amount of information that can be held for processing.

Evans notes that a definitive characteristic (in his and others' view) of what has been called Type 2 thinking is its link to working memory, which he also calls *controlled attention* (*ibid*). A proffered solution to the problem of what makes the two types of thinking distinct, then, is that Type 2 thinking requires access to working memory as one of the resources involved in any cognitive task it performs. It is this that is denied to, or perhaps more accurately not needed by, Type 1 thinking. This link also explains the slower and seemingly conscious nature of Type 2 thinking.

Evans moves to another functional level when he speaks of minds. These minds correlate with the two types of thinking, with Type 1 being a function of what he calls the old mind and Type 2 a function of the new mind. Keith Stanovich (2012) refers to these as the autonomous and reflective or algorithmic minds (though Stanovich makes a case for the latter two being somewhat distinct). Evans also refers to them, more descriptively, as the intuitive and reflective minds.[13] This can be understood in an evolutionary sense as the old mind 'operating relatively automatically, based on innate models or experiential learning and functioning independently of general intelligence' and the new mind, 'which is distinctly human and allows flexible, rule-based forms of thinking that can deal with novel problems…' (Evans, 2011, p.91). The old, intuitive mind does not require access to working memory, and gives us the ability to form intuitive judgements and to respond habitually. The new, reflective mind requires access to working memory (among other things) and works with high order representations derived from a variety of sources, such as language, memories and general knowledge.

> …we have a form of cognition which is old, having evolved early, operating relatively automatically, based on innate modules or experiential learning and functioning independently of general intelligence. This is contrasted with a newer form of cognition which is distinctively human and allows flexible, rule-based forms of thinking that can deal with novel problems, albeit restricted by working memory capacity and general intelligence level. (*ibid*).

Both minds work towards goals, though the nature of the goals and the processes utilised to achieve them are different in each. Importantly, there may be times when these goals are in conflict. The old mind works from a genetic level, using processes and automatic responses that are shared with some other animals. The old mind also learns from experience, shaping its responses and planning within old evolutionary constraints, again in a manner used by other animals. Much of the learning

[13] Dan Sperber speaks more of intuitive and reflective beliefs and moves a little away from making 'reflective' a cognitive category: "…reflective beliefs, unlike intuitive beliefs, are not a basic category of cognitive architecture" (Sperber, 1997, p.83).

of the old mind is of the sort that forms simple associations, linking stimulus to response and forming general mental patterns. The new mind, however, can focus on more personal goals that are meaningful to the individual. These goals can be achieved by the simulation of potential futures and by reasoning consequentially from actions. New minds can also learn by experience, but in doing so can also develop rules and heuristics for explicit deployment in a variety of situations (*ibid*, p.92).

It is worth noting that the temptation to locate our cognitive biases solely in the old mind should be resisted. The simplistic notion that our new mind is used to rescue our cognition from the brute and erroneous processing of our old mind does not allow for the likelihood that our Type 2 processing often relies on input from a variety of Type 1 thinking (Kahan, 2012). For example, in analysing the credibility of an argument, a distinctivley Type 2 process, we may be intuitively processing language, tone, threat levels and any number of other aspects governed by Type 1 thinking that feed into our overall ability to infer and conclude. Evans points out that while Type 1 thinking does not depend on Type 2 thinking, it is perhaps impossible for Type 2 thinking to exclude Type 1 thinking entirely. This is also true when the results of Type 2 thinking include processing heuristics, which through their explicit application are Type 2 thinking, but may due to their speed and lack of critical analysis during application create bias or error.

1.5 Putting it all together

Evans prefers a cognitive psychology approach to dual-process thinking—with an emphasis on the underlying mechanisms and a focus on access to working memory and general intelligence—above social psychology approaches (which I suggest also would include educational psychology) in which dichotomies such as deep and shallow processing or heuristic and systematic processing may not be manifestations of different categories of mental processes as much as differences in modes or ways of thinking. Whether this distinction between mechanisms and processes is relevant in an educational context is not entirely clear, and there are certainly references to deep and shallow thinking, for example, in research into effective teaching (see Collis and Biggs, 1979 for such a system—the SOLO model—in widespread use today). I will not follow Evans in preferring this cognitive approach, though I take from it its ability to both explain and plan for differences in thinking in the context of expertise. If dual process models are right about dual cognitive mechanisms (or even if other models support some degree of polarisation along an axis or axes), this suggests that there may also be developmental differences between the two types, and this in turn suggests the existence of pedagogical implications (the pedagogical implications for *psychological* changes are of course well entrenched in educational theory, and include the work of

Piaget and Vygotsky). Our understating of the underlying processes and their development seems too meagre to me, however, for definitive pedagogical directions to be determined, but it is not unreasonable to imagine this as a rich area of future study. What is of more immediate interest for this thesis is the understanding and modelling of the dynamics of each of the type of thinking, and in particular, the nature of interactions between them. I will now outline briefly a logical case for integrating this understanding of schemata, working memory, deliberate practice and expertise.

We have seen that experts have highly organised knowledge and highly effective representations of the essential concepts in their domains that have been developed through deliberate practice. We have also seen that this knowledge can be employed rapidly and effortlessly to effect immediate and accurate decisions. Some of this cognitive advantage can be explained through an understanding of dual-process thinking models. Experienced practitioners may develop schematic knowledge and representations of their domains (let me call these SRs for brevity's sake) but these SRs may not be very effective ones. What separates experienced practitioners from expert practitioners is the quality of those SRs. This is not a simple matter, as John Sweller points out: "in intellectually complex areas experts have acquired tens of thousands of schema which are the building blocks of intellectual skills" (1994, p.299) . Given this daunting number, what determines the quality of those SRs is the quality and amount of experience combined with the quality of deliberate practice. Deliberate practice, by the very use of the word 'deliberate' identifies itself as Type 2 thinking. SRs, since they do not need to be reconstructed each time they are called into service, are Type 1 thinking. The move towards expertise from either novice, in which SRs are in the process of being created, or merely experienced practitioners, in which extant SRs must be moved from Type 1 thinking into the light of deliberate practice, requires movement between these types of thinking. But SRs, once refined and developed, must once again move into Type 1 thinking to be useful to the expert. For without well-entrenched Type 1 SR constructs the expert loses her advantage. What characterises the expert, therefore, is a dynamic interplay between Type 1 and Type 2 thinking concerning the development of their SRs. The merely experienced practitioner has no such interplay. The novice may have some, but the extent to which it is enriched through deliberate practice determines their destiny of becoming merely experienced or an expert.

One of the most significant impediments to rapid deployment of knowledge is the amount of working memory required. Since schematic knowledge, once established, requires no working memory to recall, it is superior to unstructured knowledge in the context of problem solving in a domain. This explains the difference in speed between the novice and expert diagnostician outlined in the case of medical practitioners mentioned earlier. The hypothetico-deductive method demands a significant allocation of working memory, while the scheme-inductive method, reliant as it is on schematic knowledge, has very light demands on working memory. Since working memory use is a key discriminator between Type 1 and Type 2 thinking, in talking about the thinking of experts, we are talking about how these *types* of thinking are used by experts.

We are better able to model this cognitive interplay than we are to fully understand brain development, and our models may be functionally useful even without an understanding of the underlying cognitive pathways. I see this as the value of accepting both psychological and cognitive approaches to better understand expert thinking. I will use this understanding to model what I call 'warm' and 'cool' thinking in Chapter Six *Pedagogical considerations*.

Chapter Two: Teacher expertise in developing thinking skills

One might imagine that outlining expertise in teaching would be an exercise in matching general characteristics of expertise to teaching expertise—a simple instantiation of general principles—and that after outlining what makes for expertise in general it would be useful if not necessary to go through the minutiae of translating this into general teaching practice. But the characteristics of expertise I have outlined in Chapter One are, as I noted, general ones, and my intention is to make these relate to (non-discipline specific) teaching in equally general terms only. The reasons I choose this general approach are, first, that much of the work in understanding general teaching expertise has been done by Hattie and Yates and explicitly done so as an exercise in moving from a broad understanding of expertise towards understanding expertise in the general domain of teaching (as opposed to a specific teaching area). The second reason that understanding expertise in the general domain of teaching does not occupy a larger part of this thesis is that my interest is in developing expertise in the specific domain of teaching for *thinking*. While it will be necessary for me to talk at some level about general teaching expertise, the level I choose is only that which is necessary to move into the more specific domain of teaching for thinking. I draw more strongly on the general characteristics of expertise than I do on the characteristics of expert teachers, since the latter is an instantiation of the former within a domain. It is also no less instructive, I suggest, to move from an understanding of expertise directly to an understanding of teaching for thinking without too much concern for general teaching expertise since much of the talk of expert teachers is to do with teaching for *learning* (a subject domain concern) rather than teaching for *thinking* (also a subject domain concern, but with broader application as I will show), and so teaching for thinking may be less a subset of the set of teaching for learning and more a different domain all together. That this is so can be justified by appealing to the kinds of knowledge required for each (subject matter focused learning and thinking using that subject matter) and hence to the kinds of schematic organisation and other representations teachers must have for each. Let me explain further by examining how Hattie and Yates relate general expertise to teacher expertise.

The table below represents how Hattie and Yates have demonstrated that teachers manifest broad characteristics of expertise I outlined earlier (2014 — the text used relates to 'expert teacher characteristics' in the table below).

Expert characteristic	**Expert teacher characteristic**

Experience and domain specificity	Expert teachers teach their area extremely well but are far less skilled outside of their curriculum areas.
Patterns, representations and principles	Expert teachers plan lessons as interlinked sequences with different means of achieving same goals. They concentrate on tasks relevant to goals. Expert teachers recognise and interpret classroom events incredibly efficiently. Expert teachers steer activities towards classroom goals. They diagnose the need for instruction and feedback at the level of individual needs.
Speed and efficiency	Expert teachers explain complex ideas with astonishing clarity, using short time blocks. They use instructional methods with precision.
Deliberate practice	Expert teachers are able to 'stop and start' lessons most efficiently. They listen intently to (or even stare at) students to obtain feedback on their learning. They have developed unique strategies for controlling student attention. They anticipate possible problems and so can respond to keep momentum flowing.

Note that Hattie and Yates seem to be suggesting that, since teachers are less skilled outside their curriculum areas, that teaching domains are a function of curriculum specialisation. That domains are a function of teaching areas means that, if teaching for thinking is a domain in the same way that teaching for physics or music is, then expertise in teaching for thinking is an identifiable educational goal.

This list of characteristics seems a reasonable indication of what the general abilities would mean for teacher practice. But these are indications only and do not seem to speak to how their knowledge is organised, only that it is and how that translates into practice. Moreover, it is a list more of what expert teachers *do* than what they *think*. When it does mention thinking, as when teachers "recognise and interpret classroom events" it is in a very broad sense. And, as we have seen, understanding how experts *think* is the most critical aspect of understanding (not just recognising) what an expert is. I do not wish to minimise the usefulness of having such a list of teacher actions—it certainly provides the critical criteria of what expertise looks like in the classroom and recognition of when the expert is present. But what, exactly, *is* the knowledge that expert teachers have developed so well? And whatever that knowledge is, is it bound to curriculum areas? How are their schemata structured? What representations do they have that renders their teaching so effective? If it is the case, as Hattie and Yates suggest, that curriculum areas provide the domain of specialisation, how do we understand the domain of teaching for thinking as separate from (or related to) teaching for learning within an established curriculum area? Ericsson and Charness clearly allow for an exploration of expertise in thinking, and hence in the teaching of it:

> There is no reason to believe that changes in the structure of human performance and skill are restricted to the traditional domains of expertise. Similar changes should be expected in many everyday activities, such as thinking, comprehension, and problem solving... (Ericsson and Charness, 1994, p.745).

And, consequently, what does expertise in that domain look like? Here is another reason to move from general expertise to expertise in teaching for thinking without considering general teaching a necessary intermediate. If all teaching areas are their own domains, then there is nothing generalisable about teaching, or at least, to make a weaker claim, that which is generalisable about teaching is not actionable outside of expertise in a curriculum area domain. But if I am to claim, as I do, that teaching for thinking is its own domain, I must therefore provide the schematic knowledge and representations that I believe are unique to that domain, or at least make a case that they exist. It is the justification of this claim that makes up the body of this thesis.

2.1 The challenge of developing schemata for thinking

While Dual-process thinking gives us a framework to help understand how experts change their thinking as they progress within their domain, that same framework throws up an impediment to making that expert knowledge transparent.

Schematic knowledge is held in long-term memory and can be effortlessly called upon in Type 1 thinking. But Type 1 thinking contains structures that are brought into play without conscious activation and often without conscious awareness. Critically, even though experts can use this knowledge very effectively, they may not be able to articulate what that knowledge is or how it is structured. This may be in part since because of “highly valid cues that the expert’s System 1 has learned to use, even if System 2 has not learned to name them” (Kahneman, 2011, p.240). And so, while experts might be able to speak to some extent about their knowledge, “they still cannot necessarily explain why they saw situations in a particular light, or why a particular course of action occurred to them" (Stichter, 2015, p.112)—moreover, even when experts are able to speak of the decision-making behind their actions, it turns out that very often that explanation is at odds with their behaviour (*ibid*). This phenomenon is so common that the schematic knowledge behind most expert performance remains hidden enough to be problematic in the teaching of that expertise to novices. But even if some of this schematic knowledge were to become clearer, the fact remains that, particularly in complex intellectual domains, "experts have acquired tens of thousands of schemas [sic] which are the building blocks of intellectual skills" (Sweller, 1994, p.299). This multitude of schema, the substrate of expert domain knowledge, may make the clarity of individual schema insufficient to transfer domain knowledge to the novice and so further doom the project of teaching expertise.

Such muddied waters might seem to render the goal of this thesis, to develop schematic knowledge in the domain of teaching for thinking, unreachable, particularly because of its rich and complex intellectual nature. If it is the case that reconstructing expert knowledge through interrogating or observing experts cannot be easily done with substantive success, and that even if it could be done it would still leave each schema embedded in unknown structures that would need to be decoded to properly understand its function, then it would also be the case that expertise in teaching for thinking would need to be developed through the long haul of deliberate practice and there would be no potential educational shortcuts. But there remain some paths still to explore with hope for a visible and effective outcome. Most significant is the fact that not all schemata are equal.

Some schemata represent higher order structures, and some are very specific. Some are simple, and some are complex. Not all higher order schemata are necessarily complex. One might have basic schematic knowledge of the division of powers within certain kinds of representative democracy, for example the division in the Australian system between the parliament, the executive and the judiciary. How these three branches of government work together in general, and the reasons why they have some significant degree of separation, is not hard to grasp. Within each of these, however, lies enormous complexity. Parliamentarians, legal experts, journalists and others spend many years developing expertise within these elements. Consider also the theory of evolution by natural selection. The overarching schema of evolution provides the understanding that all life is connected and that all living things share common ancestors (if not one common ancestor). This simple idea provides enormous explanatory power with a minimum of assumptions (Dawkins, 2009). Within evolution, however, is a range of complex schemata dealing with large domains of knowledge, including details of the evolution of the immune system, of the evolutionary function of sexual reproduction and of the deep structure of DNA, to name a very few. Nevertheless, as Dobzhansky (1973) outlined in his famous essay, and captured in the title, "Nothing in biology makes any sense except in the light of evolution" (his title). Without evolution, the natural world seems a kaleidoscope of shape, colour and form. Within the schematic understanding of evolution even enormously complex schemata have a place and purpose that can be readily understood.

Just as evolution is a broad explanatory schema, so too is the schema that is the focus of this thesis. However, unlike the broad schema of evolution by natural selection, which is an attempt to represent a real process, I am not suggesting this is *the* schema for teaching for thinking. I am rather looking for something integrative that is designed to match the characteristics of a range of pedagogical phenomena across a range of methodologies on inquiry. Let me explain further.

There are examples of structured pedagogical knowledge regarding teaching for thinking, and there is an abundance of work from which to choose. A typical example is the Dimensions of Learning (DoL) framework developed by Robert Marzano and others (Marzano, 1992), which has had a significance presence in schools for some time. Marzano's later work in the Art and Science of Teaching program (2007) has become equally well-established. Marzano has also developed The New Taxonomy of Educational Objectives (2006) that builds on his and others earlier work to provide a principled approach to teaching based on student cognition. This latter work is forming part of the basis of program design for several systemic changes in education, including, for example, the development of the new suite of senior school syllabi by the Queensland Curriculum and Assessment Authority (QCAA, 2015).

DoL begins with a very explicit overall structure, one that has a regimented plan of implementation. The 5 dimensions of learning and their (very basic) relationships are shown in the Figure 4 below. Each dimension is elaborated upon in some detail in teachers' manuals and other supporting publications (see Marzano et al., 1990 for more examples).

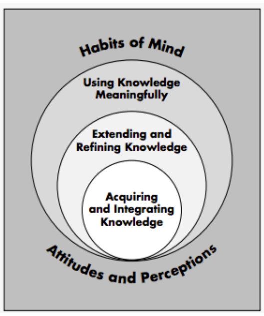

Figure 4: The 5 Dimensions of Learning

Source: https://pdfs.semanticscholar.org/e361/31ef5444f76cbcf8481b0b48d192609aeb1c.pdf

While some schematic structure within DoL is immediately clear (the diagram itself represents knowledge about the program and its relationships, and the support material is extremely detailed and highly structured), understanding that structure also requires a significant investment of time. Schools, including ones in which I have taught and been responsible for DoL implementation, often invest heavily in professional development programs to help develop teacher understanding.

Marzano's New Taxonomy is one of information processing rather than, as it was for the educational psychologist Benjamin Bloom, of cognitive skills (see Bloom and Krathwohl, 1956). Marzano uses the diagram below as a means of helping to understand the model (Marzano, 2006).

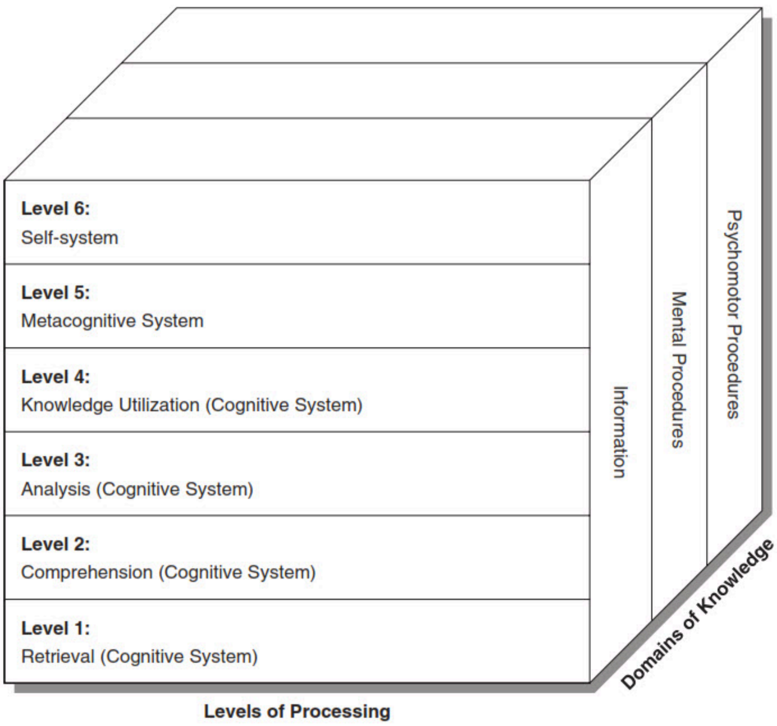

Figure 5: Marzano's New Taxonomy

It is not my intention to explain this system in detail, only to state that Marzano presents his taxonomy as a model rather than a framework and does not suggest that it is a schema. He makes the point that "models and theories are systems that allow one to predict phenomena; frameworks are loosely organised sets of principles that describe characteristics of a given phenomenon but do not necessarily allow for the prediction of phenomena" (*ibid,* p.31). This clearly also identifies DoL as a framework, since the five dimensions of learning are underpinned by four key principles (see Marzano et al., 1990). So, while this diagram acts as an aid to understanding, and it is very much focused on cognition, neither this nor DoL represents a schematic understanding of the pedagogical knowledge of teaching for thinking. This is an important distinction. Schemata organise knowledge within an area, often including the way knowledge is used to solve problems. Schemata are not frameworks, but they are clearly mental models, or representations. But they are not models as we talk about them when we say 'models and theories' as Marzano does. Models do not require a complex understanding of interactions and elements to work. A mathematical model, for example, might incorporate many dynamic aspects of a system and include many approximations and assumptions, but it not always necessary to understand them to use them (indeed computer simulations based on mathematical models are ubiquitous). To have schematic knowledge, however, is to have a certain understanding (implicit or explicit) that is contained within the schema. One cannot have schematic knowledge without understanding. This is why I am focusing on schema rather than just models in this thesis—schematic understanding is characteristic of expertise; the use of models alone is not. I will elaborate on this point in the next section.

The Philosophy for Children (P4C) approach to inquiry-based education also has a very large and coherent body of work (see for example Lipman and Sharp, 1978; Lipman et al., 1980; Splitter and Sharp, 1995; Lipman, 1994, 1998; Gregory, 2002; Millett and Tapper, 2011; Burgh and Thornton, 2016) that is dedicated to building what Lipman called "a system of thought" (2003, p.103).[14] Practicing and thinking about the many parts of P4C leads to an integrated understanding of a very complex and rich schema. Understanding the schematic nature of P4C is a lengthy process built up through long and reflective classroom practice and theoretical knowledge, often through initially highly scaffolded activities. The following is an example of the detailed approach to teaching thinking present in P4C that does not suggest schematic structures. Lipman focused on several aspects of thinking, recognising that when we talk about thinking we are talking about both thinking and thinkers, and hence he was concerned with both thinking skills and the development of dispositions. Let me focus for the moment on thinking skills. As part of a broader focus, Lipman used four general categories of thinking skills: inquiry, reasoning, conceptualisation/information-organising and translation (2003). Inquiry skills are cognitive skills involved in "self-correcting

[14] I am not attempting to characterise P4C (or variations such as Philosophy with Children—PwC) solely through focussing on Lipman. I am, rather, taking *a* conceptualisation linked directly to Lipman as an example of how a rich and complex set of ideas can be hard to reconcile in a schematic understanding without significant time and effort. The purpose of this section is not a summary or broad representation of P4C but to show that a lack of visible schemata, even in the presence of an otherwise coherent and accessible body of knowledge, is less than optimal for understanding it.

practice" which students use "to connect their present experiences with what has already happened in their lives and with what they expect to happen" (*ibid*, p.178). Reasoning skills are those that can bring us knowledge beyond the bounds of our direct experience or awareness and are typically those involved in deduction and induction. Conceptualisation or information-organising skills are those required to make sense of the plethora of information available to us, including understanding categories of concepts and the relationships between them as necessary steps for the development of "principles, criteria, arguments, explanations and so on" (*ibid*, p.184). Translation skills are those which preserve meaning as information is moved between representational systems, including symbolic ones. This is a useful categorisation of skills. That there would be educational utility in so categorising them is evident, although exactly how this would translate into pedagogical practice and theory is a more complicated question. But this is not the only categorisation of thinking Lipman uses. He also speaks of critical, creative and caring thinking, though later proponents of P4C now also use "collaborative" thinking, an addition suggested by Roger Sutcliffe (2014) and generally accepted as useful. These are what Lipman calls "dimensions of thinking" (Lipman, 2003, p.197), and, unlike the previous categories which seem to be defined by different cognitive goals, they are equal and necessary partners in developing what Lipman sees as the full measure of inquiry and are linked to the development of affective dispositions in inquirers. Critical thinking, in this system, is characterised by, among other things, criteria and standards of thinking, which may be objectively assessed as effective or otherwise. It is this objective ranking of reasons, arguments and ideas that gives us the literal meaning of the word 'critical' and moves it beyond a criticism based purely on subjective appeal. The development of criteria and standards occurs within the community of inquiry,[15] in which the community has epistemic primacy over the individual and rules and standards of inquiry are collaboratively developed (see Lipman and Sharp, 1978). Critical thinking also, according to Lipman, helps us to avoid erroneous reasoning through valuing a range of inquiry principles, such as "precision, consistency, relevance, acceptability and sufficiency" (Lipman, 2003, p.233). These "value-principles" help us to ultimately determine what criteria we consider to be worthy for application in inquiry. Creative thinking is unsurprising for selection as a domain, as without some level of creativity new ideas could not be generated, new modes of inquiry found, or alternative hypotheses or explanations developed. That this kind of creativity is essential for inquiry is not in question, and its link to critical thinking is evident in the examples just given. As Popper (1959) noted, the creative act of developing a hypothesis and designing the means to test

[15] The origins of community of inquiry can be traced back to the philosophical work of Charles Sanders Peirce (Lipman and Sharp, 1978), and has, since then, been "adopted and developed by educational theorists of different orientations", and most notably "was extensively developed by Matthew Lipman" (Pardales and Girod, 2006, p.299), as well as receiving extended treatment in in the P4C literature.

it is one that is neither purely deductive or inductive and is the engine of inquiry in the natural sciences. Lipman's scope of caring thinking, influenced strongly by Sharp (see Gregory and Laverty, 2017), is broad, though the criteria that might be used to recognise it does not share the same precision as does critical thinking, a point Lipman makes himself to justify focussing on broader attributes. Caring thinking provides for us a sense of meaning and purpose not only in the concern for ourselves and others that is often at the root of inquiry, but also in the concern for the inquiry process itself. The how and why of inquiry is ultimately a question of caring and of valuing. "To care is to focus on that which we respect, to appreciate its worth, to value its value" (Lipman, 2003, p.262).

The previous paragraph shows that Lipman's conception of teaching for thinking is dense and substantive, but it is unclear to the novice how these elements interact.[16] How do the four thinking skills of inquiry, reasoning, conceptualisation/information-organising and translation interact with the critical, creative and caring (and collaborative) thinking, and how might they relate to the curriculum needs of the general classroom? This is not a problem for someone well-versed in P4C literature, but it presents a problem for the initial conception of the material.

All of the programs above work strongly toward integrating knowledge of teaching and hence to constructing pedagogical schemata; however, the nature of this schematic structure is not clear to the novice, and there is no indication that it is clearly articulable by the expert and therefore instruction in expertise is inhibited. Together, these pedagogical constructs, including Marzano's evolving approaches and P4C, cover a very large amount of educational ground—both in theory and in practice— but they do not exhaust educational, or even thinking, frameworks. Elder and Paul (2013) have also penetrated deeply into pedagogical practice (including into P4C—see Splitter and Sharp, 1995) with their use of what they call "intellectual standards" (discussed in detail in Chapter Five *Skills values and virtues of inquiry*). Unlike Marzano's systems and P4C, Elder and Paul have a clear schematic structure—one that can be readily visualised and understood. In Elder and Pauls' work, however, certain key aspects are not explicit, including metacognition and epistemology, which I will argue later are essential elements of schematic knowledge in teaching for thinking. So, even given all this work—including Marzano, P4C, Elder and Paul and Hattie and Yates—and even given continuing discussion and deepening knowledge within these paradigms, there is still a path that needs developing: that of constructing clear schematic knowledge indicative of expertise in teaching for thinking.

[16] Although Clinton Golding has made some significant moves in providing some analytical frameworks for P4C (see 2013, 2016).

It is not immediately clear that any of these systematic programs of learning and thinking are inclusive of, or commensurate with, the others. This could be difficult since operationally there is a necessity for schools to require an either/or approach in selecting how they could proceed from these choices (it would be problematic to introduce both DoL and P4C within the same school, for example, since DoL has a series of templates and structures and other operational aspects that are not aligned with the organic nature of philosophical inquiry). In this thesis, however, I am not arguing for their individual merits or disadvantages in detail nor am I interested in a comparative analysis. Rather, I am only looking for ways to do two things: first, to understand what deep pedagogical structures they may have in common (or to what extent such structure can be discerned); and second, to augment them—not by adding to their key understandings, but by suggesting a pedagogical knowledge structure that may assist in developing expertise within each of the educational approaches. In other words, to develop a schema for teaching for thinking that each would recognise as useful because it is representative, to some extent, of their individual teaching methods. More broadly, the challenge for this thesis is to develop the pedagogical content knowledge of inquiry. I intend a schema of inquiry that is inclusive of a variety of ways of speaking about teaching for thinking, and that is in some way able to augment those projects. The schema will not be a challenge to extant methodologies, nor will it be antagonistic to them. It has resulted from understanding what these thinking frameworks and models have in common that can contribute to a broad schematic understanding of teaching for thinking—with the result intended to enrich these frameworks and models in turn, or at the very least make them more readily understandable and actionable, especially to teachers and other educational practitioners.

2.2 Expertise in teaching for thinking

Since expertise depends on how our knowledge within a domain is organised—how effective our representations and schemata are in recognising and solving the problems of practice—any attempt to develop expertise in teaching for thinking must involve how this knowledge organisation is to occur. Schemata contain both simple declarative knowledge and knowledge about how that declarative knowledge is applied in context as well as complex representations that are key to the essential concepts of a domain. Another way of describing schemata is that they are composed of elements, or categories of elements, and the relationships between them.

Figure 6 below shows how the knowledge of some birds and their limb structures can be understood schematically.

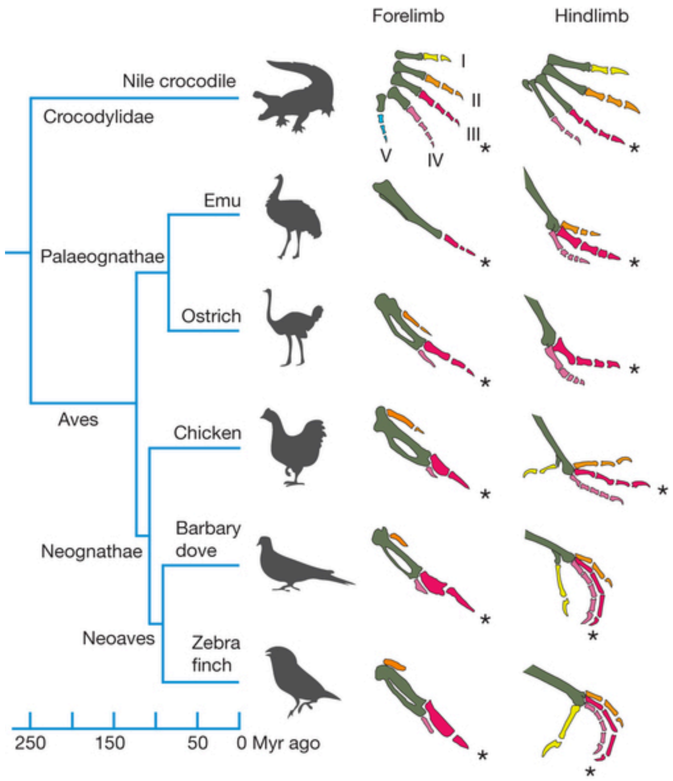

Figure 6: Bird limb skeletal structure

Source: http://www.nature.com/nature/journal/v500/n7463/images_article/nature12336-f1.2.jpg

In this representation, there is knowledge about each of the organisms but also of the relationships between them. For example, the limb structure of the Zebra finch and the Barbary dove are more similar than those of the Zebra finch and the Ostrich. This is understood as the Zebra finch and the Barnaby dove having a closer common ancestor than the Zebra finch and the Ostrich. A zoologist finding any of these bones, would be able to make better sense of them than any layperson, since, were it indeed their area of expertise, they would have such schematic knowledge available to them. (More than this, they may also have knowledge about how to distinguish between bones of birds and other vertebrates, the conditions under which such bones are likely to be found, and the ways in which certain environmental conditions degrade bones before they can be examined. All this knowledge is bound up in a variety of schemata that goes beyond what might be represented in a simple diagram and some knowledge might only be learned through experience in the field and through deliberate practice). Importantly the scientist is not expected to develop this schematic knowledge of bone relationships only through work in the field. The idea that each scientist would painstakingly recreate this knowledge from their first-hand experience is nonsense—studying the schema is an essential part of the training any scientists in that field would undertake. Consider also Figure 7 below, in which a scheme for hypertension is outlined (Harasym et al., 2008, p.349).

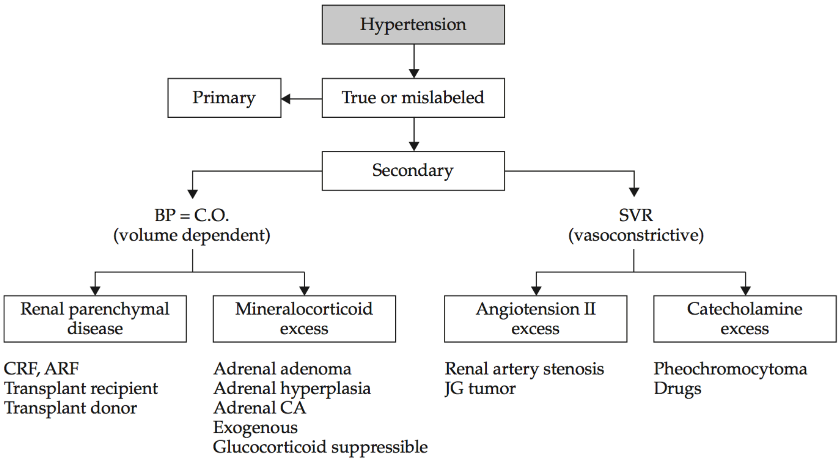

Figure 7: Hypertension schema

This schema is designed to help medical students understand how the knowledge of hypertension 'hangs together', particularly in the context of determining effective treatment. Again, the idea that a novice would need to construct this themselves through their own experience is absurd. They begin with this construct, or at least exposure to it, and deepen their understanding of it over time.

The very concept of understanding has a strong link to schematic knowledge[17]. Sweller speaks of elements of knowledge that can be learned in isolation as having low element interactivity (1994, p.304). Learning any individual element can be done in isolation from the others, and this cognitive isolation has little effect on the ability to recall the element. For example, if I ask students to learn a list of capital cities, each city stands more or less in isolation from the others—recalling one does not help in recalling others.[18] Elements with high levels of interactivity, however, "are related in a manner that requires them to be assimilated simultaneously" and are apparent "when a task cannot be learned without simultaneously learning the connections between a large number of elements" (*ibid*). I take Sweller as suggesting that there is a relationship between the degree of understanding

[17] The concept of understanding and some of its pedagogical implications is discussed more fully in Chapter Six *Pedagogical considerations*.
[18] The use of a mnemonic might help bind the elements together to some degree, helping to chunk them and reduce the need for working memory.

one has in an area and the degree to which knowledge of that area has been schematically constructed. To work on developing understanding, therefore, is, at least in part, to work on building effective schematic knowledge.

So how can we *understand* the schematic nature of knowledge involved in teaching for thinking? How can we *understand* what makes for expert performance in teaching for thinking? Why should biology and medicine be privileged by having schematic knowledge foregrounded, and why should teaching have a dearth of such experiences? Is there a diagram to draw, or a set of elements to be arranged in such a manner that the relationships between them are apparent? The primary task of this thesis is to postulate just such a thing. What follows is an attempt to articulate what things are significant in teaching for thinking, how they can be best represented and categorised, and what the relationship between these elements is. In other words, it is an attempt to outline the expert knowledge structure of teaching for thinking. But before I can proceed to that, I need to discuss what is known as pedagogical content knowledge.

2.3 Pedagogical content knowledge

Lee Shulman developed the idea of pedagogical content knowledge in response to what he calls the "missing paradigm" in teaching. The missing elements are suggested when he says:

> Where do teacher expectations come from? How do teachers decide what to teach, how to represent it, how to question students about it and how to deal with the problems of misunderstanding? The cognitive science of *learning* has focused almost exclusively on such questions in recent years, but strictly from the perspective of the learners. (Shulman, 2013, p.8)

To help understand this problem, Shulman proposed three categories of teacher knowledge that relate to content knowledge and how it can be taught in the classroom: content knowledge, curricular knowledge and pedagogical content knowledge. Content knowledge includes not only the propositions and symbolism of the discipline but also how these propositions are related to other propositions (which by definition is schematic knowledge) and how the discipline establishes epistemic credibility through its methods of inquiry. (The warrants and justifications of claims must be presented and explained through the concept of inquiry inherent in that discipline methodology. This is a decidedly epistemic approach, as well as one solidly grounded in discipline content. It is about both content and how we come, though inquiry, to know that propositions expressing that content are true. Such an epistemic focus supports the inclusion of epistemology as an essential element of a pedagogical schema, as I will discuss in Chapter Three.) Curricular knowledge is the knowledge of the range of resources (materials, people, experiments, software programs, demonstrations, readings, etc.) that can be deployed in the goal of developing knowledge. It is also knowledge about how the content currently being delivered integrates with other subject areas also being studied, and about how the current content integrates with content taught in the subject in the past and content that will be taught in the future. Pedagogical content knowledge (PCK) is more than just the other two combined, it is "the dimension of subject matter knowledge *for teaching*" and includes "the most useful forms of representations for those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others" (*ibid*, p.9). It is also knowledge of what preconceptions, including the subclass of misconceptions, students might typically bring to the subject matter and how these are best dealt with as problematic conceptual issues. While Shulman does not mention it, it would seem clear that it would also include knowledge of threshold concepts in the subject matter. Threshold concepts is an idea I use later in the thesis, so I will take some time to outline it now in more detail and suggest it is an essential aspect of pedagogical content knowledge.

Threshold concepts

Jan Meyer and Ray Land (2006) developed the idea of a threshold concept as a concept that must be understood by students to attain mastery in a discipline. These concepts are therefore specific to that discipline and require specific and deep discipline knowledge. But they are not just ideas that occupy a central place within a discipline; they are also decidedly problematic in terms of coming to understand it. It is this understanding that separates the discipline novice from the discipline expert, moving the student further into the methodology and specialist knowledge of the discipline and marking the difference between the casual understanding of the novice or dilettante and the deeper insight of the expert.

As an example, and to continue my biological theme, cladistics is a threshold concept in evolution. Figure 8 shows a cladogram (a kind of evolutionary tree) of primate evolution.

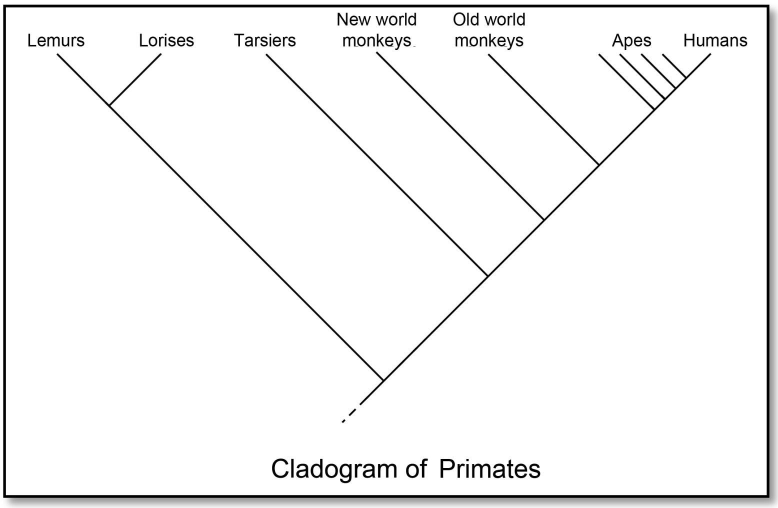

Figure 8: Cladogram of primates
(Source: https://upload.wikimedia.org/wikipedia/commons/a/a2/Primate_cladogram.jpg)

This diagram relates organisms to each other not on the basis of their shared morphology or other perceived similarity, but on shared characteristics that derive from a common ancestor and that are not present in more distantly related organisms. Understanding this allows for the realisation that any two groups of animals will have had a common ancestor. Old word monkeys and humans diverged around 25–30 million years ago, for example, at which time their common ancestor lived (Stevens et al., 2013). To go further, birds and humans had a common ancestor around 300 million years ago. Any animals that share characteristics with humans, such as hair, that are not found before this time must therefore be more closely related to us than birds. Understanding evolution in this way means that naïve questions such as 'if we evolved from monkeys, then why are there still monkeys?' are workings of the mind of a novice.

Glynis Cousin (2006) presents five main characteristics of threshold concepts, which I summarise below.

> 1. Understanding a threshold concept is transformative – it may involve a significant 'conceptual shift'.
> 2. A threshold concept is irreversible – once grasped it is retained.
> 3. A threshold concept is integrative – it exposes hidden connections and relationships
> 4. A threshold concept is likely bounded – it is 'bordering with thresholds into new conceptual ideas'.
> 5. A threshold concept likely contains 'troublesome knowledge' – which may be counter-intuitive or otherwise difficult to integrate into existing knowledge.

Consider in particular points 1, 2 and 5. Point 1 speaks of a ‘conceptual shift’ in a ‘transformative’ event. One way to understand this is that our prior beliefs sometimes need to change to accommodate the new knowledge, and perhaps change drastically, or at least include a fundamental shift to allow the new knowledge to have traction (a fuller discussion of the concept and role of in prior beliefs is presented in Chapter Three). This change in prior belief structures would also explain Point 2, that the change is irreversible. A good example of irreversibility is my own understanding that motorbikes are most effectively steered with the legs as a function of exerting force for tilt, not the hands as a function of moving the steering bar. Once that is realised it cannot be unlearned and the experience of riding is permanently changed. Point 5 can also be a problem of coherence between new information and existing beliefs. Of course, we might explain threshold concepts as something of an epistemic epiphany—the classic ‘ah-ha’ moment, if you will—and there is nothing about the above explanation which is not inclusive of this type of experience (though this experience is not a necessary one in coming to understand a threshold concept). For the case of cladistics in evolution given above, the conceptual shift described in Point 1 is that we did not evolve from current animals, we rather have common ancestors. The irreversibility of Point 2 is in seeing each animal species around us not as ancient, but as modern as we are (ends of the evolutionary branches, so to speak). The ‘troublesome knowledge’ of point 5 would be the existence of monkeys on the assumption that we evolved from them. I might also add that Point 3 is especially true of evolution, noting again the title of Dobzhansky’s essay: ‘Nothing in biology makes any sense except in the light of evolution’. Threshold concepts show that knowledge construction need not be a ‘brick by brick’ kind of process but can involve a potentially radical reconstruction of existing ideas (for more detail on threshold concepts see Bunnell and Bernstein, 2012; Kiley and Wisker, 2009; King and Felten, 2012; Meyer, 2012).

I have introduced PCK (and with this threshold concepts) because I propose that teaching for thinking contains its own PCK, including its own threshold concepts, in the same way that teaching Physics, Music, History or Physical Education each have their own PCK. PCK is part of the schematic understanding of what it means to teach within a domain, and teaching for thinking is a distinct domain. That it is its own domain is a claim I will justify by showing it has its own PCK and its own schematically organised knowledge. Before I can proceed to the chapters that do this, however, I have one final piece to bring into play: the relationship between thinking and inquiry. This relationship is important since one way I will conceptualise the project of teaching for thinking is to develop an understanding of the pedagogical content knowledge of inquiry.

2.4 Thinking as inquiry

Inquiry is a dominant theme in education and an ancient one, being famously effective in the hands of Socrates. ‘Inquiry-based learning’ is a phrase impossible to avoid in educational research (Gillies et al., 2013; Burgh and Nichols, 2011; Chu et al., 2017; Syer et al., 2013; McGregor, 2016; Kidman and Casinader, 2017), and I will not justify its large educational footprint here, but I will provide an argument for why we might see thinking as synonymous with inquiry.

Charles Sanders Peirce understood inquiry as axiomatic for progressing reason (and progressing through reason). What he calls the corollary to his rule of reason—“that in order to learn you must desire to learn, and in so desiring not be satisfied with what you are already inclined to think”—is: “Do not block the way of inquiry” (Peirce, 1899, p.48). But what can we understand by ‘inquiry’ that would show it to be as important as Peirce suggests? Peirce saw that thinking could “never be made to direct itself toward anything but the production of belief” and that beliefs themselves were things achieved to sooth “the irritation of doubt” and become in fullness “a rule of action” and “a new starting-place for thought” (Peirce, 1878). In the pragmatist tradition established by Peirce and carried through by Dewey, James, Lipman and others, inquiry is the process of moving from doubt to belief.

But simply moving from doubt to belief need not involve thinking of the sort we see as educationally valuable. Peirce, writing in The Fixation of Belief (1877), gave four paths to belief. These four paths are: tenacity, in which we hold fast to our beliefs regardless of the epistemic winds or pressures for change around us; authority, in which that which is sourced in a trusted or established authority is taken as being true; *a priori*, in which that which is intellectually or aesthetically pleasing (individually or collectively) is taken as true; and scientific, in which inductive, empirical investigation into a world with an assumed (if not actual) reality that is reliably presented to our senses in a way that is coherent to us all is the best way to determine truth. The skills involved in this last, scientific, inquiry would seem to be those best developed educationally. What also separates scientific inquiry is that, unlike the others, “no doubts of the method […] arise from its practice” (*ibid*, p. 10).

As an example of inquiry skills that would be little improved by education, there is an Australian myth that a farm dog is selected from a litter by throwing a tin can into the middle of the litter. The animals quickly scatter, but sooner or later one dog will return to tentatively sniff the can. That is the dog to keep, supposedly because it is the boldest. That dog is certainly inquiring, and certainly it will move from the “irritation of doubt” into a fixed belief about the threat level of the can, but his is not the inquiry that we see as meaningful in an educational context—it is little more that observation. The missing element that moves us from thinking as simple reaction or association into the kind of thinking marked from improvement through education is what Dewey calls reflective thinking, an “active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends” (Dewey, 1910, p.6). While Peirce’s scientific inquiry demands reflection, that reflection is part of its method. Reflection in the methods of tenacity, authority or *a priori* belief fixing can lead to doubts and therefore tensions within each of these, but scientific inquiry, according to Peirce, while clearly not free from doubt about the subject of inquiry, does not generate doubt about its method of inquiry. Lipman makes a link between inquiry and such reflective practice in an understanding of inquiry that goes beyond the broad sense Dewey gives us:[19]

> By “inquiry” I mean self-correcting practice. I do not call a behavior inquiry if it is merely customary, conventional, or traditional—that is, simply practice. But if the supervening practice of self-correction is added to that practice, the result is inquiry. (Lipman, 2003, p.178)

This is, as Lipman immediately notes after making it, a very broad definition of inquiry. Presumably tooth brushing would count as inquiry so long as we were reflective about it. But scope does not limit utility. Why would we discount determining the most effective way to brush as inquiry? As Lipman also notes, the bumbling infant exploring the world and the objects in it is engaged in inquiry, developing through this exploration the skills we value in effective inquirers in adults.

The “practice of self-correction” is a reflective practice.[20] In as much as we might call reflective thinking a necessary condition for ‘critical’ thinking, on the assumption that reflection alone is insufficient without some necessary recourse to standards and criteria that determine how improvement in practice might occur, then we see the logic of Dewey’s comment that: “The essence of critical thinking is suspended judgment [as we experience doubt and look to fix beliefs]; and the essence of this suspense is inquiry to determine the nature of the problem before proceeding to attempts at its solution” (Dewey, 1910, p.80). The type of thinking associated with inquiry is therefore reflective thinking, and the type of inquiry we engage in with students to the end of

[19] Dewey provides highly technical, symbolic definitions of inquiry in his *Logic: the theory of inquiry* (1938), but this is not helpful to the general inquiry I am discussing here.
[20] The “deliberate practice” required for the development of expertise is exactly this type of inquiry—experts inquire into their own practice.

improving their thinking is that inquiry which requires reflective thinking. But more than this, thinking for inquiry must take us into the "self-correction" of Lipman's account and so to the means by which this correction is guided. On this understanding of the relationship between thinking and inquiry we can also accept quite specific definitions of inquiry, such as requiring "comparative evaluation of competing arguments with the goal of making reasoned judgments" (Bailin and Battersby, 2015, p.123) as derived from the general conditions of inquiry outlined above.

But if we are to value inquiry, we must value doubt, for doubt is the beginning of inquiry. This has certain implications for our classrooms, as Lipman points out:

> If, then, thinking in the classroom is considered desirable, the curriculum cannot present itself as clear and settled, for this paralyses thought. (Lipman, 2003, p.21)

Lipman means that, for a thinking education, the classroom cannot simply be seen as a medium for the smooth transmission of accumulated knowledge from teacher to student. Classrooms in which things are 'settled and clear' imply an absence of doubt, hence an absence of inquiry, hence an absence of opportunities to engage in reflective thinking, and hence an absence of opportunities to improve the thinking. Logically, learning experiences inhibiting inquiry would be those in which students were asked merely to recall information, or those in which students knew the outcomes they were 'supposed' to achieve and were provided with all the steps needed to get here. Here we see one of the key differences between teaching declarative or procedural knowledge (what I called earlier 'learning') and teaching how to think: the curricula for thinking skills is not a 'clear and settled' one, but one that contains elements of uncertainty, and the classroom is one in which questions are not closed, testing simply for recall, but are open and come from both teachers and students (Cam, 2006).

2.5 Putting it all together

So far, I have set out the goal of the thesis as being to develop expertise in teaching for thinking. I have shown that the knowledge of experts is highly and efficiently organised around schema, which though grounding and explaining the reliability of superior performance of experts is not constituted by it. To produce reliably superior performance expertise is developed through experience together with deliberate, reflective practice. The pace at which expertise is attained, and the quality of that expertise is largely a function of the amount of experience gained and the quality of the feedback attained through deliberate practice. Expertise in teaching is achieved the same way as expertise in any other domain through this process, though of course the nature of the experiences, and of the consequent deliberations and actions regarding feedback are domain specific. Teaching for thinking is its own domain, though it is not necessarily one that happens at the exclusion of any other teaching domain. Let me elaborate on this point, for it is critical for the implementation of the ideas in this thesis.

In saying that I intend to develop expertise in teaching for thinking, I do not claim that that can only be done, or should be done, outside of a disciplinary context. What I will show is that expertise in teaching for thinking can neatly overlay and *complement* expertise in teaching in any other domain. The logical case for this follows from an acceptance that the primary concern of the (educational) activity in a classroom is what students are thinking. Worrying about what they are doing is only of interest in so much as it is an indication of what they are thinking. Therefore, understanding how to develop thinking is desirable in any discipline. The argument as to whether this is the most efficient way to develop discipline knowledge is of another sort, but there is evidence that focusing on thinking improves students results not just in the particular discipline in question, but across the board (see, as one example, Topping and Trickey, 2007b). How this complementarity can be achieved is discussed as the chapters are developed.

Let me now suggest what I think are some essential elements of expert knowledge in teaching for thinking and how these elements combine into an effective schema. I do not suggest this list is exhaustive, only that its members are important. There may be scope for the schema to modify or grow beyond my framing, recalling that, as I mentioned in the introduction, it is the nature of schema to develop. That these elements are important is established in the literature (as I will show when discussing them), and I do not claim that a focus on them is novel. What is less well understood, however, is how these elements can be related to each other and how they can be, through these relationships, incorporated into a broad schema that provides a platform for understanding expertise in this domain. My intention is to show how this can happen, and in doing so begin to develop the pedagogical content knowledge of inquiry.

The question of the order of introducing these elements is a necessary one, but, as with much schematic knowledge, there is no one definitive starting point. Nevertheless, since I am of a mind that how to approach the task is in some senses an epistemic project, I will begin with epistemology. The elements I suggest are essential to the broad schematic knowledge of expert teaching for thinking are epistemology, metacognition, content knowledge, cognitive skills, the values of inquiry, and virtues of inquiry. The justification for the inclusion of each, and an in depth understanding of what they are, is contained and developed in the relevant chapters. In the following chapters, therefore, I devote a considerable amount of time to understanding what the elements are and what they mean for an education in thinking.

Chapter Three: The relationship between pedagogy and epistemology

The plethora of academic definitions of 'pedagogy', and the various disciplines, social contexts and philosophical perspectives of those who write on the topic make both precision and accuracy in choice problematic (see, for example, the variety between Daniels, 2001; Boutroux, 1912; Wagner et al., 2001; Freire, 1996; Wilson and Bai, 2010). For the purposes of this section I will take the definition offered by the OED as it seems both inclusive and straightforward: "the theory or principles of education; a method of teaching based on such a theory" (Oxford English Dictionary, 2005). I acknowledge the importance of the deeper question of what philosophical assumptions drive both the theory, method and practice, but this is something I will develop within the chapter and beyond, at least in understanding the pedagogy of inquiry. For this thesis, it also means having a clear pedagogical line of sight from the actions and words of the teacher in the here and now of the classroom, though student cognitive and affective development and ending in the kinds of dispositions, virtues and appreciation of values the teacher wishes for her students in the future. Perhaps a minimally complex working definition is: 'understanding what you are doing in the classroom and why you are doing it.'

In teaching for thinking, a key pedagogical concern is establishing norms of thinking to arrive at new beliefs and new knowledge. As it involves how we might come to know things, this is an epistemic endeavour. In this chapter, I outline an argument proposed by Harvey Siegel (1989) that epistemology has a place in teaching for thinking and that, more than this, it is a necessary component. It follows from this position that, in teaching for thinking, epistemology is an essential pedagogical concern. Therefore, epistemology appears as an element of the teaching for thinking schema developed in this thesis.

I will outline Siegel's argument in this chapter in some detail and in the next section use his criteria of critical thinking epistemologies to show that philosophical pragmatism is a candidate epistemology for the teaching of critical thinking. I will then proceed by considering some potential epistemic barriers to developing thinking skills, including Bayesian reasoning and the role of narratives in forming new beliefs.

3.1 Critical thinking epistemologies

In his seminal article, Siegel (1989) established a logical argument for an epistemic component of an education for thinking. In doing so he deduced some characteristics of such an epistemology. Siegel claimed that there is an important relationship between the pedagogy of critical thinking and epistemology, arguing for two key points: first that critical thinking pre-supposes particular answers to contentious epistemological questions, i.e. that there is an epistemology underlying critical thinking; and second that these epistemological considerations are fundamental to an adequate understanding of critical thinking and should be explicitly treated in basic critical thinking courses (*ibid*, p.128)

Siegel claims that it is definitional that critical thinkers have a devotion to rationality. We would not expect a critical thinker to eschew any reasoned approach to a problem, or any methodology based on logic and argument, for example. Most fundamentally, we expect critical thinkers to have reasons for doing or thinking specific things. But having reasons for a conclusion does not of itself make someone a critical thinker; some reasons may be particularly bad. The evaluation of reasons is therefore very important in determining how well someone is thinking. But what makes for a good reason? Indeed, what is a reason? How is justification related to the use of reasons, and how does justification relate to truth? Why, in addition, is it good to be rational? Siegel notes that as soon as these questions are asked, we are on epistemological ground. They may not always be asked in the discussion or teaching of critical thinking, but they are unshakably relevant to the fundamentals of critical thinking. It is, therefore, crucial for Siegel that students engage with the epistemic issues inherent in the valuing of rationality to avoid having only a shallow understanding of critical thinking.

Critical thinkers must be able to evaluate reasons. That is, they must be able to determine whether the reason strongly or weakly supports a conclusion. Beliefs and actions of the critical thinker, in as much as they are conclusions reached, are justified by the reasons leading to them. How reasons are evaluated is therefore dependent on what criteria exist for calling them good or bad. Siegel uses the example that the proposition '*p:* abortion is baby-killing' could be a reason for accepting the conclusion that *'q*: abortion is morally wrong'. He calls this a bad reason because *p* begs the question and assumes a fetus is equivalent to a baby to bring to the argument issues of the right to life attributed to babies and adults. The proposition *'r:* a fetus is sentient and has a concept of self', however, is a good reason for accepting *q,* because we do acknowledge that this would make the fetus more baby-like and hence more relevant to claims regarding the right to life.

However, *r* is a good reason for accepting *q* only if *r* is justified. We would only have a warrant for believing that abortion is morally wrong if the assertion that the fetus is sentient and has a concept of self is itself one that can be justified. And if there are good reasons for believing that *r* is not the case, then *r* becomes a bad reason for believing *q*. In the same way, to provide my own example, that '*c:* cats are easily trained' is a bad reason for believing '*t:* cats could make useful helpers for some disabled people.' This is not a bad reason because the proposition *c* does not permit the inference to *t*, but because there is little evidence in favour of *c* being true.

Siegel suggests that a claim is justified when there are good reasons available to support it. He also suggests a reason is not good if it begs the question. In the case of begging the question, the reason is only justified if one already accepts the conclusion, which makes it untenable as an independent warrant to deliver the conclusion. What makes this an epistemic issue is that we know, and, therefore, accept that these two reasons are themselves legitimate reasons for establishing the credibility of the conclusion. What reasons might we give for accepting these criteria for being good reasons, and how would these reasons themselves be justified?

Siegel recognises the magnitude of this problem and does not attempt to provide a full answer, but he does offer some clarifying comments, which relate to the earlier examples. He notes that some criteria are quite general, applying to a range of situations and areas of study. Begging the question would be an example of this. Here, there seems to be a logical requirement to call something a bad reason that does not depend on the nature of the problem or the context in which the device is used. Logic, then, can provide a wide range of general warrants for declaring reasons good or bad. Other criteria for evaluating reasons are subject or context-specific. In the case of the fetus being sentient, some pertinent scientific knowledge would presumably be required to make the claim justifiable. To evaluate the claims of virology or cosmology, say, some discipline-specific knowledge would be essential.

According to Siegel, why we should accept logic as a guide to justifiability, or exactly how specific knowledge might better substantiate a claim, ultimately calls for an epistemic explanation. Critical thinkers not only think critically about issues, but also think critically about methodologies, and the logical implication of this is that they should also think critically about critical thinking. When we encourage students to think about the epistemic issues around what makes a reason good or bad, when they are asked to understand or evaluate the criteria for the legitimacy of reasons, we are asking them to be consistent in their thinking. Siegel does not think it coherent to ask of students that that they investigate logical, argumentative or epistemic structures of issues while ignoring those aspects of the process they themselves are applying. To ask students to apply criteria of evaluation to their own critical thinking processes is to be consistent and coherent, but it is also to be undertaking an epistemological investigation. Thus, a self-consistent critical thinking pedagogy necessarily invites students to consider epistemological questions underlying critical thinking (*ibid.* p.131).

After establishing a case for an epistemological component in the study of critical thinking, Siegel then moves to consider the nature of such an epistemology focusing on two issues: the relationship between justification and truth and epistemological relativism.

In the case of justification and truth, Siegel is clear that *q* does not have to be true for belief in *q* to be rational, reminding us that it was once rational to believe Newtonian mechanics was an accurate description of the world, i.e. that it was true, when we now know that it is and was false (*ibid*) (more charitably, and possibly in better accord with the view held by scientists, I suggest the view was incomplete). The sum of evidence available at a point in time might point towards something false being true, and just as readily point towards something true being false. Newtonian mechanics provided an example of the former, and, as an example of the latter, I offer the fact that that humans share ancestry with other animals—a proposition disbelieved on rational grounds provided by arguments based on intelligent design such as Paley's Watchmaker argument by analogy. Pedagogically, we value students being wrong for the right reasons over them being right for the wrong reasons (and so will more reliably get closer to the truth, assuming the 'right' reasons are those that more likely lead to it). Siegel concludes from this that truth is therefore independent of justification and claims this as a necessary feature of critical thinking epistemologies. There are some significant philosophical objections to this conclusion (e.g. antirealist accounts of truth), and Siegel notes several including that of Dewey, whose notion of warranted assertibility he claims is not commensurate with truth and justification being independent (*ibid.* p.132). (I explain in a following section that Siegel is in error here, and that Dewey's position is, in fact, commensurate with Siegel's requirements.)

Siegel presents a binary choice for understanding epistemologies of critical thinking: we must either show that truth and justification are independent (in apparent opposition to Dewey, in his view) or demonstrate the nature of any dependence that might exist to make it coherent with a critical thinking epistemology as discussed above. Whatever the outcome of this, however, he notes that the rational force that compels someone to a conclusion can never be guaranteed to represent all possible forces in all possible manifestations or combinations that are commensurate with the potential evidence. What we may see today as overwhelming evidence in support of a view may be shown tomorrow to be the product of a flawed paradigm, an incomplete representation of available data, or incommensurate with new information.[21] Reasons that currently seem to make a rational conclusion inevitable might be surpassed by better reasons in the future, i.e. reasons are defeasible. Whether this happens or not, at any point in time we can only pass judgment on the quality of the reasons and inferences leading to a conclusion, being unable to use the truth or otherwise of the conclusion as the ultimate validation of the argument or position. It is not that we do not consider that what is true may be attained by using good reasons and good reasoning, but our focus, particularly in an educational context, is on evaluating reasons as they stand without direct regard for whether the conclusions that come from them are true. It is, therefore, possible according to Siegel, as mentioned above, to promote the person who has good reasons for believing something to be true that is in fact false over the person who has bad reasons for believing something true that just happens to be true (again, with the assumption that students who recognise and use good reasoning are more likely to get close to the truth on a greater number of occasions than those who do not. In Siegel's words:

> […] we let the truth fall where it may, and regard the student who justifiedly believes *q*, which is false, despite the evidence in its favor, as a more successful critical thinker than the student who believes not-*q*, which is true, despite the evidence to the contrary. (*ibid.* p.133)

Siegel does not entirely forsake the connection between truth and justification, noting "claims which are rationally justified are claims we have reason to regard *as true"* (*ibid.* p.136). He notes that this focuses us on the point that it would not be rational to believe that *q* is true and at the same time believe that *q* is unwarranted. If our evaluation of the strength of a reason in support of *q* is not related to our evaluation of whether *q* is true, it is hard to see the purpose of seeking a warrant in the first place. There is no access to the truth but by uncovering reasons that, by their persuasive power, lead us to the conclusion that a proposition is true. Truth unsullied by supporting reasons is not accessible to us, or at the least we will not recognise or acknowledge it as truth. Because we do not make something true simply by believing it is true, it follows there is a possible conception of truth as absolute, removed from our attempts to reach it, existing as perhaps an endpoint of our inquiry but not influenced by it (a very Peircean notion). But we cannot separate our grasping of the truth

[21] A view that Kuhn (1970) would no doubt resonate with.

from our grasping of the warrant behind it. In Siegel's phrasing, "we 'get at' the truth by assessing warrant" (*ibid.* p.136). In my reading this is not quite tautological, since you could only explain your belief in the truth of a proposition by explaining your reasoning towards that belief.

Siegel relates the story of Galileo famously pointing the newly discovered telescope at Jupiter and seeing through the device four moons around it. It was clear to him at the time, therefore, that Jupiter had (at least) four moons. Siegel points out that opponents of this position did not have a theoretical understanding of how a telescope worked, relied on earlier justifications (from scripture and Aristotle) that Jupiter did not have moons, and hence were not at all inclined to support Galileo's assertions. For Galileo himself, seeing immediately lead to believing; for some others, this was not sufficient warrant. While what Aristotle had to say on the issue was sufficient warrant for some; for Galileo it was not. There was no agreement between all parties in this case of what constituted good reasons for accepting these particular views (including a lack of trust in the device to accurately represent reality). Recognising this difference in belief between rational participants brings with it the recognition of the need for characterisation of what makes for good reasons. If no characterisations of good reasons can be found, or indeed if no characterisations exist (about which we may be uncertain), then we are faced again with the possibility of relativism. What makes for a good reason for one person is a bad one for another, and vice versa. The quality of a reason, its contribution to the force of accepting a conclusion, is simply a function of the person judging the reason. In Siegel's view, this type of thinking is not compatible with a critical thinking epistemology.

I take Siegel's point to be that if certain warrants are equal, or at least equally ineffective as universalisable warrants, then all views derived from those warrants are worthless outside of individual selective application. If there is no universal or generally accepted mechanism by which we can evaluate reasons, a plurality of acceptable paths and therefore no preferential course in the process of concluding, then the process of augmentation degenerates into one of simple assertion, or at least reason-giving that is not rationally persuasive to others. Even if we go beyond assertion and extend to stating the reasons that supposedly justify the assertion, then those reasons themselves are nothing more than assertions, having no probative force beyond what might work for the individual for whom they are convincing. If there is nothing to criticise, nothing about which we can be critical, then critical thinking seems an empty notion (though presumably some appeal to cohesion may do). If, however, we acknowledge that some views are better than others, that some views are better warranted than others, then it falls to the critical thinker to determine the way in which this scaling and assessing can occur, and to determine the standards against which this judging is made.

Siegel gives some reprieve to the Galilean conundrum by allowing that difficulties in evaluating reasons do not logically imply it can't be done (*ibid.* p.134), and I note that history has shown what was needed to break the epistemic stalemate was more evidence and a deeper understanding of optics. This type of persistence to expand the evidentiary base rather than collapse into relativism in the fact of inconclusive arguments also typifies modern science.

3.2 Pragmatism as a solution to Siegel's epistemic concerns

In this section I will show that the epistemology of philosophical pragmatism fulfills the criteria outline by Siegel for inclusion in an education for thinking. I will develop this argument in the context of the Philosophy for Children (P4C) approach to education for three reasons. First, I do not wish to present pragmatic epistemology devoid of its educational use, as to do so would make its use as a critical thinking epistemology less clear. Second, P4C has a clear heritage of pragmatic epistemology informing its development (Lipman, 2004). Third, P4C is a well-established practice that has empirical and theoretical traction as an effective thinking program.

The primary function of the classroom community of inquiry that has become the primary pedagogy of P4C is the development and practice of a system of thought that constitutes an education in thinking (Lipman, 2003, p.103). That practice is informed by certain epistemological commitments, on the one hand, and by pedagogical commitments on the other. I will consider the relationship between those epistemological and pedagogical commitments and how, together, they constitute an approach to an education in thinking. First, I will explain that the epistemology at the heart of P4C is pragmatic, drawing on the work of Peirce and Dewey, and explain how that epistemology relates to the kind of thinking practiced in the community of philosophical inquiry. In the next section I will argue that the pragmatic epistemological commitments of P4C fulfill the characteristics that Siegel has set for any kind of education in critical thinking.

The epistemic heritage of P4C

There are a variety of disciplinary perspectives from which the classroom community of inquiry is understood and practiced (Pardales and Girod, 2006). Classroom communities may be formed around inquiry in disciplines such as history, mathematics and philosophy, and may be seen as training grounds for the broader professional disciplinary communities of inquiry to which graduates of these classroom communities can aspire (Seixas, 1993; Gregory, 2002). What these disciplinary variants have in common is a conceptualisation of education itself as a process of school-based inquiry continuous with inquiry in academic and professional communities, first developed by Dewey (2011). Dewey's theory of education was, in turn, informed by the pragmatist epistemology of Peirce. As my focus for the moment is on the connection between epistemology and pedagogy in P4C in particular, I will consider some salient epistemic points that Peirce and Dewey bequeathed to Lipman.

It is no small compliment to Peirce that he is seen by many as having offered the solution to problems raised by Descartes. This is discussed in detail elsewhere (see, for example, Gregory, 2000), but I will represent Peirce's point of view in brief in a few key ideas I choose for their pedagogical implications. Peirce does not think that systematic doubt is a mechanism by which we can dissolve uncertainty, leaving only epistemic bedrock from which we can then rebuild certain knowledge. Doubt, for Peirce, is simply a necessary fact of being in the world, so it would be nonsensical to say that we could not form beliefs or take actions with confidence unless we could first remove doubt. Peirce also employs doubt as a creative and instructive force, so that our doubt is expressed in degrees of epistemic confidence underpinned by warrants for belief. For Peirce, epistemology is not characterised by binary concerns according to which we must know for certain or abandon all presumption to knowledge. That we can and do doubt the beliefs we use to move forward in our inquiry requires that we keep our warrants strong and maintain an epistemic vigilance. Indeed, we cannot test our beliefs unless we use them as a basis for action, and once they have shown themselves reliable, we begin to ask for reasons to doubt them, rather than why we should continue to trust them (Gregory, 2000, p.47). But more than this, Peirce claims that we can never know that the beliefs we have at any moment will not be overturned in the future by better or continued inquiry. Hence, epistemic certainly is forever out of our reach and we had best make our peace with that.

Second, Peirce does not trust the model of the individual as the isolated agent of cognition, at least in as much as that cognition may lead to truth. He rejects the proposition that truth can be found in introspection for the simple reason that, were it so, a person, being convinced of the truth of a proposition, even one gained experimentally, would feel she would "have done with reasoning, and should require no test of certainty" and "thus to make single individuals absolute judges of truth is most pernicious" (Peirce, 1868, p.141). Peirce saw knowledge as derived from, and used for engagement with, the world. It was not to be found in a priori analysis, and therefore, ideas found in introspection alone could not be called knowledge. Peirce distrusted that the mind, isolated from the world and from other minds, could have any reliable understanding. He found greater epistemic confidence in the combined and coordinated inquiry of many—a community of inquiry— through which individual perspectives could be aligned into inter-subjective understandings that could approximate and approach truth and best result in the extinguishing of doubt.

> In sciences in which men [sic] come to agreement, when a theory has been broached it is considered to be on probation until this agreement is reached. After it is reached, the question of certainty becomes an idle one, because there is no one left who doubts it. (*ibid)*

The call that Peirce makes for knowledge making through the community of inquiry is a call to arms against individual prejudices in the processes of fixing beliefs. It is also a turn away from relativism since:

> Thought, controlled by a rational experimental logic, tends to the fixation of opinions which do not depend on accidental circumstances and which are independent of what anyone may think of them. (Peirce, 1905, p.628)

And

> The opinion which is fated to be ultimately agreed upon by all who investigate, is what we mean by the truth, and the object represented in this opinion is the real. (Peirce, 1878).

But we should not mistake what Peirce says about truth as a theory of truth. He simply takes the pragmatic maxim and applies it to the concept of truth — i.e. it is 'what we *mean* by truth' (see Legg, 2014 for a fuller discussion). Thus, he avoids having to stake out the ontological ground and hence can avoid the charge of absolutism.

The third epistemic point to take from philosophical pragmatism is that knowledge itself is not something that sits apart from human experience, a point championed by all pragmatists including Dewey, who articulated powerfully and in detail how we might understand knowledge, and did so in a way heavy with pedagogical implications – though he had no vision of philosophy as a methodology of education, as Lipman later did (Lipman, 2004). Dewey argued that knowledge must be arrived at, not received. He thought knowledge should not be abstracted from the process of inquiry that produced it, lest it seem more real and more certain than that process. He wrote dramatically that:

> The statements, the propositions, in which knowledge, the issue of active concern with problems, is deposited, are taken to be themselves knowledge. The record of knowledge, independent of its place as an outcome of inquiry and a resource in further inquiry, is taken to be knowledge. The mind of man is taken captive by the spoils of its prior victories; the spoils, not the weapons and the acts of waging the battle against the unknown, are used to fix the meaning of knowledge, of fact, and truth. (*ibid*, p.111)

This type of abstraction from human inquiry results in what Dewey calls the 'spectator theory of knowledge', in which knowledge is a thing to be attained rather than created, received rather than engaged with (*ibid*, p.75). Dewey sees no coincidence in the use of the word pupil to identify someone who passively receives knowledge in much the same way that the pupil of an eye simply allows light through to form an image (*ibid,* p.84) For Dewey, knowing is rather a 'mode of participation' in the world (*ibid,* p.196), a mode which is better described through an organism-environment model rather than a subject-object distinction. A subject and an object can be thought of as categorically distinct, ontologically independent and causally unconnected. Not so an organism and its environment.

I have not attempted to represent pragmatic epistemology in its entirety and complexity, only to indicate key propositions in this epistemology that have influenced the theory and practice of the classroom community of inquiry. The three key epistemic proposition I have outlined—that knowledge is fallible, that the veracity of human knowledge is warranted by a community of inquirers rather than the individual, and that knowledge is intimately linked to our being and acting in the world—are substantive enough to draw significant pedagogical conclusions. But before I do so, I will consider why a certain kind of epistemology is a necessary foundation for the pedagogy of an education for thinking.

Epistemology and Pedagogy

P4C was designed in part as an approach to education for effective thinking, particularly in its pedagogy of the community of philosophical inquiry. I have explained how that pedagogy was informed by the pragmatist epistemology of Peirce and Dewey. I will argue that the epistemological commitments of P4C fulfill the characteristics that Siegel set for any kind of education in critical thinking. As outlined earlier, Siegel argued that a particular kind of epistemology is a necessary component for any educational approach to critical thinking. Let me briefly review his case.

Siegel noted that being a critical thinker means that one's actions and beliefs are based on reasons evaluated in a rational framework, and that what constitutes 'reason' and rationality' are decidedly epistemic concerns (1989, p.127). More particularly, Siegel pointed out that "it is reasons and evidence which confer warrant and justification" to particular beliefs or actions (*ibid*, p.137), and that the relative strength of warrants and justifications depends on a determination of what reasons are good and the significance and relevance of evidence. But this kind of determination demands careful judgement, "enhanced by the skills and abilities […] constitutive of critical thinking" (*ibid*). Thus, developing effective warrants and justifications requires a process of rational justification (inquiry) and that process, he argues, presupposes three particular epistemological characteristics. In what follows I will discuss each of these epistemological characteristics and explain how each is fulfilled by pragmatist epistemology.

One characteristic of Siegel's critical thinking epistemology is that it must reject relativism: the idea that truth is relative to individuals or cultures, or that there is no principled way to distinguish among beliefs and actions that are more or less reasonable. Were relativism not rejected, there would be no sense of a warrant for belief or action that did not go beyond the personal or the communal. There could be no appeal to a higher rational court if a cogent argument was rejected or an irrational one accepted. Indeed, the entire notion of critical thinking as a method for basing beliefs and actions on sufficient reasons would become nonsensical. As shown above, Peirce's pragmatism rejects relativism and hence meets this criterion. Siegel's rejection of relativism does not imply an absolutist conception of truth, however. Each of his other two epistemological characteristics describes aspects of fallibilism.[22]

Another characteristic of Siegel's critical thinking epistemology, which might be thought of as non-absolutist, is that what is rationally justified may not be true, and what is true may not be rationally justified. Rational justification does not constitute truth in absolute or final terms. To perhaps labour the point, a student who follows a rational justification but is wrong is generally seen as a better thinker than someone who is right while accepting a poorly justified claim. Truth and rational justification are therefore independent of each other, and this independence constitutes one aspect of fallibilism. Siegel claims that this contradicts Dewey, since he claims Dewey defined truth as "warranted assertibility", thus linking justification and truth. But Dewey is using truth in a different way.

[22] It is worth noting that the rejection of relativism does not equate to rejecting pluralism, particularly since a commitment to fallibilism requires a willingness to seek and entertain other views. Indeed, while relativism may be rejected as an ultimate philosophical goal, it can be a generative starting point for evaluative discourses.

Dewey (1938) holds the epistemic credibility of any truth statement (knowledge) to be a function of the inquiry process that produced it, seeing as untenable any claims about truth independent of that process, but also, critically, that any truth claim must be subject to future revision.

> It is the convergent and cumulative effect of continued inquiry that defines knowledge in its general meaning. In scientific inquiry, the criterion of what is taken to be settled, or to be knowledge, is being so settled that it is available as a resource in further inquiry; not being settled in such a way as not to be subject to revision in further inquiry. (*ibid*, p.16)

and

> When knowledge is taken as a general abstract term related to inquiry in the abstract, it means "warranted assertibility." (*ibid*, p.16)

What's more, according to Dewey the idea that we are getting asymptotically closer to the truth as our inquiry progresses is delusional: "The conception that growth and progress are just approximations to a final unchanging goal is the last infirmary of the mind in its transition from a static to a dynamic understanding of life" (Dewey, 2005, p.35)

Hence, Dewey's views, and those of Peirce, are compatible with Siegel's principle of non-absolutism, or not conflating rational justification with truth.

Siegel's third epistemic characteristic is the other side of non-absolutism: that while the relationship between truth and justification is problematic, we can, and indeed we must, regard beliefs justified by effective warrants as *prima facie* candidates for truth. "Truth thus functions for us […] as a regulative ideal: the upshot of justification is a prima facie case for truth" (1989, p.136). Thus, though Siegel argues for the independence of truth and justification, he also maintains justification as a necessary condition for, and indicative of, truth. Significantly, when Siegel writes of truth as a regulative ideal he means that it should regulate the process of rational inquiry. No particular truth claim can serve as such an ideal, for we might not know truth separate from warrant. Rather, Siegel has in mind the very notion of truth as constructed and warranted by certain modes of inquiry. In other words, the nature and form of the inquiry that lead us to a truth claim are paramount. And, as Siegel notes, this is just another way to arrive at fallibilism (*ibid.* p.137).

Siegel's notion of fallibilism, consisting of the principles of non-relativism, non-absolutism and truth as provisional warrantability, is essentially a pragmatist notion—Dewey would simply collapse these principles into *pragmatism*, plotting a middle way between absolutism and relativism.

In summary, Siegel argues that an effective thinking education must be underpinned by an epistemology that rejects relativism, that is non-absolutist in that it sees truth and inquiry (or rational justification) as independent from each other, and that is fallibilist in taking truth to be a regulative ideal comprised of norms for rational inquiry. The rationality of the community of inquiry can provide a bulwark against relativism, even in the rejection of certitude, and its norms constitute that very kind of regulative ideal. I have also shown how the fallibilism of pragmatic epistemology satisfies Siegel's own epistemic requirements of fallibility and non-absolutism. I have, therefore, demonstrated that pragmatist epistemology constitutes a firm foundation for an education in thinking.

Methodological pragmatism

A pragmatic epistemology meets the criteria that Siegel specifies for an education for thinking, however, conscripting such an epistemology for a teaching methodology does not require any corresponding ontological commitment to it. Recall that pragmatism is defined in large part by its embracing of doubt and fallibilism. Indeed, the great generative force of pragmatic inquiry is a function of these things. But because a pragmatic epistemology demands continual vigilance and the cultivation of doubt, one might imagine the term 'methodological pragmatism' to be a truism, for pragmatism is largely a methodology. It is a methodology built on assumptions about the nature of knowledge, but the pragmatist, in cultivating doubt, must doubt also these assumptions. Hence, there is no ontological rug that can be pulled out from under pragmatism and render it inoperable. Even if there were such a rug, I suspect it would be found first by a pragmatist, in the same way that scientific errors are usually picked up by scientists. As a result, one could hold to rationalism, say, at home but be a methodological pragmatist in the classroom for the primary reason that pragmatic epistemology best cultivates the skills of critical thinking. Methodological pragmatism is also linked to the concept of evaluative epistemologies that I outline in §6.1, *The developmental nature of teaching critical thinking.*

3.3 Epistemic barriers to reflective practice

While a pragmatic epistemology, as an example of a critical thinking epistemology, is an identifiable and deliberate element of teaching for thinking, not all epistemic concerns are so subject to choice. The understanding that our domain knowledge is optimally effective when organised into highly effective schemata implies that our knowledge, as described by such schemata, must be in some way constructed. Such knowledge construction has long been an educational focus and it is informed by more than just knowledge of schemata, it also includes how our prior beliefs influence the formation of new beliefs. This view that our knowledge is not delivered to us in a form identical to the product of our assimilation, that we in some way process knowledge or build it from other knowledge elements characterises constructivism.

Broadly speaking, constructivism is the view that knowledge is constructed through an interactive process between the individual and the environment (including other individuals) or perhaps solely through individual cognition (see Phillips, 1995; Applefield et al., 2000; Gregory, 2002; Hyslop-Margison and Strobel, 2008 for some useful overviews and discussion). Exactly how this knowledge is constructed is very much an open question; suffice it to say that constructivists believe at the least that the knower and the known are intimately connected, and that the process of knowledge formation is a function of the knower—it is not passively received from the environment. This is not too dramatic a claim (we have seen this in schema construction) but for some constructivists this lack of an innate knowledge base extends also to a lack of an innate base from which to establish epistemological criteria and to methodological rules (Phillips, 1995). What this means is that not only knowledge, but also the criteria by which we recognise knowledge, and the methodologies that can create it, may also be constructed. It is central to constructivism that knowledge cannot be acquired simply by passive reception.

It is not necessary to believe that humans are born with no cognitive mechanisms or potentials to be a constructivist (we simply do not know enough about the brain to claim this with confidence), only that in *general*, our knowledge and methodologies are constructed. But this need not be limited to our individual development. The social groups that contain what we think of as the body of knowledge of a discipline may also construct this discipline specific knowledge rather than passively receive it. Hence, constructivist may focus on individual knowledge development or on the development of knowledge in large social contexts, or both. They may also consider the degree to which knowledge construction within the individual is the result of individual (as per Piaget, 1936, 1970) or social (as per Vygotsky, 1978) processes. Clearly, constructivism is a broad church.

Not all constructivism has equal educational traction, however. Kant's active construction of knowledge through mental categories is so opaque as to provide little in the way of immediate and practical advice for discerning teaching in the classroom. The constructivism of Piaget and Vygotsky however, being explicitly concerned with the cognitive development of children, has immediate relevance and significance. Certainly, for these latter two, and for the constructivism of Dewey, whatever the process of new knowledge creation it involves the dynamic interplay between old and new knowledge. Perhaps it is precisely because certain constructivist theories have an emphasis on the nature and structure of pre-existing knowledge, and the mechanisms by which these can be modified or overturned by new information, that these are the ones most relevant to educational and developmental theorists. Old knowledge, or what we might call prior beliefs, are central to the three latter theorists' accounts of knowledge formation (Hyslop-Margison and Strobel, 2008, p.75).

It is reasonable, and consistent with the findings outlined in previous chapters, to view existing knowledge as not simply sitting in a database of facts, indexed and accessible as required by the mind, but rather organised into structured systems. Piaget, predating Glaser, first named these structures schemata and, however they may be realised, they seem to have an inertia that resists structural change. He noted that a schema is a "cohesive, repeatable action sequence possessing component actions that are tightly interconnected and governed by a core meaning" and "every schema is thus coordinated with all the other schemata and itself constitutes a totality with differentiated parts. Every act of intelligence presupposes a system of mutual implications and interconnected meanings" (Piaget, 1952, p.7). Plucking on one schematic thread (with an epistemic finger), therefore, can have a significant effect on the whole web. The more radical the potential shift in views and the more significant the rearrangement of our knowledge structures, the more resistant we seem to be to change (Flavell, 1996). For experts with highly organised schemata, this could be problematic. Hugo Mercier notes that "if an expert is able to conjure more arguments for her point of view than a layman, she's likely to end up even more polarised and overconfident" (2011b, p.317).[23]

This constructivist notion of prior belief, and of this belief being resistant to change through the epistemic inertia inherent in complex schemata, is consistent with Bayesian reasoning, generally

[23] Experts may be saved, however, by their dedication to deliberate practice as outlined earlier. Such reflective behaviour would presumably provide some degree of protection from what I might call 'proof by overwhelming citations'.

seen as a rational model for modifying our beliefs about the world (Hahn and Oaksford, 2007; Zenker, 2013; Cohen et al., 2017; Tenenbaum et al., 2014; Hornberger, 2001). I will explore Bayesian reasoning below, as it attempts to place the idea of prior belief into a model of decision-making that will also be useful later in this thesis.

Bayesian Reasoning and prior beliefs

Our belief construction must be more than the algorithmic processing of information to reach objective truth. If we were such simply described algorithmic truth-seeking devices, then by this stage we would all have reached the same conclusion about everything (assuming the same inputs). As this is evidently not the case, other factors must be in play. We know from psychology that thinking is at least as much something that happens to us as it is a consciously controlled process (Tversky and Kahneman, 1981) showing that there is a need to understand what particular cognitive topography might cause our thoughts to end up in one place rather than another. This is an epistemic concern since it influences how we come to think we 'know' something to be the case.

Bayesian reasoning provides a useful methodology for understanding how our decision-making occurs in so much as it shows how our existing belief systems interact with acquired information to give credence to a new belief. In a Bayesian system, the fact that each of us starts from a personally unique belief system, a product of our own fingerprint-unique schematic webs, goes some of the way towards explaining why we process information differently and hence arrive at different conclusions.

By way of explanation, let us say that some evidence, E, is presented that a proposition, H, is true. Bayesian reasoning, or Bayesian inference, allocates a weighting to the belief that H is true given E as a function of two things: the likelihood of H being true *before* seeing E, and the perceived strength of the connection between E and H. When calculating a probability using Bayesian reasoning,

$P(H \mid E) = P(H).\frac{P(E / H)}{P(E)}$ where

1. $P(H \mid E)$ is the probability of H being true given E
2. *P(H)* is the probability of H being true before seeing E
3. $P(E \mid H)$ is the probability of E given that H is true

4. $P(E)$ is the probability of E occurring

Note that the combination of 3 and 4 in this way provides us with a measure of the strength of the connection between the evidence and the hypothesis. For example, if H implies E, and E is unlikely, then this strengthens the case for H, given E. If other propositions also imply E, the case for H is weakened.

This is mathematically clear as a means of determining probability, but it also reflects a mental process for arriving at new beliefs. Crucially, this process is entirely rational. Hence, two rational people may arrive at different conclusions given the same evidence, as their prior beliefs may differ. While both may accept E, there may be disagreement over how likely E is to occur, whether H is necessary or simply sufficient for E, or whether H is both necessary and sufficient for E. Variation in any of these will result in a change in the value of P(H|E), which is in this context the likelihood of a person adopting a new belief, H, based on E.

An example will help. Consider a paper claiming a correlation between two factors, say a specific diet and a specific health outcome. Further, this correlation is claimed to signify an underlying causal connection. In this hypothetical paper, the evidence E is the claimed correlation. The Hypothesis H is the claimed causal relationship. The conclusion is that $P(H \mid E)$, the probability of the causal connection given the correlation, be given a high value. What we can see from our initial general discussion is that the assigning of $P(H \mid E)$ is conditional on other aspects of the situation. The first is the prior belief in the likelihood of the casual connection being true. This is $P(H)$. The second is the strength of the connection between the correlation and the casual connection. This is $P(E \mid H)/P(E)$. Let us explore how these might differ between two readers.

The prior belief in the probability of H being true may be a result of the existing knowledge of the reader. Someone well read in the area may have had a long-standing suspicion that H may or may not be the case. Someone working in an allied area may have insights that could influence how likely H seemed. Being versed in the theoretical aspects of the claim, having access to a range of evidence, and skill in the evaluation of evidence and methodology from past research could all affect how the likelihood of H was perceived prior to reading the paper. A good paper will attempt to address many of these issues, in effect placing readers as much as possible on an equal footing in terms of prior beliefs; however, doing this so comprehensively as to exclude variation is in practice challenging.

The perceived strength of the connection between the evidence and the hypothesis, in this case the casual connection explaining the correlation, may vary with coherence with accepted wisdom, the ability to falsify the claim, the power and precision of the theoretical model, limits of theoretical knowledge and so on. The likelihood of the evidence, in this case the correlation, may be influenced by methodological factors such as sampling techniques, data selection and use, statistical analysis and correction for other variables, and ontological factors such as theoretical possibilities and succumbing to the false cause fallacy.

Different prior beliefs result in different processing of inputs. It is therefore not surprising that we see different conclusions between decision-makers faced with seemingly the same or similar inputs. For example, in the case above where it is important to determine the exact theoretical relationship between E and H the precise nature of the correlation (linear, inverse, power, etc.) needs to be understood, which may in turn depend on factors such as appropriate data selection and statistical analysis; in deciding whether to accept H, its cohesion with existing theories must be considered; whether positing H complicates or simplifies the overall picture needs to be made clear. Of course, these values are applied from an individual knowledge base; hence both differences in knowledge *and* how these differences impact the application of values are important.

Bayesian reasoning provides a rational model of how knowledge is actively constructed; it also indicates that prior beliefs have a role to play in how decisions are made. These prior beliefs are what Hyslop-Margison and Strobel call 'epistemologically persistent" (2008, p.78) in that they act as inertia against change. Prior beliefs may be specific to tightly defined propositions, for example that a specific scientific or social hypothesis is true or false. They might also represent a large and encompassing world-view, for example a specific political or religious ideology. While the origin of some beliefs can be seen as an outcome of Bayesian reasoning, there is no reason to suppose that this is the only mechanism for producing belief, and many reasons to think that it is not. A full discussion of the creation of belief outside of rational processes, however, is not the focus of this thesis and it is only necessary to consider here that prior beliefs do exist, that they can be created rationally (using a Bayesian model, for example), and that they have an inertia that opposes change. There are several reasons why this persistence is significant, and it is worthwhile outlining some ideas for use in the model to be developed in Chapter Six.

Narratives

In a seminal paper on the topic, Craig Anderson, Mark Lepper and Lee Ross (1980) demonstrated belief perseverance in the face of discredited information and suggested a mechanism by which this occurs. The authors begin by noting anecdotally how often conversations whose goal is to change someone's mind by presenting evidence in support of a position so often fail to do so. They consider the proposal that "…our beliefs are less responsive to empirical or logical attacks than they 'ought to be'…" (*ibid*. p.1037). Experimentally, they explore an extreme situation in which subjects form a belief based on information that is later revealed to be false. The experiment demonstrates that this belief persists in the face of full knowledge by the subjects that it is false. It also provides a key experimental insight into why this might be the case. I will briefly outline the relevant aspects of the paper below.

The goal of the authors is worth repeating in their own words

> …we sought to demonstrate that perseverance effects may occur even when subjects' theories are initially based on minimal, and indeed logically inadequate, evidence—when their beliefs are of exactly the tentative, hastily-formed, and ill-founded variety most likely to face subsequent logical or evidential discrediting in everyday experience. By focusing on tentative social theories, the studies to be reported attempted to examine the perseverance of beliefs that may occur even in the absence of strong emotional or behavioral commitments, or logically compelling prior evidence. (*ibid,* p.1038)

They also devised a test for a potential mechanism for this phenomenon.

> This process involves the formulation of relevant causal scripts or explanations, and derives from people's propensity to seek or construct explanations to account for salient events or relationships among events that one has noted. (*ibid,* p.1038)

In other words, the authors determine that belief perseverance is occurring, but also suggest that developing a casual account of the belief is sufficient to transcend the elimination of the evidence that caused that causal account to be created in the first place.

Briefly, subjects were given information about the propensity for risk taking by firefighters and a correlation between this and the supposed success of the individual as a fire fighter. Some were told that those individuals who were comfortable with risk taking were successful firefighters, and others were told that those who were of a more cautious disposition were successful. In each case, the information was without grounding in data. Subjects were asked to create an explanation as to why the suggested correlation existed. It is easy to imagine typical accounts of firefighters who take risks being more willing to engage with dangerous situations and perhaps in doing so save lives and property. It is equally easy to imagine that a wise, cautious firefighter would take more effort to control a dangerous situation and not needlessly risk lives, sticking to hard-won knowledge about the best procedures to follow in a given set of circumstances.

After subjects had created their explanatory account they were informed that the data on which they developed their account was fabricated, and that the researchers had no knowledge of any actual correlation. They were then asked to undergo testing that indicated whether their initial beliefs about the correlation were maintained. Despite knowing that they had made their accounts using discredited information, the subjects maintained the belief expressed in their initial explanation. Moreover, after analysis of the explanations, a stronger persistence of belief was evident in those subjects who had created an account that was not just a restatement of the connection suggested by the researchers but involved a causal explanation. Further experimentation designed to answer questions concerning the magnitude of this effect were conducted, showing clearly that the creation of such an explanatory narrative is highly significant in belief perseverance.

The authors draw three distinct conclusions from their results, which I paraphrase below.

1. People will create and maintain beliefs well beyond what is logically warranted.
2. Beliefs may continue to exist once the evidence on which they were formed has been shown to be false.
3. The strength of belief perseverance may be influenced by causal explanations that develop an explanatory framework for the evidence even when the evidence is falsified.

I note that belief perseverance is not necessarily an undesirable thing — the inertia it supplies can be a stabilising influence. Consider that much of the information we process on any given day may have some epistemic uncertainty about it. It would be irrational to change our beliefs without engaging in a period of epistemic evaluation or to suspend judgment until confirming information was received. We need to be able to 'park' new data even as we entertain the implications of accepting it. Even when information that cannot be falsified contradicts a prior belief, we may simply file it away for later consideration. An interesting example is the recent speculation among some scientists that neutrinos travelled faster than light. Einstein had long since established a theoretical framework, according to which the speed of light is the fastest possible speed. This has been a fundamental belief of scientists since his time. The evidence of superluminal travel was greeted with some scepticism and has since been shown to be faulty, notably in a paper titled 'Can apparent superluminal neutrino speeds be explained as a quantum weak measurement?' (Berry et al., 2011). The abstract from this paper reads, in full, "Probably not."

Clearly some resistance to change can be epistemically useful. As Anderson, Lepper and Ross note:

> In any given case, therefore, the rationality of such changes will depend on the status of the individual's own prior beliefs and of the evidence and reasoning that originally underlay those beliefs. (1980, p.1046)

The authors show that creating a causal explanation for phenomena can result in a persistent belief beyond that which would be justified by data alone. It is clear from their work that the causal explanation itself has persuasive power, becoming "largely autonomous" from the evidence that initially spawned it (*ibid.* p.1046). I will add that it seems evident that the causal explanation, as the warrant for the belief, must now itself become a belief. Indeed, since the evidence from which the explanation was created has been discredited, all that remains is the coherency of the explanation (assuming the individual has not found other supporting evidence for the belief, of course). We must consider that this gives rise to a loop from which there is no exit. If the evidence has been discredited, then it can be reaffirmed anew by the explanation. This is easily the case if, as in the study above, the researchers have admitted that they are ignorant of the actual correlation. The subjects, then, would perhaps feel justified in holding a view based on their explanations. In cases in which the evidence is less easily dismissed, a strong explanation may be used to manufacture hypothetical cases that could stand against the proffered evidence. Overall, it is a kind of creation *ex nihilo*.

I have already suggested that prior beliefs in Bayesian decision-making may be of many kinds, from narrow hypotheses to broad world-views. For example, in deciding how efficacious a drug treatment is I might hold a narrow hypothesis about its likely mechanism of action; in considering capital punishment I might hold a broad view that killing of humans is to be avoided on moral grounds or in accordance with a religious position. I might hold the narrow view that soft phone cases are superior to hard ones and the broad view that libertarian principles are the best for the pursuit of happiness. This is an artificial dichotomy, but it makes the point that there is variety in what stands as prior beliefs (as opposed to *a priori* beliefs) moving into decision-making and the processing of new information. To encompass this range of belief I will use the term 'narrative' to stand for causal explanation (in the sense used above). I do this because 'causal explanation' seems inadequate to represent a broad religious or ideological position (parts of which may not be causal), and while 'narrative' seems a bit grand for the tale of a simple hypothesis, the meaning can remain commensurate.

Here I am assuming, following Anderson, Lepper and Ross, that it is the narrative having overall explanatory power that is the dominant factor in belief perseverance. The sense in which an explanation can be causal is not exhausted by material explanations and may be the result of adopted or learned views; it may be a cultural norm or a personal preference. In the case of whether high or low risk-taking behaviour makes for the best firefighters, it is possible that a subject will associate physical strength with bravery and bravery with high-risk behaviour, and from physical strength conclude that the form of the ideal firefighter is one with the highest risk-taking propensities. This could be an association formed by personal experience, and hence is not directly causal but could be used as a reason to justify the decision. Assimilating physical strength with risk-taking could be associative without being causal but could still be an explanation that contains reasons (albeit unconvincing ones). The use of the term 'narrative' allows for the possibility of many prior beliefs contributing to a single position as prior in a Bayesian sense. Let me then rephrase the Bayesian condition as one with existing narratives that may encompass one or many prior beliefs, some or all of which (prior beliefs) could be an explicit part of a decision-making process.

Construction and non-construction

The importance of considering narratives in this section on constructivism is evidenced by the following example of meaning making in the construction of knowledge. Imagine that we find, through direct experience or through probes of radio communications from deep space, that life exists outside our solar system. The propositional content of the phrase 'life exists outside our solar system' is reasonably straightforward. If there in understanding exactly what life is, then replace the term 'life' with 'intelligent life able to communicate with us'. This positions the situation more directly and perhaps removes quibbles about the exact chemical nature of life. In hearing that 'life exists outside our solar system' we add to our knowledge. We did not know it before, though we may have suspected it, but we know now with certainty. So, what has been constructed? One way of considering this is to imagine how this fact would impact on our understanding of who and what we are. We could no longer claim the distinction of being the only place in the universe in which life was known to occur. We could see ourselves biologically as part of an evolutionary narrative that suggested life was more common than we might have supposed. Our relationships with other species might be re-evaluated. The religious connotations would be significant, perhaps rendering some world-views logically untenable. Depending upon the sophistication of the new life forms, we might see ourselves not as an advanced species in command of the natural world but as children just beginning to learn what is possible. Our sense of community would expand outwards and perhaps engage the notion of interstellar society.

This is all speculative, but what is clear is that all of these implications are possible ways in which individuals may have to rewrite their existing schemata to accommodate the new information. While the fact of extra-solar life is simple to comprehend, the meaning for the individual associated with its assimilation is a function of existing world-views and the impact this new information has on them. Meaning, in the sense of how this is relevant and significant to the individual, is created with the acceptance of the new knowledge. As the meaning and the knowledge are not separate within the individual, the restructuring is entirely consistent with a constructivist view of knowledge.

The impact on existing world-views of the discovery of extra-terrestrial life would profoundly alter some narratives. Indeed, the impact may be so severe that the evidence is rejected to maintain the integrity of the narrative, an extreme example of the inertia of prior knowledge. Examples of this rejection of evidence to preserve a narrative include the denial of climate science, which is known to be a function of political and religious background (see, for example, Kilburn, 2014) and hence subject to issues of narrative integrity and cohesion. The construction of knowledge is, therefore, not just subject to manipulation by existing narratives (prior beliefs) it is possible that these narratives may block the assimilation of some knowledge entirely, preventing the Bayesian switch from being thrown at all (in effect, setting P(H) too close to zero).

I have mentioned above that there are two main factors involved in the Bayesian reasoning model, one being prior beliefs and the other the strength of the connection between the new evidence and the new belief. Recall the Bayesian model is represented by

$$P(H \mid E) = P(H).\frac{P(E / H)}{P(E)}$$

$P(H)$ represents the strength of the prior belief and the connection between the evidence and the new belief. Given that prior beliefs have inertia against change, the model itself present a mechanism for preserving prior belief. A very low initial belief *P(H)* in the hypothesis requires a very convincing contribution from the evidence linked to the hypothesis

$$\frac{P(E/H)}{P(E)}.$$

If we consider the prior belief as a narrative that has persuasive power it can act against the acceptance of the connection between the evidence and the hypothesis to preserve itself. It can logically do this in two ways. The first is the outright rejection of the evidence as flawed or invalid. The second is to reject the connection between the evidence and the new hypothesis. I suggest that the addition of the need to preserve a narrative, changes the way in which we might understand Bayesian reasoning in the practice of decision-making. The preservation of the narrative can become an active need rather than simply supplying inertia by virtue of its extant epistemic mass. An example may help.

Consider providing a person, let me call him Maurice, who has a low prior belief in anthropogenic global warming (AGW), with some new evidence of AGW. Imagine also another person, let me call him Tim, who has a high prior belief in AGW receiving the same evidence. I will explore the potential thinking of Maurice through a Bayesian lens.

I might first ask why Maurice has such a low prior belief in AGW. There are many possible reasons. Perhaps he has simply not read the relevant science and is unaware that such a thing as climate change exists. Perhaps he has heard of climate change research, but believes the evidence of his own experience, through which he has noted no discernable change in weather patterns in his immediate environment. Perhaps he is well aware of climate research but believes that scientists are engaged in a conspiracy to perpetuate a hoax for the purposes of centralising control of global resources through the United Nations. For each of these scenarios, there could, in theory, be an equal strength of prior belief against AGW. But as we move through the three example positions, what can potentially increase is the determination to maintain the prior belief against any epistemic force for change. In other words, the opposition to change moves from a passive structural resistance to an active process of narrative preservation. Following from ALR, the narrative has increasing epistemic authority over new information.

An implication of this active resistance to assimilate new knowledge is that for those seeking to persuade others towards or against a specific view, it would be useful to cause people, or at least help them, to construct narratives to that end. This could be achieved by explaining that scientists were engaged in conspiratorial behaviour, that the peer review system in climate science was deeply flawed, that the number of scientists not accepting AGW was much larger than it is, or that the United Nations is in the process of orchestrating a global takeover of sovereign states. Alternatively, narratives can be spun about scientific incompetence or media bias in presenting scientific findings. This explains why so much effort has been expended by those with financial or political reasons to oppose the science of AGW to provide evidence against it (Oreskes and Conway, 2010). If people have reasons not to change an initial view, then change is less likely, even if evidence for change is strong. In the case of Tim, who has a high prior belief in AGW, it is far more likely that he will accept the new evidence, as it coheres with his existing narrative.

3.4 Socially distributed cognition

According to Ilias Karasavvidis (2001), it has historically been the case that 'the individual is used as the unit of cognition' (p.13). From Socrates to Descartes knowledge has been seen as the output of the mind in action; one cannot imagine a clearer declaration of this than *cogito ergo sum*. The shorter but just as influential history of psychology has also focused on individual cognition, locating it in the brain and studying it in isolation. Karasavvidis notes how much of psychology is concerned with uncovering cognitive process through experiments designed to focus on cognitive skills and functions in situations without context or meaning to the participants[24]. An assumption (and perhaps conclusion, to beg the question) of this disconnect between use and function is that the human mind is regarded as the 'locus of all cognition and intelligence', operating in clinical disregard for environmental inputs (*ibid*). An alternative view of cognition, distributed cognition, removes this locus from the mind and expands it out to include aspects of the material and social environment.

Distributed cognition is not of itself a theory of cognition but is rather a perspective on how cognition may occur by allowing environmental inputs to be part of the functioning of the brain during cognition (Resnick et al., 1991; Hutchins, 1995; Menary, 2010). Instead of the intuitively obvious conclusion that since the brain is encapsulated and limited in space by the skull so too must

[24] A view made by Dennett (1989)

our thinking be limited in space within the same boundaries, distributed cognition considers the system of which the brain is only a part of the location of cognitive processing. There are at least two ways in which distributed cognition can be understood. The first of these is materially distributed cognition.

Materially distributed cognition is evidenced by the use of tools that aid our cognitive processes. These tools can, but need not be, complex ones. Anything that helps scaffold our thinking, that holds a kind of working memory for information as it is being processed, or that guides our processes can be a tool. Calculators are an obvious tool for aiding our processing of mathematical information, as are notebooks for holding working memory or referring to guides, clocks for structuring and sequencing, GPS systems for navigation or keyboards for delivering our thoughts into written form. Cognition can also use the natural environment to mark and guide thinking, as in the case of Micronesians navigating for many days using stars, ocean tides, winds and sea bird movements to help position themselves and determine their progress. Many of the tools that we use on a daily basis are so taken for granted that they fade from our conscious awareness and contribute to the impressing that out thinking is done entirely in our own heads. Many tools, such as maps, are so useful to us precisely because they have stamped onto them the previous reasoning of their creators. They are not items without inherent cognitive value that simply exist as a companion to our cognition; they are a part of it and make our cognition greater because of their internal rationality. They are fully formed subroutines in the machinery of our thinking.

It is not just elements of the external world acting as passive holders of information that leads to a conclusion of materially extended cognition. Clark and Chalmers (2010) point out that there are times when we change the physical environment in such a way that the process of change becomes part of our cognition. The change is not a rearrangement of material to hold information, as a repository for working memory, but to assist in the act of cognition. It is an "epistemic action" (*ibid*, p.29). Epistemic actions can be contrasted with pragmatic actions, whereby the material environment is altered for some instrumental end. Epistemic actions are part of the cognitive machinery above simple acts of information holding. As an example of an epistemic action, Clark and Chalmers give the act of rearranging scrabble tiles in searching for a word to fit the game in progress. The reordering of tiles in the tray from which letters are selected to make a word is not done as an aid to working memory; it is done without a clear output in mind and is better understood as part of thinking, wherein the tiles themselves "are just as causally relevant as typical internal features of the brain" (*ibid.*, p.30).

There is, perhaps, an evolutionary significance to this way of thinking. It may be that our brains have evolved to utilise and seek opportunities in our environment to help ease our cognitive load. This easing may be through the regularity of behaviour or spatial relationships between physical structures contributing to our working memory or even through reforming problems so as to best solve them using environmental manipulation through epistemic action. While this is speculative, it provides a plausible (though not necessary for this thesis) account of evolutionary pressures contributing to the success of materially extended cognition.

Cognition may be extended in ways that go beyond the merely physical. It is also possible that we might make use of the cognitive mechanisms of other people and create a system of cognition that has a shared locus of activity. Clark and Chalmers suggest language as a means for this coupling with others to occur (*ibid*, p.32). Cognitive connections with others can of course simply be a matter of recalling or resourcing information held by them which in turn feed into our internal cognition. But it can also be imagined as a more complex procedure, in which there is a genuine interplay of thinking wherein ideas can be formed and conclusions made that would not have been able to be reached in isolation.

It is easy to provide examples of tasks in which social cognition could be seen to be a central characteristic. Karasadivvis (2001, p.16) gives learning to read as an example of a massively extended process, involving not only the books on which the child practices, but also the communication and monitoring that occurs between the child and the teacher. The growth and regulation of the ability to read is critically dependant on both materially and socially extended cognition. School children and university academics both employ peer review, discussion and feedback to better improve outcomes through social interactions that enhance cognition.

Vygotsky makes it explicit that knowledge is constructed socially (Vygotsky, 1978). In his view, early experiences of social collaboration and knowledge forming are used to develop understanding and consequently internalised for later use in private application. It is not that accomplished thinkers cannot act in isolation, but the mechanisms by which they do think in isolation were laid down in social contexts and developed through social interactions they have successfully internalised. Recall that materially extended cognition may not be recognised as such because the use of the material environment has been so thoroughly automated and pervasive that its presence in our cognition becomes taken for granted and unremarkable. So too the argument could be made that the social origin of our effective cognition has been lost as we develop, and what seems to be the smooth operation of our internal cognitive machinery as an outcome of a mature mind in which the parts have been properly developed and positioned is in fact a legacy of early developmental collaboration; a legacy that includes a history of socio-cultural influence but also one that has shaped a mind functioning so smoothly in its social cognition that it seems to operate in splendid isolation. As an analogy, driving a poorly built car over a rough dirt road leaves no room for ignorance of the interplay between road and driver, but driving a well-designed four-wheel drive over the same road might lead the driver to imagine that it was all about her skill, forgetting the impressive technology that provided such a smooth ride.

An implication of accepting distributed cognition is that it is problematic for traditional cognitive science to consider individual minds in isolation from the environment in which they are operating, both material and social, imagining that the system properties are those of the mind alone. Moreover, cognitive outputs seen without regard to their environmental influences could be misrepresented as flawed or incorrectly operating. A bit like a dog attempting to run when picked up, or a fish trying to swim when placed on the ground, the process seems pointless or maladaptive.[25] I think there is an echo of Dewey here. The organism-environment distinction he uses in place of the traditional subject-object dichotomy is one that attempts, above all, to connect knowledge to the knower through organic inquiry. If we adopt his abhorrence of knowledge abstracted from inquiry, it leads to some sympathy with the notion of materially distributed cognition as one of the pathways to unifying the two.

While materially extended and socially extended cognition have significant roles in education, social extension relates most strongly to this thesis (but not necessarily to education in general) for two reasons. First is that socially constructed knowledge is explicitly linked to social cognition, a conclusion that sits well with pragmatic views of knowledge and inquiry and with constructivist theories of knowledge formation. Second is my claim that social cognition is a critical factor in the normalisation of how the values of inquiry are applied in critical thinking (an application that will be explained in detail in Chapter Five, *Skills and values of inquiry*).

3.4 Putting it all together

I have outlined in this chapter the value of including epistemology as an element of a schema of teaching for thinking. I have also shown that pragmatism can provide a fit for Siegel's criteria for any epistemological component of an education in thinking. I have also justified including a broader

[25] A view shared by Dennett (1989)

range of epistemic issues such as Bayesian reasoning and the role of narratives in belief formation, pointing to their significance in how we come to form new beliefs, or, as Dewey (1910) would have it, how we think. The additional epistemic foci I mention here do not exhaust the list—I have simply included them for their ubiquity and prominence. There are a vast number of additional cognitive biases and heuristics that impede clear thinking, but these are too many to mention here (see Kahneman and Tversky, 2000; Stanovich and West, 2000 for examples). What binds the ideas of this chapter together is the necessity to engage with epistemic issues in considering teaching for thinking. It is one thing to have a framework, such as methodological pragmatism which can guide inquiry through questioning and challenging of assumptions, it is another to recognise some of the mechanisms and powerful effects that influence how we come to new beliefs. Therefore, we now have both normative and descriptive epistemic accounts of inquiry, the understanding of which is essential for the pedagogical schema of teaching inquiry. But epistemological understandings do not arise fully formed in the minds of students. They are developed as students advance and as a result of learning experiences, if not the learning intentions of teachers. A discussion of how of epistemic stances influence students' views of knowledge, learning and thinking, including metacognition, is presented in Chapter Six, *Pedagogical considerations*.

Chapter Four: The importance of metacognition for critical thinking

Having established the value of epistemology as an element of any schematic approach to developing expertise in teaching for thinking, in this chapter I continue building the schema to include metacognition. One reason metacognition is important is that it provides an understanding of what is involved in deliberate practice, that essential component of developing expertise. Since deliberate practice is a reflection on what we are doing, what we have done and what we ought now to do, it is entirely metacognitive in nature. Developing expertise, therefore—and especially in those domains with complex intellectual skills—demands metacognition. But developing thinking skills in students, and the greater project of establishing for them the norms of effective thinking, also demands that they consider the same set of questions regarding their own thinking. Metacognition is therefore essential in the development of expertise in teachers who wish to teach for thinking and for students who wish to improve their thinking. It is therefore also an essential component of schematic knowledge in this domain.

Philosophers have had much to say about education, and educators have had much to say about metacognition. Philosophers too are arguably experts in metacognition, if we understand the term as thinking about thinking. But while philosophers have concerned themselves with reflective and critical thinking for millennia, they have not treated metacognition in a pedagogical context by name or in detail. Such a pedagogical focus is a relatively modern phenomenon. Dewey did not have much that was positive to say about examining thinking as metacognition in an educational context, and indeed seemed antagonistic to it.

> Just in the degree in which they [students] are induced to be so aware, they are *not* studying and learning. They are in a divided and complicated attitude. Whatever methods of a teacher call a pupil's attention off from what he [sic] has to do and transfer it to his own attitude towards what he is doing impair directness of concern and attention. Persisted in, the pupil acquires a permanent tendency to fumble, to gaze about aimlessly, to look for some clew of action besides that which the subject matter supplies. (Dewey, 2011, p.104, italics in original).

It is interesting that Dewey does not consider thinking about learning as 'subject matter'. This is curious because he promotes thinking as "the method of intelligent experience" (*ibid*, p.91). Given that he sees "thinking as method" (*ibid*, p.91), and that he speaks against separating subject matter and method, recognising “the essential unity of method and subject matter” (*ibid,* p.188), it might be thought that, as one thinks about a subject matter such as the problem and the resources and materials at hand, one should also include the thinking brought to bear on the problem as worthy of attention. But, for Dewey, thinking is not what we understand as metacognition, but understood as subject matter itself in that it is engagement with subject matter in an intelligent way.

> Thinking is thus equivalent to an explicit rendering of the intelligent element in our experience. It makes it possible to act with an end in view. It is the condition of our having aims. (*ibid*, p.87)

Also

> …the measure of the value of an experience lies in the perception of relationships or continuities to which it leads us. It includes cognition in the degree in which it is cumulative or amounts to something, or has meaning. (*ibid*, p.84)

For Dewey, then, thinking is not about analysing the capacity for reason into its constituent elements and then training those elements. It is about using those elements in a meaningful way to achieve an aim. The experience of using those elements is thinking, and it is this experience that counts as subject matter. While this is a valuable conceptualisation in my view, this is not metacognition as we speak of it in education today.

But if we follow Dewey to Lipman, who, as I pointed out earlier, was more concerned than Dewey about philosophy as a methodology being present in the classroom, we find a different view. Lipman was concerned to more explicitly understand what kinds of thinking were going on in the minds of students. In Chapter One, I spoke of Lipman’s division of thinking into inquiry, reasoning, conceptualisation/information-organising and translation. I also spoke of critical, caring, creative and, more recently, collaborative thinking as kinds of thinking, if not cognitive categories. Lipman also sharpened his focus to the kinds of cognitive skills that are involved in critical thinking (2003, see especially Chapter 10: Education for Critical Thinking), noting and applauding the work of Siegel, for example (*ibid*, p.61). He was also instrumental in producing “The Delphi Report: Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction” developed by the American Philosophical Association (Facione, 1990). This report attends in detail to a range of cognitive skills, examples of their use, and their value in educating for critical thinking and explicitly includes references to metacognition. I take from Dewey the value of the experience of thinking, and from Lipman and others the value of articulating the skills of thinking. Some of these thinking skills include what are also known as cognitive skills, and these will form another important element of the schema for teaching for thinking and will be developed in Chapter Five.

In this chapter, however, I focus less on the set of cognitive skills often thought of by educators and philosophers as being constitutive of critical thinking (inferring, analysing, evaluating, justifying, etc.) and more on the role of metacognition in thinking critically. Metacognition, as I mentioned, is often elucidated as thinking about thinking. This simplistic definition does not, however, shine a bright enough light on what we shall see is a cognitively and philosophically complex phenomenon. I have therefore provided a model of metacognition, via an explanation given at a functional level, that I hope will be productive in two ways: first, it will improve our understanding of critical thinking; second, it will provide some clear pedagogical principles that can guide the construction of learning experiences and assessment design. I use this model of metacognition to propose a model of critical thinking in which metacognition is a *necessary*, unifying element, but in which it is not sufficient—it is, rather, the element that allows any cognitive skillset to be used most effectively, and provides the experience of thinking that, critically, can be recalled and applied across disciplines and situations. In this I use Dewey's idea of thinking as experience. I shall also focus on the evaluative aspects of critical thinking—with the critique of one's own thinking the focus—an emphasis that moves me to name this the *metacognitively evaluative* (ME) model of critical thinking, with full appreciation of the "me" acronym.

4.1 It's all about ME

Metacognition as a concept suffers from the same lack of categorical precision as critical thinking, so it may be a risky strategy to promote it from its role on the periphery to the centre of attention as a critical thinking attribute. Let me therefore provide a brief overview of how metacognition may be understood, along with how it is said to be beneficial as an educational strategy.

Understanding metacognition is not just an issue of constitution (i.e. what makes it up); it is an issue of framing. Are we to understand it as a feeling, as a cognitive skill set, as a clutch of strategies, or as intellectual self-governance? It is also debatable as to whether some concepts, such as self-regulation, are subordinate to, or inclusive of, metacognition (Veenman et al., 2006). These are questions generally bound up in cognitive science, and the hierarchy or relationships linking these ideas is far from clear. Despite this confusion, metacognition makes regular and frequent appearances in the literature on critical thinking (see, for example, Chaffee, 1988; Elder and Paul, 2001; Petress, 2004; Van Gelder, 2005; Mulnix, 2010; Scriven and Paul, 2011 for a range of conceptualisations)

This may be because, while there is no suggestion that metacognition is synonymous with intelligence, it does seem to be the case that metacognition, or the skills of self-awareness and self-regulation one might associate with it, improves learning outcomes. Veenman et al. (2006), for example, claim that "on the average intellectual ability uniquely accounts for 10 percent of variance in learning, metacognitive skills uniquely account for 17 percent of variance in learning" (*ibid*, p.6)

That metacognitive skills or strategies may contribute to academic success is not difficult to imagine if we accept that "a person who is metacognitive knows how to learn because he/she is aware of what he/she knows and what he/she must do in order to gain new knowledge" (Wilson and Bai, 2010). How this might work would presumably be a function of discipline or situational context, and involve a grasp of metacognitive strategies and skills, including knowing how and when to apply these.

What does seem consistent in discussions regarding metacognition is that the 'meta' part of the word means that we create representations of our thinking, specifically our "first-order mental states" (Fletcher and Carruthers, 2012, p.12). These states are those desires and beliefs, including beliefs about the truth of factual knowledge, which we use to move through an inferential process to reach conclusions or direct actions. It is also the case, however, that we make higher-order representations, which may be about how these states or representations interact, including the dynamics of the learning and reasoning process. For example, when we perceive a chair we create a mental representation of it. We might also have a mental representation of the fact that our legs are sore, perhaps from a long day standing. Working with these two representations we could create a further representation of the chair being used to relieve the pressure on our legs, and so on until we take appropriate action. What's more, we may work with several representations of chairs and call into use an existing representation of an evaluation process to determine which chair would best suit our immediate needs. More formally, we might construct a mental representation of a valid deductive argument.

It is not the case, however, that higher-order representations are, simply by being higher-order, consciously attended. We may drive a car using a remarkably complex suite of higher-order representations, including some very impressive future matching and evaluation processes, while chugging comfortably along in cognitive neutral, giving these representations little or no conscious attention. The use of the term 'metacognition' for simply *having* both first-order and higher-order representations, while perhaps cognitively descriptive, does not seem able to account for the rich educational concept of consciously modifying or accommodating our thinking towards a specified end with a view to optimising how we get there, let alone evaluating the process as one possible path among many. I suggest that it is at least necessary to both have *and be consciously aware* of these representations to be metacognitive. We in education might find a definition of metacognition that goes along the following lines more informative and productive: metacognition involves attending to mental representations such that the representations themselves, and their interactions, become objects of study.

I will attempt to show that using this definition (or perhaps focusing on this aspect) has pedagogical implications that deliver insights into creating better critical thinkers.

This sounds, and is, a complex way of thinking about metacognition, but we can achieve much the same end using an idea grounded more in philosophy than in cognitive science. This is not to ignore the science of cognition, but rather to frame the concept of metacognition at a different functional level. While the cognitive science underpinning our understanding of metacognition continues to develop, how it is eventually understood may remain coherent with this higher function. In the same way as our idea of a car allows us to plan for transport needs even as the specific nature of cars changes significantly over time, progress may be made in the use of metacognition as an educational concept grounded in a functional understanding while our scientific understanding of its nature continues to develop.

The Intentional Stance

Daniel Dennett's (1983) development and use of the intentional stance provides a useful conceptualisation of the issue that focuses on the functional aspects of metacognition rather than the underlying cognitive processes studied by cognitive scientists. The intentional stance is one that is adopted to explain the behaviour of complex systems (biological or otherwise) through the attribution to them of states of desires, needs, goals and ambitions – i.e. to consider them as agents (Dennett, 1988, p.496).

A point to consider with regard to the intentional stance is that these states, such as we might ascribe them, are a consequence of an agent's place and purpose in the world. It also assumes that the agent holds, and is subject to, a rationality which prescribes for it courses of action to take or avoid. This is to say that the dynamic interactions of representations unfold in a way that is goal-driven and geared towards a specified end. We automatically take the intentional stance towards others because we are naturally vigilant as to the way in which other agents may benefit, inform or deceive us, and the intentional stance is useful in predicting their behaviour. It is very much to our advantage to understand what they may do in the future based on their intentions, even if the system is not a conscious one.

As an example of adopting the intentional stance towards a non-conscious system, Dennett uses a computer chess program. When playing against the computer, we might observe that the computer moves its bishop in a certain way. We could ask the question ‘why did the computer move its bishop?’ The answer could be expressed in a variety of ways. We might say that the bishop is nothing more than an arrangement of light and dark spots on the screen. These spots are displayed according to rules generated in the electronics of the computer, and these electronics are circuits designed to regulate the flow of electrons. From this stance, the answer to the question ‘why did the computer move its bishop?’ is a causal one involving knowledge of semiconductors and electronic circuit theory. The answer that makes sense to a person playing a game against the computer, however, is that it moved its bishop to protect its queen. The attributed urge to protect its queen speaks to the computer as an agent with goals and a motivation to achieve an instrumental end. In practice the computer is being treated as a human opponent would be. This is not a matter of politeness or quaintness on the part of the human player; it is done to best effect victory over the computer. Adopting the intentional stance is an effective strategy to achieve an end, even if the agency and goal-oriented behaviour displayed by the system is known to be artificial or simply algorithmic.

Of course, there is nothing artificial about adopting the intentional stance towards other humans. Conscious beings clearly have goals and strategies to achieve them. Metacognition can be achieved by the deliberate and explicit adoption of the intentional stance towards oneself —an internal rather than external application. In considering our own drives, beliefs, desires, thoughts and processes, we become the object rather than the subject, of our predictions — just as considering another agent would make them the object, for the purposes of anticipating or planning possible future outcomes. Our own mental representations, or some of them, become explicit, thence making them objects of study to better understand and direct the intentional systems that we individually are. There is an asymmetry between the external and internal intentional stance, however, as we ascribe states to others but experience our own; however, as we consider ourselves as agents, we can use our inwardly directed intentional stance to interrogate ourselves as to what these states might be. We adopt the intentional stance when we ask questions such as 'what are the agent's beliefs in this matter?' or 'how do these beliefs influence the agent's thinking?', and 'what are the agent's goals in this situation and how can they best be achieved given the resources and opportunities available?' To replace 'the agent' in these questions with 'my', and to then engage with the question, is to become metacognitive.

In contrast to the asymmetry mentioned above, another result of this duel external and internal adoption of the intentional stance is the emergence of symmetry between how we think critically in processing and evaluating the beliefs and arguments of others as well those of ourselves. It means the set of skills and abilities, and criteria, developed for external parsing can be applied with equal efficiency internally.

Diagraming mental representations

To better understand this concept of representing mental states, Figure 9 shows a visualisation of thinking processes that I have trialled in critical thinking courses to promote metacognition and assist students in learning how to critically examine their thinking. I call this an MRI diagram (Mental Representations and their Interactions) in the hope, I suspect forlorn, that the analogy with the medical MRI (Magnetic Resonance Imaging) of making things clearer will stay with students.

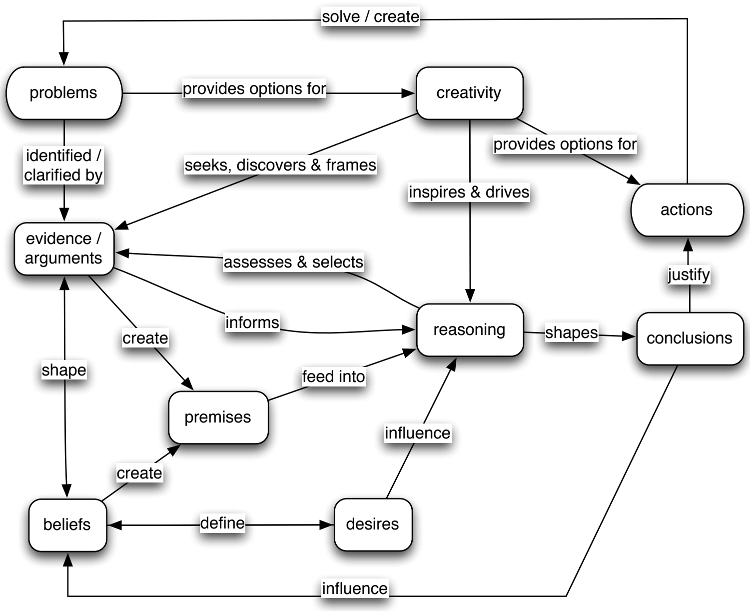

Figure 9: Mental representations and their interactions – a tool for examining thinking (note: there is no defined starting point).

This tool allows students to visualise their thinking. It captures in a diagram the non-linear, temporally recursive processes that make up thinking about an issue. It is not suggested that this particular MRI diagram is definitive, or that it is comprehensive; it is simply presented as a type of diagram that assists critical analysis of thinking. Any number of similar diagrams could be constructed to accommodate different educational contexts.

The specifics of this diagram go beyond what might be considered necessary for critical thinking (the inclusion, for example, of 'creativity' as a consideration), but it does show that such a representation is consistent with the intentional stance in that it incorporates states such as beliefs, goals and desires, as well as how these may contribute to the reasoning process. It helps students render explicit that which might otherwise have remained implicit in their thinking.

Visualisations of thinking processes are common, and they have significant educational benefits. Argument mapping, in which evidentiary links, premises, reasons and conclusions are explicitly stated and diagrammed to support or explain reasoning, have been shown to be efficacious in developing critical thinking skills (Van Gelder, 2005, p.45). While argument maps focus on cognitive reasoning skills, Figure 9 broadens the approach to include inputs to a reasoning process that are not part of the structure of an argument per se or that might be the occasioning cause of argument development (e.g. problem identification) and which are implied in the process of adopting the intentional stance.

4.2 Metacognition and Critical Thinking

Let me further explore the relationship between metacognition and critical thinking, and consider also the cognitive skills so often associated with the latter.

The American Philosophical Association developed, through a commissioned systematic inquiry, an expert consensus on what skills and affective dispositions are constitutive of critical thinking known as the Delphi Report (mentioned in the beginning of this chapter). Cognitive skills and sub-skills agreed upon in this report include (see Facione, 1990: for a summary):

1. Interpretation (categorising, decoding, clarifying)
2. Analysis (Examining and identifying)
3. Evaluation (Assessing claims and arguments)
4. Inference (Querying evidence, conjecturing alternatives, drawing conclusions)

5. Explanation (Stating, Justifying, Presenting)
6. Self-Regulation (Self-examination and correction)

While the practice of all these skills may be considered as, or at the least to characteristically involve, the manipulation of mental representations, I contend that the last of the cognitive skills, self-regulation, recognises the necessity of metacognition in critical thinking. Self-examination (the sub-skill of self-regulation) without metacognition seems untenable under the ME model so far described, considering the things to be examined are mental representations, the procedures by which they are generated and their interrelationships. I also propose that the remaining skills are best enacted in a metacognitive mode. In other words, metacognition is categorically distinct from these other skills, being more a type of thinking, or mode of cognition. Recall that, for my purposes here, metacognition involves consciously attending to mental representations. The cognitive skills 1-5 above require working with these representations, even as they themselves are mental representations. Cognitive skills can be processed algorithmically, even the skill of evaluation, as feedback loops on flow charts show, and while a thinker may be well-versed in applying such skills, such application need not be beyond the capacity of a computer program. It seems that critical thinking, in as much as we wish to distinguish it from algorithmic thinking, is metacognitive. Moreover, it is metacognitively evaluative, since good critical thinkers should presumably be adept at continually monitoring and evaluating the selection and application of their cognitive skills. It is the evaluative component that addresses the issue of 'correction' in point 6 above, for one must both evaluate and then correct with a standard in mind.

As for the issue of consciously directed thinking, I make the point that consciously evaluating and consciously directing our representations are not exclusive; indeed they are sides of the same coin. To evaluate thinking is to compare it to a standard, the application of which requires directed representation. To consciously direct thinking is to work towards an end, the choice of which, and the path to which, is something that requires evaluation. Hence, to be metacognitively evaluative is also to direct, to some degree, one's thinking.

The metacognitive experience

Critical thinking is often said to be about how to think rather than what to think (see, for example, Mulnix, 2010). There is more to this than simple procedure, however. Critical thinking is, in the language of Ryle (1970), a knowing how rather than a knowing that. It should be noted immediately that although the use of the terms 'how' and 'that' in this context refer to the nature of the knowledge in question, English allows other terms to be substituted to keep this distinction, as the following examples will show. Knowing how to play the piano is different from knowing that downward pressure on the keys produces sound. Generally speaking, *knowing how* is non-propositional and experiential, *knowing that* is propositional. To say that 'knowing that' type questions elicit propositional knowledge, is to say that they elicit knowledge that could be either true or false. For example, knowing the number of piano tuners in a city, knowing where piano tuners can be found, knowing why piano tuners may be necessary, or knowing how people usually find piano tuners is propositional knowledge. But knowing how to play a piano is non-propositional knowledge.

This is a different epistemic categorisation than is often used in many syllabi or work programs. More commonly a distinction between knowledge and skill is made, such that 'knowledge' is material known to be true and 'skill' the ability to apply the knowledge. This does not map well onto the knowing that/knowing how division, since knowing how to perform a chemical analysis, say, while arguably an application of knowledge (knowledge about mixtures, machinery, procedures and the like), can also be propositional knowledge and can be carried out algorithmically—indeed computers routinely do so.

The significance of this for critical thinking is that knowing how to think is, on the model I am proposing, non-propositional knowledge. Knowing how to manipulate and direct mental representations is non-propositional knowledge in the same manner that knowing how to keep your balance while riding a bike is non-propositional knowledge. This does not mean there is an absence of propositional knowledge. In both manipulating mental representations and in riding a bike, we must know that certain things are true; we must know that representations are present and that some rules governing how they interact, and we must know that pedals provide forward motion and that gravity is ever-present, but ultimately this propositional knowledge is not sufficient for the job. There remains, as Dewey might say, an experience to be had.

But the analogy between knowing how to ride a bike (play a piano, throw a boomerang) and knowing how to think seems weak. The latter activities are strongly sensory-motor activities, while thinking is not. Can we speak of physical activities, where we use terms like 'muscle-memory' and 'coordination', and mental activities, where we do not, in the same way? What could it mean to 'know how' to think? Isn't 'know how' bound to sensory-motor activities (and the mental processes that control them)?

Let us consider first that thinking is action—it is something that we do, and that we can be aware of doing. For example, I could analyse speech or text to identify an argument and test it for validity or seek patterns in a table of data. If I am aware that I am analysing or seeking patterns, an activity that has my attention and that I am directing, then I am having a subjective experience, just as I have when riding a bike. Of course, simply having a subjective experience does not imply there is a 'knowing how' involved. If I taste salt I have a subjective experience, but I do not 'know how' to taste salt. I 'know that' if a put salt on my tongue I will have that experience, but I cannot control how I taste something (i.e. decide when to activate my taste buds or control how that taste seems to me). There is something that it is like for me to identify analyse an argument, just as there is something that it's like for me to taste salt.[26] But, unlike tasting salt, identifying and analysing an argument is something over which I have some control. There is, therefore, a difference between the two experiences because there is also something that it's like for me to control and direct the process of identification and analysis. Riding a bike requires both mental and physical direction and control, but it is not at all clear that 'knowing how' is bound only to physical direction and control. If argument analysis is only about 'knowing that', in other words it is exhausted by propositional knowledge, then students could become proficient at argument analysis without ever attempting to analyse arguments in text or speech, in the same what I could become proficient in my times tables by remembering them without having to use them. 'Knowing how' to analyse an argument often requires a recognition of context, the ability to determine the propositional content of a sentence and to the ability to seek and understand relevant and significant information within text or speech. It might also require a significant synthesis of these things.

Also, if argument analysis was only a 'knowing that' it would make sense to ask a student if they remember how to analyse an argument and to assume that the propositions they give in response would be a full measure of their understanding and ability. It is certainly a question that can be answered to some degree by pointing out that one has to identify the premises and the conclusion and then to test the strength of the inference made, but this answer seems to miss too much about the actual process of argument analysis in the wild. This kind of response is indeed a 'knowing that', but the *use* of this knowledge (would we not realistically ask the student to use this knowledge on an example before granting a pass mark?) seems to require non-propositional knowledge and is therefore a 'knowing how'. To give another example, there is something that it is like to direct and control analysing a sentence containing a generalisation, identify the propositional

[26] Making use here of Thomas Nagel's (1974) 'there's something that it's like to be a bat' argument for the irreducibility of conscious experience to physical mechanisms.

content that expresses the generalisation and then seek a counterexample. That process in practice cannot be completely described by propositional knowledge.

I suggest that the consciously directed manipulation of mental representations towards an end that is itself represented, *is* the metacognitive experience of critical thinking. It is the experience of operating metacognitively that we note, the experience of calling to attention and directing the interplay of our mental representations. Just as knowing *how* to ride a bike provides a conscious experience, the characteristics of which we can recall, so too the experience of being metacognitive is one with recognisable, recallable characteristics. In this sense, critical thinking becomes less a collection of cognitive skills and more of a craft, looking more like the Greek *techne* than *episteme*. As critical thinkers, we analyse, infer, justify and interpret as we do play a piano or ride a bike, as an experience not just as an algorithm. What ties the cognitive skills together and makes them most effective is the metacognitive evaluation of what we are doing and the experience of doing so. I am not suggesting that playing the piano or riding a bike must be done metacognitively—indeed they are often not done so—I am suggesting that the experiential knowledge about these things is the sort of knowledge we also have about thinking when we know how to be metacognitively evaluative.

Let me now give an example of metacognitively evaluative critical thinking. I have chosen piano playing and bike riding as instances of the use of ‘knowing that’ *and* ‘knowing how’. My claim is that being metacognitively evaluative is *also* an instance of the use of ‘knowing that’ and ‘knowing how’. I am relying on an analogy here, where the significant issue is the use of two kinds of knowledge. I know from my experience of analogies that an analogy is strengthened if the property being analogised (the use of two kinds of knowledge in this case) is present in cases whose other properties are quite different. While the piano player uses the propositional knowledge about written music, tempo and the physical aspects of the keyboard, and the bike rider uses propositional knowledge about pedals, gears and gravity, they both have that is more than the sum of their propositional knowledge. The ‘knowing that’ and ‘knowing how’ in both cases is quite different, but they both use the two categories. This variation in particulars between the two cases allows me to be more confident in the application of this categorical distinction in the third case of metacognition. What I have done here is to use my knowledge that an analogy is strengthened when the property being analogised is constant across instances where other properties vary with knowledge of how to construct and analyse analogies to draw a conclusion. In this construction and analysis, I have intentionally represented aspects of the concepts I wish to discuss, manipulated these concepts towards an end, chosen examples to instantiate them, attempted to communicate this concisely and evaluated the possible effectiveness of my methodology.

‘Higher-order thinking’ and ‘problem solving’, are often used interchangeably or in association with critical thinking and should be put in context using the ME model of critical thinking. I have already suggested that higher-order thinking is not the same as critical thinking, since higher-order representations need not be consciously attended to and hence are not metacognitive, as metacognition is understood here. Higher-order thinking is a necessary part of critical thinking, however, and to make explicit these higher-order representations and to understand and direct their interplay is to make them part of metacognitive evaluation, and hence to think critically. Therefore, discussion of higher-order thinking with students is a necessary part of creating critical thinkers, an imperative I will expand on in the next section. Having said that, it is important to understand that this definition of higher-order thinking is not the only one, and in some definitions higher-order thinking incorporates critical thinking (see, for example, Lewis and Smith, 1993). Higher-order thinking as explained in the ME model of critical thinking in accord with the definition given here and is more integrated and explicitly supports pedagogical imperatives, as I will show.

As for problem-solving, the term is too vague. What constitutes a problem, after all, is open to interpretation. The range of definitions of ‘problem’ covers Dewey’s organic interpretation of problems as disequilibria to the solving of deductive puzzles in mathematics and hence does not seem to be categorically clear in terms of common or academic understanding. Problems over this range of definitions could be solved through simple reflex physical action, intuitive or heuristic thinking, by the application of algorithms, or by thinking critically. I claim that the phrase is unnecessary in the ME model of critical thinking beyond identifying a problem as an area of investigation to which cognitive skills may be applied. In the ME model, as evident in part from MRI diagrams, the issue becomes part of the set of mental representations to be recursively addressed. It is an important idea but does not require categorisation beyond common use.

I have considered metacognition as an application of the intentional stance towards one's self. This is not only intended to produce an awareness of one’s self in intentional terms and to link this to behaviour, but also to make those intentional states, and their interrelationships, objects of inquiry. Such a view situates metacognition more centrally in critical thinking as a mode of operating in which other cognitive skills are best utilised. In the ME model of critical thinking, the application of cognitive skills *is* the manipulation of mental representations, and when this is done metacognitively and evaluatively critical thinking is occurring.

The vast majority of our thinking is done without consciously attending to it, and we operate at the level of heuristics and intuition much of the time (Kahneman and Tversky, 2000)). There is recognition in the literature that the paradigmatic critical thinker can, to some degree, internalise the knowledge of critical thinking and perform effective, habitual thinking below conscious control. This is easily understood by analogy with piano playing. While the beginner learns how to move her hands, how to translate symbols on a page into notes on the keyboard and how to monitor and control timing, she is being metacognitive. Many actions, physical and mental, are subject to conscious control and evaluation. Over time these skills are removed slowly from conscious awareness and become more intuitive and habitual. So too the ability to recognise a fallacy, to analyse text for logical inconsistency, to detect pseudoscience, or to evaluate an argument can become part of our heuristic response to stimuli.

This movement from the metacognitively evaluative mode of thinking into the intuitive, internalised, rule of thumb mode of thinking is a deliberate educational outcome and can be understood as a form of mastery. In a trivial sense, one might master the times tables, but this is simply the skill of recall. To internalise and habitualise the use of a broad range of skills involving higher-order representations and to make from these heuristics or algorithmic approaches that rapidly decrease processing and response time would sit better with the common idea of mastery.

This progression from the metacognitive to the heuristic is consistent with the assumptions of the ME model of critical thinking. To make a claim of conflict would be to confuse critical *thinking* with critical *thinkers*. Critical thinkers, by definition, can think critically, but they need not always do so. Over time critical thinkers may develop heuristics that are highly effective in problem solving, for example, without the need for the conscious attention necessary for a beginning critical thinker. Even though the use of heuristics may be successful on many occasions, while the process is not been reflected upon to ascertain its effectiveness it is not critical thinking in the ME model. But such heuristic thinking is not to be discouraged, as an experienced critical thinker might only spend a small amount of time thinking critically, and a large amount of time using effective heuristics developed through extensive metacognitive evaluation. Having a wide range of useful heuristics and the ability and willingness to metacognitively examine them as the need arises, and to know when this need has arisen, is critical thinking mastery. I am not excluding the assimilation and use of a wide range of propositional knowledge about critical thinking from the concept of mastery, just augmenting it with a range of broader skills.

In the movie Shine, which explores the life of the pianist David Helfgott, a memorable conversation took place between the characters of Helfgott and his Professor. I believe this captures the concept of mastery very well.

> P: The page, for God's sake! The notes!
> H: I'm sorry I was, uh, forgetting them, Professor.
> P: Would it be asking too much to learn them first?
> H: And-And then forget them?
> P: Precisely.

In summary, research in critical thinking forms a broad church. This is useful in that a range of thinking skills and their relationships can be explored. It is less useful in the lack of any clear pedagogical direction that a more unified understanding may deliver. The metacognitively evaluative (ME) model of critical thinking provides unification, in that it can accommodate several understandings of critical thinking, including a focus on skills, metacognition and habitual critical thinking, as well as pedagogical imperatives drawn from the nature of metacognition and evaluation within the model.

Metacognition is proposed to be conscious attention to mental representations treated as objects of inquiry and evaluation. This level of description allows space for the science of cognition to develop to some extent without invalidating the model. One path to achieving metacognition is the adoption of the intentional stance toward one's self, requiring an introspection of one's goals, desires, and beliefs, as well as an understanding of one's rationality and the norms of reasoning.

Experienced and effective critical thinkers have a wide range of cognitive tools, including well-developed heuristics and a comprehensive set of cognitive skills. They also have 'know how' about critical thinking, including an ability to operate metacognitively and an ability to recognise when such metacognition is required.

Critical thinking and expertise

Whatever temptations might exist to equate expertise and critical thinking deserves some resistance. One of these temptations might be born of the recognition that deliberate practice—that necessary condition of reflecting on practice with a view to improving performance—sounds very much like metacognitive evaluation. But there are two reasons why I do not accept that critical thinking and expertise are the same thing. The first reason is that I do not think deliberate practice and metacognitive evaluation are synonymous. Recall that experts are experts because of what they *do*, and that their domain knowledge is deeply embedded in practice. They are recognised by their consistently high *performance*, not simply by the quality of their knowledge structures but by how those structures are integrated with their practice. A large part of the deliberate practice of experts is therefore reflection on the outcomes of their actions measured against criteria of success. This reflection is not necessarily a reflection on their cognition, therefore, but on the outputs of that cognition. The expert diagnostician, for example, may take feedback from erroneous or successful diagnoses and internalise this information to modify their schematic structures, but, as we saw in Chapter Two, experts are often not aware of the architecture of these structures (they are a result of Type 1 thinking). If they are not aware of those structures, or at least not trying to make themselves so aware, then they are not necessarily being metacognitive. They might be simply aware of receiving feedback and of how that feedback relates to their success or failure. Another example from a domain of expertise that relies strongly on sensory-motor cognition will help to explain further. Consider expertise in whip-cracking. The purpose of this endeavour "is to produce, under expert manipulation, a very distinct, loud crack" and "anyone who picks up a whip knows that making it crack requires skill, practice, and dexterity" (Goriely and Mcmillen, 2002). How the whip is held, how the movement of the whip is initiated and carried through, and how the body moves to assist the arm in delivering momentum to the whip are just a few of the factors that are susceptible to modification from feedback. While the novice struggles to attain expertise, she may well be thinking very hard about how her body is moving, and there may be some change over time as certain neural pathways are laid down and reinforced based on how she reacts to the quality of the sound produced. But that thinking does not necessarily give rise to knowledge that is visible to the expert herself. Asking the expert whip cracker how they can crack a whip can be as uninformative as asking an expert diagnostician how they arrived at a diagnosis.[27] More significantly for this point, it might also be difficult for the diagnostician to explain how any feedback as to her success or failure is being used to modify her internal schematic knowledge of the process of diagnosis—just as it would be difficult for the whip-cracker to do so. Though I acknowledge the possibility that some kinds of deliberate practice might involve metacognitive evaluation, deliberate practice, by the reasoning above, is not *necessarily* the same thing as metacognitive evaluation.

The second reason not to equate expertise with critical thinking is that even if deliberate practice were synonymous with metacognitive evaluation, that would only mean that experts were critical

[27] It is not that the expert diagnostician does not have explicit, articulable knowledge of the field, of course, but rather that how that decision is reached, being Type 1 knowledge, is possibly not clear to the expert.

thinkers, it would not follow that critical thinkers must therefore be experts. This is more than a simple instance of the deductive fallacy of affirming the consequent, however. Even if critical thinkers were engaging in deliberate practice on each occasion that they were being metacognitively evaluative, they might be doing so in many different domains. Since expertise depends on deliberate practice within the one domain over a long period of time, deliberate practice *of itself* is not a sufficient condition for critical thinking. A critical thinker need not have domain expertise. Someone who is being both metacognitive and evaluative can be doing so in a range of contexts that do not need to equate to a domain of their expertise.

4.3 Putting it all together

So far in this thesis I have outlined the need for a schematic approach to teaching for thinking. I have discussed what it means to have schematic knowledge and have described some of the elements of such a schema. The previous chapter focused on the need for epistemology as an element of that schema, but also as a driver for inquiry that is the *sine qua non* of thinking. This chapter has established a case for including metacognition as an additional element of schematic knowledge of teaching for thinking. While epistemology is the driver of inquiry, metacognition gives us, among other things, the means by which the progression of our inquiry, that is our thinking, can be monitored and improved. Recall that expert knowledge is not only representative of static states but also of dynamic ones, those involved in real-time problem-solving in the domain of expertise. Considering that the domain in question is that of teaching for thinking, the relevant dynamic states are often cognitive ones, and the need to make these objects of study demands a metacognitive strategy.

Chapter Five: A pedagogical schema relating the skills, values and virtues of inquiry

In Chapter Four *Metacognition*, I developed an understanding of what it is to think critically. I described two conditions that need to be met for thinking to be called 'critical'. The first condition is that the thinker is being metacognitive. The second condition is that the thinking so brought to the thinker's attention is evaluated. While this provides a categorical distinction between simply thinking and thinking critically, it still leaves questions about the nature of the cognition involved and the precise means of evaluating thinking. In this chapter I go deeper into what we mean by both cognition and evaluation in the context of teaching for thinking. I then suggest that to understand our thinking, we must consider what specific things our minds are doing, at least at a functional if not neurobiological level. At one particular functional level, we might call these things our minds do 'cognitive skills', or, as Marzano would have it, cognitive verbs (2006, Chapter Five). It is the use of these skills, I argue, that is the referent for metacognition at its highest resolution—at least as far as we are concerned in general education. I shall provide examples of cognitive skills and show how feedback can be provide to students on the use of these skills using the values of inquiry, thus connecting inquiry, skills and values within the schema of teaching for thinking begun in Chapter One, *Expertise*. I will then explore the concept of epistemic virtues in inquiry, noting how they can be developed within the practice outlined in the schema and their relationship to the practice of inquiry including use of the skills and values. Before leaving inquiry, I explore its value in the pragmatic sense as a means by which we can collectively establish norms of cogent, critical thinking.

5.1 Cognitive skills

The act of cognition describes a mental process. It is not something associated with purely reflective behaviour or characterised in its use by reference to just any kind of neural behaviour. Cognition, as the term is routinely used, involves knowledge formation or manipulation by direct perception, by representation, or by higher order processing of information and as such is a specific kind of mental process.[28] Neurologically, the highest levels of cognition are understood as executive control, expressed with admirable clarity by Miller and Wallace:

[28] The more common use of "higher-order" in education in the term "higher-order skills" will be discussed in §6.2 *Teaching skills and values.*

> Cognitive, or executive, control refers to the ability to coordinate thought and action and direct it toward obtaining goals. It is needed to overcome local considerations, plan and orchestrate complex sequences of behavior, and prioritise goals and subgoals. Simply stated, you do not need executive control to grab a beer, but you will need it to finish college. (2009, p.99)

The abilities and skills that may be called 'cognitive', however, range across such diverse areas as the use of language, the attribution of causal connections, pattern detection and the recognition of agency in others. Cognitive skills may be classified in apes, for example, as being developed through association with tools and causality, social learning, communication and a "theory of mind" (Tomasello and Herrmann, 2010) insofar as that implies the capacity to anticipate and represent what other apes are thinking. Humans extend this cognitive skill range to include language and other types of abstraction such as music and mathematics.

I focus in this section on one set of skills that involve the mental manipulation of higher order mental representations. Higher-order mental representations are those that are themselves representations of lower order mental states, such as basic desires or beliefs (Fletcher and Carruthers, 2012), as I outlined in Chapter Four *Metacognition*. For example, argumentation as a process between individuals is dynamic and temporal, but a specific argument such as:

(Premise 1)	Fred is a Gronk
(Premise 2)	All Gronks are green
(Conclusion)	Fred is green

is itself a higher-order representation containing premises, conclusions and the inferential process that binds them (Mercier and Sperber, 2011). While each of the premises and the conclusion can be statements of belief, the argument itself is an abstraction—a mental representation that contains other concepts such as validity and soundness. Not all manipulation of higher order representations may involve the cognitive skills as I present them, but these skills do presuppose the manipulation of higher order mental representations.

In educating for thinking, it seems evident that we must be at some level targeting the development of such cognitive skills. It would therefore be useful to understand which cognitive skills (beyond those we share with other apes) students are bringing to bear on which educational tasks, and how these tasks might be developmentally arranged to produce and promote excellence in the use of these skills. It would also be useful to name such skills so that we can speak meaningfully and with purpose about what we wish students to cognitively do with some element of control. In speaking about teaching cognitive skills, I am speaking about teaching students aspects of how to *think* and therefore teaching them how to inquire (as outlined in §2.4 *Thinking as inquiry*). This is not the same thing as teaching them how to *learn*. Of course, we might quibble that students are learning how to think, and this is indeed true, but often talk of learning is directed towards factual or procedural knowledge in which thinking, and how to go about it, is not the focus. Asking how students best learn factual or procedural knowledge—often the bulk of the curriculum—gives a different set of answers from asking how they learn to think.

Exactly what cognitive skills are we talking about? Happily, assessment criteria and syllabi from schools and universities are already populated with terms that describe cognitive skills and how they might relate to one another. Words such as *analyse*, *evaluate*, *infer*, *synthesise*, *categorise* and *interpret* all represent cognitive skills. Moreover, each of these skills may require the application of some others in its execution. For example, it might be necessary to analyse something before it can be evaluated. Any number of other words might be used to represent different cognitive skills such as *compare*, *contrast*, *decode*, *justify*, and *estimate*.

Cognitive skills such as those named above are often associated with effective or critical thinking. In this more specific educational use, in which very fundamental cognitive skills such as language formation or theory of mind are assumed to have become sufficiently developed to allow students to extend their thinking into more complex areas, I suggest cognitive skills can be thought of, using a simple conceptual handle, as things we do with or to knowledge (and sometimes to create new knowledge). The knowledge on which these skills operate can be factual, conceptual or procedural knowledge, to use Bloom's original categorisation (Bloom and Krathwohl, 1956). At a basic level, for example, knowledge could be *recalled*. Analysis, synthesis, justification and evaluation would require our knowledge, including our knowledge of processes and procedures, to be used with more sophistication. Bloom's Taxonomy of Educational Objectives (Bloom and Krathwohl, 1956), Anderson and Bloom's revision of that taxonomy (Anderson and Bloom, 2001), and Marzano's consequent work in Dimensions of Learning, The Art and Science of Teaching and most recently the New Taxonomy (Marzano, 1992, 2006, 2007) contain many references to cognitive skills so defined. Competence in the use of cognitive skills is strongly associated with paradigmatic critical thinkers (Facione, 1990) and examining these skills and how they are best taught provides a sharp educational focus. I will therefore use the terms 'thinking skills' and 'cognitive skills' interchangeably for the moment but allowing that cognitive skills could be a substantial subset of thinking skills.[29]

An additional value in relating cognitive skills to knowledge use is that content-heavy curricula need not be immediately seen as bereft of opportunities to teach thinking skills. Teaching thinking skills does not imply the need for removal of swathes of content. Rather the challenge is to look for opportunities within the content to develop cognitive skills, to ask the question: What can we do with this knowledge?

In Chapter Two *Understanding teacher expertise,* I spoke of inquiry as inseparable from thinking (at least the sort of thinking we wish to improve educationally). Since thinking here means, in part, the use of cognitive skills, inquiry must demand the use of cognitive skills. Inquiry can be recognised in the classroom through opportunities to use cognitive skills and understanding aspects of inquiry is a function of how we understand cognitive skills. This has two broad and immediate pedagogical consequences. The first consequence is that subject content knowledge gives us the grist to develop cognitive skills. This is because cognitive skills involve the manipulation of higher order mental representations ultimately based on this content (as it is commonly said in relation to thinking critically, you have to be thinking about something). The second consequence is that we need to provide opportunities in the classroom for the use of cognitive skills so that these skills can be used (and developed). But consider that the use of cognitive skills is analogous to the use of physical skills in that neither can be learned without the opportunity to use them (Ellerton, 2015a). As it is not possible to learn to surf, for example, without at some stage getting on the board, it is not possible to develop a range of cognitive skills without an opportunity to think. They are both experiential. A fuller discussion of cognitive skills, their relationship to each other, and how they can be taught and implemented in lesson planning will be provided in §6.2, *Teaching skills and values*.

5.2 Values and Virtues

Given that students can be provided with the opportunity to inquire, which is to say use their cognitive skills, it follows that a means of evaluating their thinking should also be provided. It is

[29] Regardless, we should not imagine that cognitive skills only represent the chrome and steel of analytical thinking. Words such as create, speculate, generate, hypothesise, and synthesis represent more imaginative and creative aspects of our thinking.

axiomatic that simply doing something is not of itself sufficient to improve, we must receive feedback of some sort. In playing the piano, for example, feedback is provided by listening to the outputs of our playing. The use of the cognitive skills with no feedback or no set of criteria by which students or teachers can judge the quality of thinking would make improvement in thinking problematic. It would be like playing the piano and not hearing the notes. The root of the word 'evaluate', however, would seem to be 'value'. When we evaluate something, we apply a set of criteria generated by a set of things we value. To evaluate inquiry, therefore, we need to be clear about those things we value in the process of inquiry. In making what we value clear, we then have the means to construct criteria for evaluating inquiry. And to evaluate our inquiry is to evaluate our thinking.

To understand what kinds of things might be valuable in inquiry, I turn to the physicist and philosopher of science Thomas Kuhn, who notes that scientists are not rule-based in their decision-making (1970); were they rule-based, then two scientists applying the same methodology to the same evidence would inevitably assess this evidence identically (assuming they were equally proficient at this) and inevitably and invariably come to the same conclusion. Such an algorithmic application of rules does not allow for any difference in the conclusions of the scientists. Since scientists obviously do disagree with each other even given the same evidence, they must not be just following rules (at least rules that, when equally applied, result in the same outcome). For Kuhn, scientists reach different conclusions given the same evidence because they apply values in different ways. These values might be shared between the scientists as a result of the education they have received within their discipline, but their application is contextual and dependent on each scientist's individual judgement. While one scientist may value accuracy over simplicity, say, another may not. This results in changes in how evidence is attained, understood or assessed between scientists and hence can lead to different conclusions. Kuhn identifies accuracy and simplicity as values. He also lists consistency and plausibility (1970, p.185). From these examples, we might induce others including precision, clarity, coherence, breadth and depth of treatment, reproducibility, logical development, and any number of things that scientists apply in a preferential manner. The weighting of any of these values may change as the issue under investigation, or the way it is investigated, change. Some may not be relevant to one inquiry but be considered critical to another. Moreover, as Fred D'Agostino (2009, p.185) notes, as well as individual scientists' personal understanding of these values developing uniquely over individual practice and experience, the values themselves may take on different meanings in different situations (for example, simplicity in designing models can be valuable to increase utility and ease of application, or even for educational purposes, while simplicity in experimental design can be better understood as efficiency, something that might minimise complexity but only so far as it does not distort the required level of accuracy). The synthesis of judgement over the range of applied values, therefore, is a very organic process and complete uniformity of judgement is not to be expected (or even desired if we also value divergence).

The values I have noted (through Kuhn) apply to scientific inquiry, and I will leave this undeveloped except to say that there is clearly nothing about these values as a set that would seem to limit them to science. Granted that reproducibility would seem strongly connected to experimental work, but I take it that there may be a sense in which the methodology of other disciplines could claim it as important. For example, an analytical tool for predicting financial patterns or buyer behaviour in economics would need to be reliable to be useful, so too a pedagogical technique for developing critical thinking skills. Regardless, values such as precision and coherence are employed in the inquiry of many disciplines; no historian, for example, would eschew these or assign them no methodological value. These values I will call 'values of inquiry'. It is not necessary that we have a definitive list of these values to work with, only to acknowledge that those I have named, and others like them, are employed in the business of inquiry to introduce variation in outcomes given the same evidential input.

A significant application of these values of inquiry is to provide feedback on the use of cognitive skills. Consider a student engaged in the skill of analysis. Just because she is analysing does not mean she must be doing it well. Feedback could involve comments about the *breadth* or *depth* of the analysis. It could mention that there was a lack of *clarity* in how the elements of the analysis are represented. An analysis may have shown depth, but not in a *significant* area. The analysis may suffer from a lack of *precision*, perhaps by not quantifying some important aspects. The representations within the analysis may not be very *accurate*, and so on. Part of a thinking education, therefore, is educating students in the values of inquiry. A thinking education requires a values education.

There are at least three aspects to this values education: first to teach that something is a value (knowledge), second to teach why it is a value (understanding), and third to learn, as we must with all types of values, how, and also when, to apply them (application). This last aspect is an important one. The first two would seem to constitute only propositional knowledge. Knowing that something is a value and knowing why it is a value could be learned and recalled. Knowing how to apply it, however, is subtler. As mentioned in Chapter 4 *Metacognition*, it is more akin to 'knowing how' than 'knowing that'. Again, we see an experiential aspect in learning how to think. Knowing how to use the cognitive skills and knowing how to apply the values of inquiry are examples of knowledge that exceeded propositional knowledge (Ellerton, 2015a, 2017).

Elder and Paul (2013) have chosen a selection of these values of inquiry, calling them “Intellectual Standards”, to form the basis of their understanding and teaching of critical thinking. The standards that these words imply are “criteria, rules or principles used to determine the quality of something” (*ibid.*). The existence of criteria against which the merits of any decision is measured is a necessary condition for judgements to be made as to the quality of those decisions. Those wishing to improve thinking must also have standards against which to measure their progress. That this is something as true for thinking as it is for any activity capable of progress carries on from the points made in Chapter Three *The relationship between pedagogy and epistemology* by Siegel in considering effective epistemological assumptions necessary for critical thinkers. Intellectual standards, according to Elder and Paul, are those standards applied to our thinking in forming judgments and making decisions based on reasoning.

It does not seem particularly problematic that things such as clarity and plausibility might be called both standards and values. Standards are ubiquitous in educational curricula, forming the basis for many assessment criteria sheets. Values, however, seem to be more on the periphery of academic curricula, as indicated by the treatment of values in the Australian Curriculum (‘Ethical understanding - Exploring values, rights and responsibilities - The Australian Curriculum v7.5’, n.d.). I prefer the Kuhnian use of the term ‘values’ rather than standards for a variety of reasons. The first reason is that standards suggest benchmarks. Benchmarks in turn suggest that certain levels have been attained or not—it is a binary conception of thinking values. The second reason for preferring values over standards is that standards suggest specificity of approach. For example, one might have specific industrial standards for the manufacture of a type of chair, and another set of standards for the length of car battery life. Values, on the other hand, are general—reliability would be valued in both cases, for example. In terms of values of inquiry being generally applied, clarity can be improved in writing by ensuring only one key idea is encapsulated in a paragraph, or in science by taking care in the labelling of axes on a graph, or in mathematics by setting out working in a systematic way. Clarity is a general value of inquiry, and the art of inquiry involves learning how to apply the general value in specific circumstances. The third reason to prefer values to standards is that standards suggest a compliance model, in which basic standards, having been met, can be thought of as attained or even exhausted, seeming more like competencies than nuanced abilities. But educational excellence does not come from a compliance model; it comes from teacher expertise. The fourth reason to prefer values is that unlike standards, which can be quite discrete, values overlap. Precision can contribute to clarity. Depth of analysis can benefit from clarity and improve logical development. The image of a graphic equaliser comes to mind. As certain types of music benefit from a specific mix of frequencies, some genres sounding better when mid-range frequencies are boosted and others when lower frequencies are damped, certain types of inquiry, and certain types of inquirers, will prefer certain values over others according to their sensitivity to context and to their past experience. This was precisely Kuhn's point. Elder and Paul certainly do not propose such industrial use of their intellectual standards and do treat them as values in the Kuhnian sense. It is simply the potential for misunderstanding in an educational context, as well as following the original work of Kuhn, that leads me to prefer the term 'values'.

A class I teach provides a further example of subtlety in value application. The class is composed of students preparing to be Physics teachers. These students, as you would expect, typically come from a strong background in physics and mathematics. One of the first inquiry activities I introduce them to is to experimentally determine the factors influencing the period of a pendulum, requiring them to develop an experimental approach and generate a list of the materials they think they will need. Invariably, students will request a protractor to measure the initial angle of release of the pendulum, and a stopwatch for measuring the period. They usually seem quite happy to record the angle of release using the hand-held protractor at plus or minus 5 degrees, or more, and combine this with the reading on the stopwatch of a period measured by eye but recorded on the device to a hundredth of a second. The key lesson is to understand how they are valuing precision. What is the value of using the reading to a hundredth of a second while other factors are so uncertain? How concerned should they be that they cannot be very precise and therefore accurate in their measurement of the angle? Might we value, say, reproducibility more in this case? Precision pursued for its own case, in ignorance of context and use, shows a lack of understanding in the application of this value. It is also a good indicator of acting outside the norms of a discipline, and hence an indicator of the novice or the charlatan. For example, advertisements for miracle pendants that increase your resistance to 'negative energies' by 92.5%, or shampoos that make your hair 26% fluffier show a poor understanding of the application of the value of precision in science, both in incorrect use of quantification and in vagueness of language. Such inappropriate application of a value is a reliable indicator of pseudoscience.

I have not given a definitive list of cognitive skills nor of the values of inquiry. Not only might such a task be impossible, at least to the satisfaction of all, but also it is sufficient for the schema that the skills and values are categorically defined with enough coherence so that others can be generated or recognised for what they are as required. For example, one might find words like *extrapolate*, *speculate*, *hypothesise*, *classify* and *translate* in assessment criteria sheets or in tables of outcomes. It is not difficult, I hope, to recognise these from what I have outlined above as cognition based in content—they are clearly cognitive skills. Similarly, *explanatory power*, *falsifiability* and, perhaps above all things, *cogency* are things we would value in the activity of inquiry. Considering the terms *generalising* and *generalisability*, we would see the first as a cognitive skill and the second as a potential value. If I now introduce the term *persistence*, one might ponder its categorisation. It does not seem quite like a cognitive skill—it is not something we would do with knowledge. It is tempting to say it is a value, but I would not include this as a value for a simple reason: it is a characteristic of a person and is therefore best seen as a *virtue*. Other virtues commonly associated with critical thinking are things such as *inquisitiveness*, *open-mindedness* and *intellectual honesty* (Fairweather and Zagzebski, 2001; Baehr, 2011; Macallister, 2012; Siegel, 2017). They are also called 'affective dispositions', being characteristics that we value in people, rather than characteristics of good inquiry itself. We might say we also value *clarity* in people, but that merely describes what they produce—we are generally quite happy with their individual opacity!

I present now some examples of how the values can be applied as feedback for, or as descriptive of the quality in application of, a range of cognitive skills. More specifically, I will outline how work that shows appropriate use of the values of inquiry can be described. To facilitate this I have produced a matrix of cognitive skills and values, based loosely on cognitive skills outlined by Facione (1990) and the intellectual standards outlined by Elder and Paul. The cognitive skills are represented in rows, and the values of inquiry in columns. Although the matrix is too large to appear here in full, it is reproduced in Appendix 2.

The matrix is populated by a collection of statements describing student work. These statements are not meant to be definitive or comprehensive, they are simply descriptors of some characteristics of that work. They represent the kind of statements that educators could provide to students to evaluate their work and to provide feedback. The following are examples of how the values of *clarity* and *depth* might be applied in a selection of cognitive skill use.

Table 1: How values are applied to the use of cognitive skills.

Cognitive skill	Clarity	Depth

Interpretation-categorising	The criteria for categorising are unambiguous and the common characteristics of elements within the category are explicitly stated and recoded as necessary.	Categorisations are made through relevant and significant characteristics rather than superficial resemblances.
Inference-conjecturing alternatives	Possible inferential pathways are articulated based upon varying use of evidence and argumentation. Alternative hypotheses and potential conclusions are distinguished with relation to their assumptions.	Alternative hypotheses maintain the emphasis on significant and relevant information, as well as a focus on solving the core problem. Complexity is managed and problematic causal and evidential relationships are addressed across possible outcomes.
Explanation-presenting arguments	Argumentative prose, diagrams, charts, graphs and graphics convey unambiguous meaning which adhere to convention. Points at issue are clearly defined and stated.	Counter-arguments are identified and addressed. Causal and logical relationships that relate to the argument are identified and their role made explicit. Problematic aspects identified and solutions explained.
Evaluation-assessing claims	The nature of evidence is well defined and presented in context. Inferential pathways between evidence and claims are made explicit.	Claims and conclusions are connected to the nature of the problem and of the evidence. Cognitive and social biases are explored. The contextual relevance of questions, information, principles, rules or procedural directions are assessed.

Note that the descriptors as I have written them are not discipline-specific. That they can be written in this way allows two significant claims to be made: first, learning to think well is not the domain of any particular discipline—the skills and values involved in thinking well are generic;[30] second, because these descriptors can be instantiated within individual disciplines, these skills and values are themselves legitimate objects of study.

I have already suggested how the value of clarity might look across different contexts. Teaching analysis, as an example of a cognitive skill, can also be done outside a discipline context. Consider that we could define analysis as the breaking down of a conceptualisation into its constituent elements, with some regard to how these elements may be categorised, how they relate to one another and to the overall nature, function or purpose of the original conceptualisation. It is not necessary that we agree on this definition, just that a definition of this sort might be made. Now, having gone through this with students, we might examine a work of visual art and ask questions based on our definition. What elements are involved and how they do conspire to produce a specific effect? We could present a scientific model, or a poem, or a text-based account of the reintroduction of wolves into Yellowstone National Park and the consequent impact on the ecosystem and ask the same questions.[31] There is nothing about this hypothetical method that logically restricts the teaching of analysis to a discipline. Similar accounts could be given for any of the cognitive skills and, for that matter, any of the values of inquiry. Of course, the nuances of how the values of inquiry are applied between disciplines do vary, though Kuhn (1970, p.184) himself noted that these are the most easily shared aspects of all the disciplinary matrices.

We can now see the dynamic between the first two nouns in the title of this chapter. Effective educational inquiry can be understood, in part, as allowing for the development of a range of cognitive skills. Cognitive skills involve the things we do with knowledge; specifically, they involve the manipulation of higher order mental representations (though not all manipulations of higher order mental representations may involve cognitive skills as used here). The values of inquiry provide feedback on how the cognitive skills are developing and, through this, students learn how these values are to be applied.

A path to virtues of inquiry

[30] The context in which these skills and values are used are discipline specific, but they can be described broadly as cognitive actions in a similar fashion.
[31] This example is presented in detail in §6.2, *Teaching skills and values.*

Virtues have long been the focus of attention in first ethics and (much) more recently in epistemology. In ethics, a virtue lens makes the individual the object of study, raising considerations of character and agency rather than of the metaphysics of morals or the rightness or wrongness of actions. The only thing that can be virtuous is a thing with the kind of agency required to make rational judgements. Neither a theory nor a program nor an ideology can be virtuous—though these can all be fashioned with a worthy outcome in mind—for these things do not have characters. Actions are called virtuous derivatively from the assessment of the virtuous characters of their agents. Virtue, therefore, is about people, not their pursuits, pastimes, politics or paradigms.

It could be that proper training in the values of inquiry would lead to inquirers with specific intellectual virtues. Understanding and appreciating the value of clarity and accuracy, and being proficient at their application, would suggest a tendency towards intellectual honesty, for example. Valuing falsifiability in a theory may produce an inclination to open-mindedness. There seems nothing about mastering the application of values that logically necessitates developing particular virtues, but it is possible to see mastering values in practice as a path to virtue. It is sensible to imagine, however, that virtues such as inquisitiveness and a willingness to revise theoretical assumptions could only enhance the inquiry process. As Elder and Paul (2013) say, "There are numerous concepts [virtues] (e.g., integrity, empathy, fairmindedness) in natural languages which, though not themselves intellectual standards, presuppose intellectual standards" (*ibid*, p.34).

Bailin and Battersby (2016a) note a move towards the use of a virtue lens in argumentation and, by extension, into critical thinking. This is a move away from considering the knowledge and skills of critical thinking as its most fundamental aspects and towards the character of the agent (i.e. the critical thinker). This is a logical and perhaps expected development considering that much of the discussion around critical thinking has employed terminology demonstrating, to a significant extent, the flavour of virtues. This terminology includes 'habits of mind', 'rational passions', 'critical spirit', 'dispositions' and indeed 'virtue' itself (*ibid*, p.386). These have been codified on many occasions and a list of common elements makes up a large part of the prospectus of most educational institutions that wish to impress by the quality of their output. Terms such as 'open-mindedness', 'curiosity', 'integrity', 'humility' and 'perseverance' are ubiquitous as attributes of graduating students (granted that they may be more represented hypothetically than existentially, the intent is clear). What is not so clear, however, is how these virtues are to be realised through the experiences students have in the classroom. What must they do, and how must they think, that will result in at least a greater opportunity to develop such virtues?

Let me begin this task by considering the concept of dispositions within critical thinking. I begin with dispositions because this is a focal term in theorising about virtue, the idea being that virtues represent stable patterns of response that their subjects possess even when the response is not occurrently manifested (Annas, 1995; Baehr, 2013, 2015; Fairweather and Zagzebski, 2001; Siegel, 1999). I will then show how the move from speaking of dispositions to speaking of virtues, encouraged by Bailin and Battersby (2015), can carry with it the utility established by Siegel and others and hence provide a solid foundation for virtue in the context of inquiry. Julia Annas' (1995) conceptualisation of virtue as having "some kind of intellectual structure, accessible to the reflective agent" (p.233) allows for a framing of the final section of the schema that is the primary work of this thesis and provides a pathway to developing the virtues of inquiry that can be integrated into classroom practice.

It is a logical argument, assuming the existence of dispositions, that one could fail to think well because of either a lack of dispositions that enable good thinking or by not having the appropriate intellectual constructs that contribute to contextually necessary understanding. What remains, then, is to understand the nature, role and, ultimately, means of production of the dispositions associated with the cognitive skills outlined above in the teaching for thinking paradigm.

The New South Wales Department of Education (1999) claims that 'dispositions' "refer to the way in which learners engage in and relate to the learning process. Learning dispositions affect how students approach learning and therefore the outcomes of their learning" (NSW Department of Education, n.d.). Siegel defines a thinking disposition as "a tendency, propensity, or inclination to think in certain ways under certain circumstances" (*ibid*, p.209) and notes that dispositions can have causal influence on behaviour, explaining perhaps the often-used qualifier of "affective" (see, for example, Facione, 1990) when speaking about dispositions.

It is important to note that dispositions can manifest in a variety of ways. A disposition to work collaboratively with colleagues rather than solely by oneself, for example, could manifest as seeking out others for their expertise, identifying the potential for collaboration in certain tasks, volunteering for such tasks in preference to individual tasks, setting joint goals, or even attending morning teas regularly. As Siegel (2017) notes, these behaviours may look quite different from one another, but they indicate an underlying disposition. This insight provides the significant pedagogical implication that one cannot train for a disposition by inducing repetitive behaviour because (1) various behaviours may all be indicative of a disposition and (2) dispositions are not reducible to behaviours.

According to Annas, at the least "a virtue is a disposition to do the right thing" (Annas, 1995, p.233). By this definition alone, virtue is a species of disposition. One is morally virtuous if and only if one is disposed to do the right thing. Annas moves beyond this, however, to include something both deliberative and systematic involving "some kind of intellectual structure accessible to the reflective agent" (*ibid*). Not only must a disposition be present, but the virtuous agent must be able to justify why the actions that come from that disposition are worthy, and indeed why the disposition itself, as the causal factor in bringing about that action, should be developed. Jason Baehr speaks of a deep appreciation, indeed "love", of such outcomes creating a motivation to move towards those things identified as "epistemic goods"[32] (Baehr, 2013, p.248). This treatment of virtues results in a richer description than we had for dispositions that includes reference to the intellectual and emotional motivations of agents. Bailin and Battersby precisely locate this difference in the evaluative quality: "The aspect that is captured in the notion of virtue [in critical thinking] that is missing in the notion of disposition is that of valuing or appreciating" (Bailin and Battersby, 2016a, p.368).[33]

We can synthesise these views to understand, for the purposes of this schematic construction, intellectually virtuous people as those who (1) recognise certain epistemic goods, (2) are motivated (disposed) towards achieving those goods—and perhaps, as Baehr (2015) suggests, take some degree of pleasure in the activity of doing so, (3) can offer reasons why such goods ought to be pursued (to themselves and others) and (4) have the necessary understanding and intellectual skills to enable them to move towards those goods and put them into use in inquiry, including the sensitivity to context necessary to use them effectively. This last point seems necessary since it seems jarring to say of someone that they are intellectually virtuous but cognitively incompetent. They must also be "*skilled* and *intelligent* in their pursuit of these ends" (Baehr, 2013, p.250, italics in original). But I suggest it is misleading to imagine that the first three characteristics of the virtuous person could exist in isolation from the fourth. This is because the disposition to seek those goods can only come from an understanding of *why* they are goods, which then provides a means of

[32] What makes for an 'epistemic good', whether it is a matter of utility, of recognising truth or of providing a pathway to the truth is difficult to pin down. For an over view and critique of these ideas, (see Macallister, 2012; Baehr, 2011; Fairweather, 2014; Fairweather and Zagzebski, 2001). For the purposes of teaching for thinking, I take epistemic goods to be the norms of inquiry that are established through existing disciplines and teaching practices, including P4C, for that is the task that teachers are charged to deliver.

[33] Virtue epistemologists might include definitions such as: "Intellectual virtue may be demonstrated when: an agent deserves credit for obtaining reliable truth; truth-seeking inquiries are regulated by virtue; a person has a virtuous motivation for truth" (Macallister, 2012, p.253). This is incommensurate neither with the comments so far made, nor with the following synthesis.

recognising them as goods. Traversing such an intellectual landscape is not possible without first developing the skills to construct it.[34] The extent to which these characteristics are necessary for each other or independent of each other remains unresolved. Siegel (2017), for example, considers dispositions and abilities independent of each other and it is not hard to think of examples of skills without disposition to act or dispositions that motivate action that falls short of success. That each is desirable, however, is not in question, and so the distinction has less significance for the educator than the philosopher (*ibid*, p.94).

An education towards virtues of inquiry, however, must still be concerned with what we get students to *do* to help them to develop these skills, dispositions and abilities. The simple answer to this simple question is that we must get students to develop the *disposition* to inquire and to *value inquiry in the right way*, for it is in inquiry that students "focus on what it is to have the good judgement required by guidelines for going about inquiry" (Haack, 1993, p.264). The virtuous elements discussed above are developed through the business of inquiry and hence through the organic nature of thinking about those things required for our inquiry to be productive. Through practice the development of the skills, processes and understanding of norms of intelligently regulated inquiry, including the justification for why these ought to be accepted as legitimately derived and applied, are "intimately intertwined" with the development of virtues (Bailin and Battersby, 2016a, p.369).

The things that we wish students to do to improve their thinking are captured in the schema. We wish them to engage with the subject matter, through a sophisticated and broad use of cognitive skills and to receive feedback on the use of those skills. We also wish for them to appreciate and apply the values of inquiry to their own work and to the work of others in a manner reflective of the norms of inquiry as they have been understood (or model as understanding develops). In the schema, values guide the epistemic practice motivated by the virtues. An education in the values—including through the application of values—is itself an integral part of an education in the virtues. Applications of the values of inquiry are instantiations of the understanding, dispositions and skills that constitute the virtues of inquiry. This is the generalised practice of teaching inquiry and of

[34] I would be overly disposed to codify if I attempted to match particular dispositions with particular virtues on a one-to-one basis. There does not seem anything discordant about saying that a particular virtue, say open-mindedness, contained dispositions to seek out others to test our ideas, to read widely on a topic or to test our own thinking as rigorously as we would the thinking of others. This might sound like a restating of the earlier notion of a disposition—open-mindedness in this case—simply manifesting in different behaviours, but whereas before I might have spoken about the *behaviour* of seeking out others to test our thinking as indicative of a disposition, I am now speaking about the *disposition* to so behave as being part of a virtue.

developing skills, dispositions and virtues. This is a dynamic process, and how it unfolds is of deep pedagogical concern. One key aspect of this dynamic is that it is social.

Just as it is not possible to learn the norms of a language in isolation, it is not possible to learn the norms of effective thinking without social interaction. When learning a language, our skills develop fastest and most fully when we have a chance to speak to another person who also has some understanding of that language. It is only by getting feedback from them that we can determine the success or otherwise of our efforts to communicate with them through that language. If we mispronounce a word so that its meaning is lost to the listener, or if our grammar is so distorted that either meaning is lost or an incorrect interpretation of what we are saying is made, then we have opportunities to correct what we are doing in the full knowledge of what has gone wrong and how we can best correct it. Without such interaction, growth in our competency is difficult. There are parallels here with learning how to reason well. If our arguments are unclear, if we do not express all the assumptions we hold that lead us to a conclusion, or if our conclusions are the result of webs of beliefs that are not shared by others, we might fail to be persuasive to others. More than this, we know that the bar for convincing ourselves that something we wish to be true is in fact much lower than the bar for other people who are not so motivated (see, for example, Strickland et al., 2012). We must learn that the sincerity of our beliefs, or the volume or frequency with which we express them, are not necessarily effective as persuasive techniques. The respect and care we develop for epistemic rigour and rational engagement is born from our experiences with others, not from the introspections of our own minds alone in *a priori* fashion. Thinking well is, in part, a result of our experiences of what others find persuasive and why, as well as reflection upon our own thinking to produce such persuasive effects. Moreover, "socially mediated metacognitive talk about thinking may be a key factor in conferring any benefit the collaborative activity provides" (Kuhn, 2015, p.49).

Let me briefly summarise the elements of the schema having arrived at this point, leaving a more detailed overview for the chapter's end. It is possible to understand effective thinking as, in part, the proficient use of a broad range of cognitive skills and the result of an education in the application of the values of inquiry. Cognitive skills can be thought of as things we do with knowledge, including creating knowledge. The values of inquiry are those things we value in the process of inquiry. We may value them because they lead to more effective outcomes, because they are more closely linked to a preferred epistemology, or because they are the norms of a discipline of which we aspire to be a part or for which we hope to be an exemplar. Pedagogically, the interplay between cognitive skills and values is best facilitated in an environment in which inquiry, including the requirement to use a range of cognitive skills, is permitted and encouraged. A mastery of the values, including a deep understanding of their value and use, developed in a social and collaborative community of inquiry, suggests a pathway to individual intellectual virtue. A version of the schema is presented in full in Appendix 1 but presented in part in Figure 10.

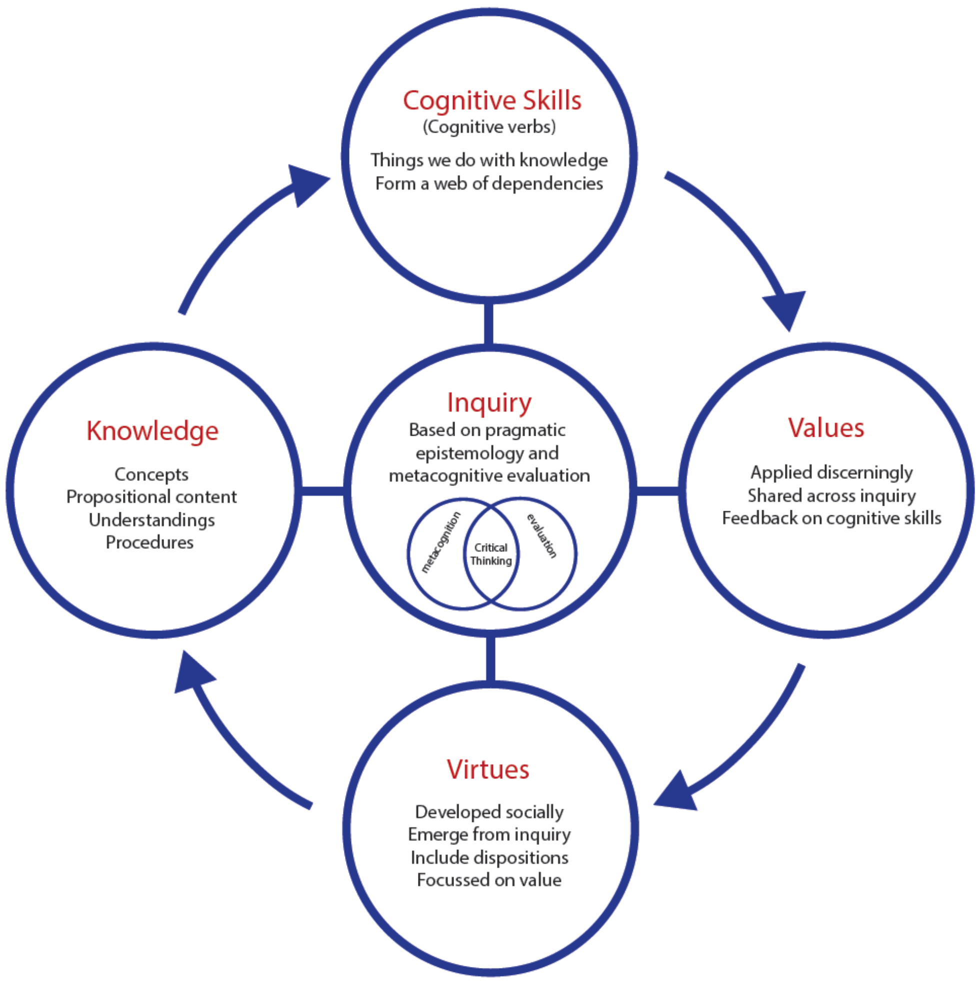

Figure 10: A pedagogical schema for teaching thinking (the pedagogical content knowledge of inquiry)

Note that the elements of the schema included in the diagram are knowledge, cognitive skills, values, virtues and inquiry. I earlier suggested that epistemology and metacognition were also elements, and it might be confusing that they do not appear in the diagram on their own. As the previous chapters have shown, however, epistemology and metacognition are central to the dynamics of Teaching for Thinking and form not only the basis for the inquiry that must drive the development of thinking skills (at least in this conceptualisation) but also the epistemic vigilance for which feedback on thinking is so critical. It is this that justifies the central placement of inquiry in the schema, rather than suggesting or emphasising a direct relationship with the other elements that could each be understood in isolation.

Inquiry as a value

The values of inquiry include simplicity, precision, accuracy, coherence, plausibility and consistency. There is no need for a taxonomy of these terms; they may be grouped coherently together as values that can be applied in the course of inquiry. As so far discussed, they are values evident in the sphere of human activity, which may be physical or intellectual, and may range beyond inquiry and encompass all manner of tasks. Precision is clearly favourable in watch-making, for example. Accuracy is appreciated in architecture. Simplicity is a value that could be applied in furniture design. Nonetheless, they are also values of inquiry. The understanding and use of the values of inquiry within a community of inquiry deliver utility and variety of outcomes. But these have been spoken of as the values of inquiry, being plural. I now wish to speak of the value of inquiry, or, to phrase it slightly differently, inquiry itself as a value.

I have already indicated that there is a strong relational aspect to the application of values of inquiry, as well as to the development of the values themselves in a social context. From this there are two ways in which inquiry itself can be considered a value. The first is that an environment in which inquiry is valued and encouraged is an environment in which the social development and social application of values (including both the values of inquiry and ethical values) occurs. Consequently, the community of inquiry provides a relational structure to facilitate and enhance social cohesion, if only through the propagation of shared values of inquiry. This is not limited to academic disciplines as previous examples might indicate, but might include watch-making, architecture and furniture design, as communities of inquiry are also inevitably communities of practice. Each community has its norms, each can respond to change and innovation, and each can be responsible for its own innovation through inquiry. Perhaps most significant, however, is the input of communities of inquiry into educational systems, which traditionally has been apparent as crafts, trades and academic disciplines contributing to educational programs and experiences. These allow, in theory, the norms of inquiry, and a broader range of them, to be developed at an earlier age than might otherwise occur if children had to engage fully with the individual communities on a vocational basis. If we consider the values of inquiry 'values', then we also value the community of inquiry as the means of developing and refining those values. But the educational community of inquiry, not bound by the demands of a discipline or craft for utility, can extend its epistemic feelers further into the deep inquiry of norms themselves, and to do so in the assurance that it "aims at the production, maintenance and renewal of consensus, a consensus, predicated on the inter-subjective recognition of criticisable validity claims (Habermas, cited in Dallmayr, 1988, p.559).

The second way in which inquiry can be thought of as a value, draws on the pragmatic nature of inquiry outlined in Chapter Three *Pedagogy and epistemology*. It is a consequence of the recognition that, as participants in communities of inquiry, we are not only working within the norms of inquiry to a greater end than we might have been able to achieve individually (via our understanding of the values of inquiry), we are also co-creators of these norms. Because we are intimately connected to inquiry through our contributions to developing and refining its norms, we are ultimately responsible for creating the knowledge that is derivative of this inquiry. In as much as we inquire, we create truths, and, pragmatically speaking, truths have value only as the consequence of inquiry. This parallels the Kantian idea that we draw respect not only as participants in, but also creators of, the moral law. To mirror this syntactically, we draw respect not only as participants in, but also creators of, the norms of inquiry. As we value truth, and as we value those norms as guides to truth, recognising them as 'epistemic goods' we value the inquiry in which the norms are developed and applied also an epistemic good.

5.3 Putting it all together

What has become clear from the ideas developed so far is that teaching people to think well is a pedagogical project rather than a curriculum project. It cannot be achieved through the development of resources that teachers simply implement or that students simply work through. To continue the analogy between learning a language and learning to think, just as it is not possible to learn a language from a textbook (or any collection of resources), it is not possible to learn to think well by just having access to curriculum materials. *What is needed is a teacher with expertise in teaching for thinking who allows their schematic understanding to guide their practice*. That understanding includes a deep appreciation of the relationship between epistemology and pedagogy, a knowledge of how to develop the metacognitive capabilities of students through targeted activities that help them articulate their thinking, and to help students learn to evaluate their thinking by fostering an appreciation of the values of inquiry in a collaborative environment that establishes the norms of inquiry through meaningful social interactions that are both caring and cognitive. Throughout that endeavour, the teacher is able to engage in deliberate practice through conversations with their peers and through private reflections that interrogate with precision and accuracy the schematic understanding and skills she is developing within herself.

The primary concern of this thesis is the development of that expertise, and the work so far has been to develop the schematic structure that is indicative of expertise in the domain of teaching for thinking. The next chapter focuses on several pedagogical considerations that help move this understanding into practice.

Chapter Six: Pedagogical considerations of a schematic approach to Teaching for Thinking

While it could remain the work of this thesis to only outline the schematic structure of pedagogical expertise in teaching for thinking, the implications of having knowledge of that structure are many, significant and arguably urgent. There are several ways to understand this importance. One is that employers consistently rate critical thinking skills very highly in lists of desirable employee characteristics. The Association of American Colleges and Universities (2013) survey noted that 93% of employers believed that "a candidate's demonstrated capacity to think critically, communicate clearly, and solve complex problems is more important than their undergraduate major" (p.1 emphasis in the original). Another is that critical thinking routinely makes the list of those things considered "21st century skills" and is the first one mentioned in the Queensland Curriculum and Assessment Authorities analysis of such skills in education (2015).

Given this, some specific and targeted attention to how to cross from understanding the elements of the schema in the context of practice will be useful for teachers. In §6.1 of this chapter, I extend the understanding of pedagogy and metacognition into implications for teachers of students moving through adolescence, showing how the development of epistemic awareness and metacognition in students can complement each other and what can happen in the classroom to assist this mutual development.[35] I will explain how cognition and content can be linked and how complex content allows scope for developing more sophisticated cognitive abilities. In §6.2, I expand upon the work of the previous chapter and consider some specific concepts and practices in the teaching of skills and values, with some examples of how this can be done. From all of this, I will draw in §6.3 three key pedagogical imperatives that can inform teaching practice and allow the elements of the schema to develop in the classroom. I will show how these imperatives can inform the design of unit plans and of individual learning experiences that focus on cognition and provide opportunities for feeding back on student thinking. In §6.4 I consider how teaching argument structure and the means of evaluating arguments can provide much of the pedagogical and collaborative opportunities that have been identified as essential to develop thinking skills and dispositions. In §6.5, I propose a model to help understand how changes in student cognition can occur as they move towards mastery of conceptual understanding and of the development of a range of heuristics that are

[35] I choose adolescence over early childhood since it is more within my area of expertise, but also because some of the key epistemic and metacognitive changes happen during this phase.

characteristic of good critical thinkers, drawing also on the earlier work of Chapter Four, *Metacognition*.

6.1 The developmental nature of teaching critical thinking

At the end of Chapter Three, *Pedagogy and epistemology*, I mentioned that students' epistemic views did not arrive fully formed. In Chapter Four, *Metacognition and critical thinking*, I indicated that critical thinking was not a binary affair. It is possible to be thinking critically but not be doing it well—in the ME model, to be aware of only some of your thinking or not have very effective means of evaluating it. That progression on both of these fronts is necessary means that serious pedagogical consideration needs to be given as to how they can develop.

Thinking critically requires a range of understandings, skills and abilities, some of which might still be emerging in adolescence. Identifying these factors helps to inform expectations regarding adolescent thinking and provides some guide as to how they may be further developed educationally. I choose adolescence as a focus for this section for three reasons. The first and least important reason is that adolescent students represent the bulk of my own teaching experience. The second reason is that I wish to make moving through epistemic stages rather than cognitive development the central concern of teaching for thinking and focusing on adolescence minimises, if not removes, some issues of cognitive development. While I acknowledge the work of the Swiss psychologist Jean Piaget in childhood development, I leave the question of how any cognitive developmental concerns or epistemic changes as I frame them here may or may not relate to younger students for the analysis of others. The third reason I focus on adolescence is because during this time students typically experience more complex subject matter and this has relevance for my approach, as I will show. A deep analysis of critical thinking includes an investigation of the assumptions and frameworks that individuals have concerning the nature of knowledge and of the act of knowledge acquisition and belief formation. This deeper analysis is an issue of epistemology and was the subject of Chapter Three *Pedagogy and epistemology*. Within this broad understanding of the role of epistemology, a number of factors are in play.

Since critical thinking is not an expectation of toddlers, there are clearly times at which elements of critical thinking remain underdeveloped, or not developed at all, as individuals move towards and through adolescence. Piaget's stages of cognitive development, representing one of the most widely known and educationally prevalent models of cognitive development, are claimed to be largely complete by the time of adolescence.[36] Some individuals, according to Piaget, in early adolescence may still be moving into the final Formal operational stage—which allows for an intellectual engagement with ideas abstracted from their instantiations, and inductive and deductive forms of reasoning—however it could reasonably be assumed that the majority of individuals in adolescence are operating within the Formal stage, and hence that Piaget has less to say about development within adolescence. I acknowledge Piaget here as this is a thesis with educational implications and Piaget has been, and continues to be for some, an influential figure. It is important to note, however, that the idea of clear developmental stages of cognitive ability fixed to the age of the child are not supported by current research nor by the majority of cognitive developmental psychologists (Green, 2017, p.40). Moreover, work in P4C has shown that very young children (3-5) can adopt practically significant epistemic positions through "philosophical play" (Stanley and Lyle, 2017) and properly "philosophize" at age 6 (McCall and Weijers, 2017). Other key concepts of Piaget's, however, are outlined in *Genetic Epistemology* (1970). In this work Piaget identifies some psychological factors involved with knowledge and the act of knowing. These factors, whether or not some are developmental as Piaget suggests and including those which remain relevant throughout adolescence, and indeed into adulthood, contribute to a deeper understanding of critical thinking that goes beyond articulating a series of cognitive development stages, as I will explain in the upcoming section on epistemology and metacognition. These factors include the complexity of domain knowledge, the ability to be aware of and guide one's own thinking, and certain epistemological stages or positions that, following Piaget, can have a significant impact on reasoning towards conclusions.

Critical thinking and domain specificity

I have earlier raised questions about whether critical thinking can be taught, or even practiced, outside of a knowledge domain or discipline (while there is some discussion as to how the terms "domain" and "discipline" are understood, they are treated as synonymous here). Even so, arguments can and have been made so far that the mental processes that we find valuable in thinking are not without some discrete identity that allows them to be themselves objects of study (Kuhn, 1999). The schema contains several of these elements.

Working with ever-increasing knowledge complexity within a domain permits opportunity for even more sophisticated thinking. Since increasing knowledge complexity within a discipline is a

[36] See Piaget (1962) for a short summary of these stages.

characteristic of higher levels of education, and particularly as individuals enter adolescence around the time of their secondary education, it follows that a curriculum that develops in discipline complexity could also help develop the ability to think critically—with a focus on skills other than simple recall. Dealing with complexity involves *understanding* that which is complex (see §1.3 *The nature of expertise*). The relationship between understanding and thinking is an important one to articulate again at this point, since doing so helps to appreciate how effectiveness and efficiency in problem solving and decision-making, both characteristic of critical thinking, can be achieved. Recall that something that can be understood is something that has complexity in terms of its constituent ideas or elements and the relationships between them (Sweller, 1994). A list of random names, places or numbers can be remembered, but the concept of understanding does not apply to such tasks. It does make sense, however, to ask if someone watching a soccer game understands what they are seeing. The game is complex because it contains many elements—players, markings, goals, referees, positions, rules, etc.—and these elements have a high level of interactivity as the game progresses. Similarly, simple ideas in the disciplines of history or chemistry, for example, require less understanding than do complex ones. But understanding is more than simply knowing that relationships exist, it is also about knowing the elements through their relationships with each other. A food web showing a predator's relationship to its prey and other elements of the ecosystem, for example, helps define that predator in terms of its environment as well as by its intrinsic characteristics. A complex idea that is well understood therefore allows individuals to think better with it and within it. We think to attain understanding and understanding allows us to think towards greater understanding or to use that understanding to solve problems and make decisions. Hence, an increased understanding of complex ideas, objects or constructs helps us to think critically using them. Understanding, therefore, is not a cognitive skill, it is a mental state to be attained.

As I explained in Chapter One *Expertise*, knowledge that provides frameworks for categorising information and representing structural relationships among those categories rather than held as individual, isolated elements is called schematic knowledge. Schematic knowledge has several advantages over non-schematic knowledge in terms of the ability to think effectively and efficiently, including minimising the need for working memory and speed of access to information. The amount of working memory accessible to us at any one time is severely limited and fades rapidly without reinforcement through stimuli. To learn a phone number in the short term, for example, it is necessary to repeat it to yourself or write it out several times to prevent the numbers from fading from memory. Individual elements of disorganised information require the use of working memory so that they can be made available for specific cognitive purposes. Schematic knowledge, however, can be recalled as a unit without taxing working memory and with all the elements of that schema readily available as a resource. This transition towards schematic knowledge and the state of understanding is also indicative of expert knowledge and of mastery in a domain, explaining both the speed and efficiency of expert's thinking. Novices and the inexperienced think slowly and inefficiently using disconnected information, while experts think quickly and efficiently using schemata. Much of the knowledge children learn formally in school is non-schematic knowledge. As they develop, their view of the external world becomes more integrated and meaningful. This transition from disorganised knowledge that can be recalled in isolation to highly organised, schematic knowledge committed to long term memory is accompanied by a reduced need for working memory, or a reduced cognitive load.

The ability of adolescents to deal with increasing complexity is therefore a function of, in part, their educational experience. If attention is paid to developing understanding and building schematic knowledge, rather than focusing on recall of content, and if that understanding is used to think critically, solve problems and make effective decisions within a domain, then this provides a viable path to developing critical thinking in adolescence.

Cognition and self-regulation

The development of students' domain knowledge as they progress through their educational experience is determined, in part, by the design of the curriculum they experience. Other factors involved in the development of critical thinking are intrinsic to adolescents. These include factors related to cognitive capacity and to emotion. The continuing maturation of the frontal lobe (and its connections to other regions of the brain) during adolescence and the onset of puberty are potential biological conditions to consider, with possibly significant consequences for how cognition occurs and for the dispositions and self-regulatory processes that mark effective critical thinkers. These considerations create an environment in which several distinct developmental dimensions may be moving forward with some degree of independence from each other, rendering the broader process of developing critical thinking in adolescents non-linear and multifaceted.

In terms of cognition, individuals in the early phases of adolescence typically display a rapidly increasing ability to engage successfully with situations involving more complex reasoning skills and that require more abstract information to be processed (Steinberg, 2005). The exact nature of the link between this development and growth in the brain remains unclear, though the two factors are clearly causally connected. This increased reasoning ability would seem to bode well, but cognitive capacity is only a necessary condition for developing critical thinking; it is not a sufficient condition. Distinguishing between critical thinking and critical thinkers (see Chapter Four *Metacognition and critical thinking*) helps to make this point more clearly.

The characteristics of paradigmatic critical thinkers—the virtues of inquiry—include openness to new ideas, a willingness to engage, persistence in inquiry, intellectual integrity, a commitment to reason, and a willingness and ability to change one's mind based on evidence and argument. Another essential characteristic is the ability to self-regulate mental processes including applying criteria that distinguish good from bad thinking. Self-regulation, however, is problematic in adolescence as a result not only of continuing frontal lobe development and the executive control it subvenes, but also of puberty and the emotional turbulence it creates. Susceptibility to factors such as peer-pressure, the development of early sexual and romantic relationships and a developing understanding of norms of good behaviour also contribute to this problematic self-regulation. Even when cognitive function is at a level where rational decision-making can occur, confounds originating in emotion and inexperience may significantly inhibit the ability to make effective choices.[37] Over-active emotional responses may also impact upon the ability of adolescents to work well with domain knowledge. Working memory is highly sensitive to stress, for example, with even small increases making its use difficult if not impossible—something true for all ages, not just adolescence. Puberty is not only emotionally distracting but creates social and individual circumstances that can significantly affect information processing and self-regulation of cognition (Steinberg, 2005; Casey and Caudle, 2013; Farley and Kim-Spoon, 2014).

Epistemology and metacognition

As we have seen, the very notion of what is rational, what makes for a good reason and how we understand the concepts of justification, truth and evidence are all epistemological issues. Without a discussion of these issues, we would not be being critical about being critical thinkers. Students' ability to deal with these concepts improves their effectiveness as thinkers. This could be seen, as in the concepts of understanding and schematic knowledge mentioned above, as a curriculum project; that is, while it may certainly be influenced by other developmental factors, it could be planned for in isolation from them. This stance is based on a philosophical understanding of epistemology in which knowledge, and the issues that relate to it, can be understood themselves as objects of study distinct from the individual as the knower. Piaget, as mentioned earlier, found this view deficient in

[37] Not all emotional activity is detrimental to decision-making, indeed emotion is a necessary condition for making rational decisions (Damasio, 1999, 2001).

that it did not address the developmental aspects of human psychology that could contribute to an understanding of epistemology. This insistence upon the importance of psychology to epistemology is consistent with Piaget's view that knowledge of an object was not something passively received but was rather a way in which the object could be cognitively acted upon. While the complexity of this notion cannot be explored fully here it will suffice to note that the cognitive actions involved in knowing must be a function of cognitive development. Piaget, then, widened the focus of epistemology from knowledge itself to include the cognitive landscape of the knower. (This focus was explicitly psychological, unlike that of Dewey, whose focus on the knower was also central to understand thinking and education but was not from a psychological perspective.)

In the context of critical thinking, epistemology and metacognition are strongly related concepts. Metacognition is the awareness of one's own mental operation at a variety of levels from basic acts of thinking to the possession and achievement of broad strategic goals. Self-regulation implies metacognition, since to self-regulate one must be aware of the thing to be regulated, which in the context of critical thinking is our cognition. Self-regulation via metacognition also implies the existence and effective use of criteria by which success can be judged or by which progress towards some perceived end-point can be measured. Certain epistemological changes in individuals provide both the possibility and opportunity for more effective metacognition.

William Perry's (1970) work on the epistemological views of students has provided the foundation for a range of continuing research into how epistemological theories can affect student performance. This original work led to others (see, for example, Knefelkamp and Slepitza, 1976) postulating four broad sequential categories: dualism, characterised by a belief in the absolute nature of truth and that this knowledge is held by experts; multiplicity, characterised by an acknowledgement of a plurality of views but seeing this plurality as either a consequence of ignorance of the truth or of the truth being unattainable; relativism, characterised by an awareness of the role of the self in knowledge (and meaning) making and that knowledge is contextual and non-absolute; and commitment within relativism, characterised by a commitment to and affirmation of certain positions within a relativistic framework . Barbara Hofer and Paul Pintrich (1997) have outlined the development of this research from Perry's original work and have also provided a useful summary of this and other models of epistemological change from adolescence into adulthood. There are a number of commonalities, if not ubiquities, in this work, and some key ideas that can be applied to adolescent development in critical thinking. Some of these now follow.

Assertions are generally viewed by individuals below the age of four as representing beliefs that are themselves accurate mental representations of reality (Kuhn, 1999, p.19). The possibility that different people hold different representations of reality does not seem to be engaged with[38]. The epistemological reason that toddlers do not think critically, as noted above, is that, in their world picture, there is nothing to be critical about. If all beliefs are accurate, or at the least applicable, then there is no call for the application of criteria to help discern which statements should be believed. In such an epistemologically flat world, there are only direct connections and representations of reality to deal with. This lack of epistemological variety also implies a lack of metacognition. At best, it is logically possible for the individual to state only that they have a belief or not. At worst, the concept of belief itself is an odd one. After the age of four individuals become aware that others hold different beliefs, which are expressed through assertions different from their own. It is at this time that some level of critical thinking can begin to emerge. In the first case, it becomes possible to evaluate a claim by reference to the available evidence, which itself provides the criteria for truth. Thus, a claim that there are two bananas in a bowl can be subject to empirical investigation. Perhaps more significantly for abstract thinking, it also becomes possible to locate knowledge in part as a function of the individual rather than just in the external world, even while the source of truth remains external. This shift in focus requires a representation of that belief and how it might have been developed and hence the possibility of understanding the means by which such a belief is developed. The potential increase in epistemological variety therefore implies a richer potential metacognitive experience. Even so, epistemological investigations at this age are generally restricted to checks against reality and do not provide scope for the kinds of critical thinking we would expect in adolescence.

The extent to which further epistemological progress represents progress through developmental stages or simply changes in positioning (or stances) as experiences and intellectual engagement with the world increase in sophistication and complexity is not entirely clear. Either way, it is common to conceptualise this progress as having two aspects, first the nature of knowledge and secondly the nature of knowing, or knowledge acquisition (Hofer and Pintrich, 1997). 'Knowledge' moves from being regarded as absolute and independent of the knower to being regarded as contextualised, tentative, provisional and dependent upon the knower (and hence is more aptly described as 'belief'). 'Knowing' moves from knowledge being received more or less passively

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[38] This has been supported by early work in so-called 'false belief' tests, in which children below the age of four seemed unable to attribute what they saw to be a false belief to others. Recent work, however, in which the abstract nature of the tests and the children's verbal responses has been replaced with an observation of their actions in less abstract situations has shown even children much younger than four years old understand that others have false belief (Brincker, 2014).

from an authority, requiring little or no justification beyond its source, to being constructed by the knower and, in the process, subject to methods of critique and evaluation to determine its credibility (and hence is seen as justification for beliefs).

Individuals entering into adolescence (or before) can evolve epistemologically from an initial position that recognises a plurality of views in the individuals around them, each of which can be a candidate for truth, but insists that only one view can claim that status. This represents an absolute view of knowledge as fixed and external and a passive view of learning as receiving the correct representation of reality. The next position is to allow the views of others to each be seen as epistemologically valid. Experts may disagree because there is no right answer, and each person makes sense of the world around them in a way that is internally coherent and legitimate according to their own criteria. This is a kind of subjectivism, in which no absolute or external standard can trump individual knowledge. From here, however, individuals can move to another position in which this equivalence of credibility is challenged. Assertions and beliefs, and the arguments used to support them, can be analyzed and evaluated according to criteria based on rational norms. While accepting that knowledge can remain tentative, the degree to which it can be trusted to guide behaviour and to further inquiry depends on warrants such as demonstrated utility, coherence with broader claims, evidentiary support and its capacity to be used to generate more knowledge. Personal views justified by collectively established epistemological criteria take the place of views justified solely by authority, or by the lack of any credible means, or motivation, to replace existing views. Theorists divide these epistemological positions—from knowledge as absolute and fixed to knowledge as contextualised and provisional and from knowing as passive reception to active construction—using a range of resolutions. Perry (1970) chose nine distinct positions, with others condensing this to four (as mentioned earlier) and others framing their own in style and number of positions as a result of slightly different conceptualisations or methodologies of inquiry.[39] Nevertheless, a general epistemological trajectory as outlined above allows some useful points to be made.

The first point is that this is not an inevitable progression from adolescence to adulthood. There are many adults, for example, who have not progressed beyond either an absolute view of knowledge or, if they have, beyond a subjectivist stance that eschews any requirement to subject claims to objective criteria of evaluation. That this is the case speaks against the notion of epistemological development being entirely described by stages of cognitive development. The second point is that

[39] See Hofer and Pintrich (1997) for details of these conceptualisations.

the need for effective critical thinking skills is most pressing in the last position of epistemological development, and largely absent in the subjectivist position. While testing competing claims for truth in the earlier absolute position requires some analysis and evaluation, it is not, as mentioned above, as comprehensive nor sophisticated as in the later position.

As before, this change in epistemology allows for a change in metacognition. An epistemological position in which context is critical and in which the act of knowing is a part of that context broadens the metacognitive landscape to include complex factors such as our own cognitive biases, warrants for belief, alternative positions and framing of problems, the way in which the self and others may be persuaded through argument and the need to nurture an "epistemic vigilance" (Sperber et al., 2010) to avoid being deceived by others.

This metacognitive gain from epistemological pain also extends into what Deanna Kuhn (2000) calls "metastrategic" thinking. The complexity of metacognition possible in a well-developed epistemological position allows for several levels of contemplation. Not only can individuals consider their thought processes as they go about the business of thinking and evaluate these as successful or otherwise against the desirable outcomes of the task at hand, but they can also strategically consider which of the cognitive skills and capabilities at their disposal could best be applied in a particular context and why these would be the best. This is a level of representation that goes beyond that involved in awareness and acknowledgement of basic cognition and speaks directly to the concept of self-regulation that is necessary for critical thinking.

The idea of metastrategic thinking follows the work of David Perkins and Gavriel Salomon (1989) who have also pointed to the value of the so-called "high road" transfer of knowledge from one domain to another resulting from a deliberate focus sustained across contexts to determine unifying principles that can be applied to novel situations either within a domain or between others (as opposed to the 'low road' transfer of knowledge through automaticity of a skill to new situations which has limited impact). Both of these attempts to articulate high-level metacognitive activity as the strategic and intelligent application of general cognitive skills suggest this 'metastrategic high road' is also the key to enabling transfer of skills from familiar to unfamiliar contexts, since it is the discerning selection of skills for specific contexts, rather than just the existence of the skills themselves that permits transferability.

Recall that an advanced epistemological position—the pragmatic epistemology outlined in Chapter Three *Pedagogy and epistemology*—is an important educational objective at the core of Philosophy for Children. This epistemology rejects relativism (and subjectivism), gives more weight to justification than claims of truth and uses collaboratively constructed norms of inquiry to develop a regulatory framework for inquiry within which competing claims can be judged. One of the strengths of the Philosophy for Children movement is its focus on developing exactly the pragmatic epistemological stance that is a necessary condition for developing high-level thinking skills as outlined above.

The conclusion to be drawn from all of this is that the optimal development of critical thinking skills in adolescence requires the development of a sophisticated epistemological stance that provides the possibility, opportunity and motivation to engage in high-level metacognition. Epistemology and metacognition, especially in the discussion of transferability, therefore build on the connection between critical thinking and domain specificity.

Adolescence is a time of cognitive and emotional development, and these two components do not necessarily grow in a coordinated fashion. Consequently, critical thinking skills may be potentially accessible through cognitive growth but also influenced by still-developing skills in self-regulation. Because of this disconnect, and the fact that they are at an age in which vulnerabilities in terms of relationships and self-knowledge are inevitable, it is therefore an educational imperative that adolescents are provided with the intellectual skills that make understanding their place in the world more achievable. Critical thinking as an educational goal is also concerned with the development of virtues of inquiry and therefore with issues of character, something that remains somewhat malleable in adolescence.

6.2 Teaching skills and values

In this section I will develop some simple activities and ideas that can assist students to make this journey. These activities have been delivered and trialled in professional development sessions with teachers and have formed the basis for systemic change in several schools.[40] They are intended only as exemplars of practice (noting that the common use of exemplar as an outstanding example should be replaced by the more accurate use of a typical example) and there are many possible variations of these activities that achieve a similar outcome. It is not the purpose of this thesis to

[40] Several independent evaluation reports have been produced for internal use within schools (e.g. Cavendish Road State High School and Brisbane Grammar School) but are yet to be published.

provide a rich source of resources, only to show how they can be generated from a schematic understanding using a few examples.

Cognitive skills

As mentioned in the introduction of this thesis, there is some debate about how the teaching of effective thinking can exist outside a discipline context. In the previous chapter, I presented a way of understanding the relationship between the categories of cognitive skills and the values of inquiry, specifically that the values can provide feedback on the application of cognitive skills, in the hope of providing a clearer understanding of how thinking can be understood and therefor progressed.

In this section, I explore an aspect of how we might specifically teach the cognitive skills, or at least better structure our approach to doing so. I hope to show through this, as I did earlier, that some effective teaching for thinking can occur outside a discipline context, but without diminishing the value of doing so within a discipline context. Indeed, I hope to make doing so in the latter case easier through the following examples. Before I do so, however, I will extend my earlier discussion of cognitive skills, focussing on some issues of pedagogical significance.

Relationships between cognitive skills

The most common structuring of cognitive skills has been that of Bloom's taxonomy, which has had a high profile in education since its introduction in 1956 (Seaman, 2011, p.23). The taxonomy represented a hierarchy of cognitive skills as shown in Figure 11, and from this the term 'higher order skills' came into common use.[41]

[41] Despite 'understanding' as represented on the taxonomy not being a cognitive skill as discussed §6.1 *The developmental nature of teaching critical thinking*.

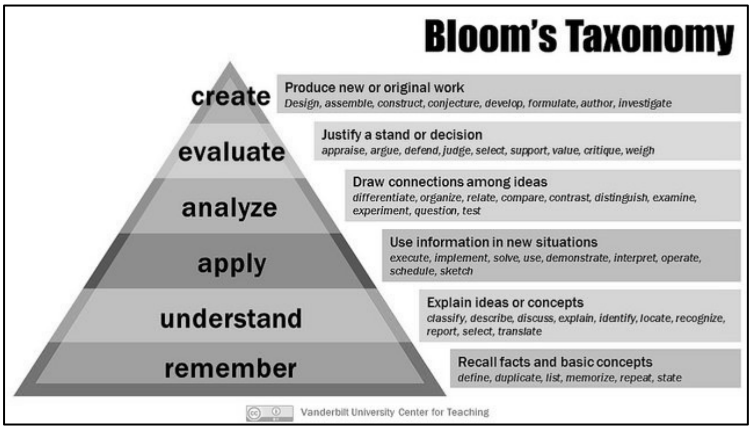

Figure 11: Bloom's taxonomy
https://flic.kr/p/LQuqT2

Bloom's taxonomy has been extremely influential in educational thinking, and it is rare to find a school or university that would not contain posters, books or activities built around his ideas. But the nature of a hierarchy of cognitive skills is problematic on several fronts, and significantly so. That it has serious flaws is so serious a charge in the minds of some that I reproduce Marzano's criticism below in detail.

> As influential as Bloom's Taxonomy has been on educational practice, it has experienced some severe criticisms (for a review, see Kreitzer & Madaus, 1994). One of the most common criticisms was that the taxonomy oversimplified the nature of thought and its relationship to learning (Furst, 1994). The taxonomy certainly expanded the conception of learning from a simple, unidimensional, behaviorist model to one that was multidimensional and more constructivist in nature. However, it assumed a rather simple construct of difficulty as the characteristic separating one level from another: Superordinate levels involved more difficult cognitive processes than did subordinate levels. The research conducted on Bloom's Taxonomy simply did not support this structure. (Marzano, 2006, pp.8–9)

and

> The problems with Bloom's Taxonomy were indirectly acknowledged by its authors. This is evidenced in their discussion of analysis: "It is probably more defensible educationally to consider analysis as an aid to fuller comprehension (a

lowerclass level) or as a prelude to an evaluation of the material" (p.144). The authors also acknowledged problems with the taxonomy's structure in their discussion of evaluation: "Although evaluation is placed last in the cognitive domain because it is regarded as requiring to some extent all the other categories of behavior, it is not necessarily the last step in thinking or problem solving. It is quite possible that the evaluation process will in some cases be the prelude to the acquisition of new knowledge, a new attempt at comprehension or application, or a new analysis and synthesis" (p.185). In summary, the hierarchical structure of Bloom's Taxonomy simply did not hold together well from logical or empirical perspectives. (Marzano, 2006, pp.8–9)

Such criticisms, once made, open the gate to verification through simple reflection. The skills of categorising, for example, which may be seen as lower order by some, invariably requires some level of analysis to complete. To identify something might demand very sophisticated analysis, synthesis and evaluation. The counterexamples to the hierarchical claim quickly reach critical persuasive mass. But if a hierarchy does not exist, how are we to understand the relationships between these skills? I suggest it is far more educationally useful to understand cognitive skills as nodes in a web of actions each of which, when called into play, pulls on others around it as context demands. When analysing, we might also be identifying, interpreting, organising, synthesising, and so on. When justifying, we might need to also evaluate, infer, analyse and organise. This kind of relationship is suggested by Figure 12. I will explain shortly how this looks in practice.

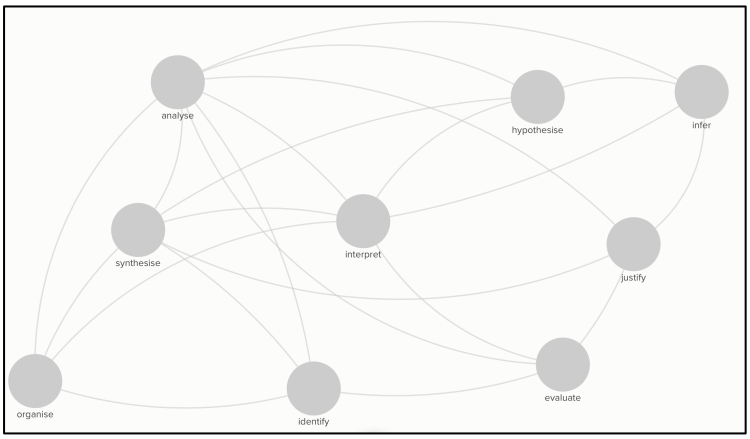

Figure 12: A web of cognitions

Teaching about cognitive skills

When discussing the values of inquiry, I suggested there are three things to know in their teaching. The first is that something is a value, the second to know why it is a value, and third is knowing how to apply the value. There is a similar structure for cognitive skills, but application is replaced by execution. Let me explain using the example of the cognitive skill, of analysis.

We might first consider teaching students what analysis is. This is a relatively straightforward matter in terms of its definition, but there is no need to be overly pedantic in word choice. Perhaps something along the following lines will suffice for a discussion with students: analysis is the process of breaking down an object or construct into its constituent parts or elements, looking for categorical similarities between and within the elements, considering any logical or causal connections between these elements and their categories, and determining the relationship between each of these elements in terms of the overall purpose or function of the object or construct. We might also include some discussion of how or why each of the elements or categories of elements might be more significant and relevant than others.

If we accept this kind of definition, granting there are many other ways to say much the same thing, then it immediately becomes possible to fashion some questions that can be used to clarify a particular instantiation of analysis. These questions could include:

1. What are the elements that make up this object/construct?
2. Can these elements be grouped into categories?
3. Are there causal or logical relationships between these elements or categories?
4. What role do each of the elements or categories play in the overall purpose or function of the object/construct?
5. Which elements are the most significant or relevant? Why is this?

I do not suggest that these are *the* questions of analysis, but they are some questions that relate to the concept of analysis. It is the process of both coming up with a workable definition and then using that to generate a list of questions that seems to me to be a worthwhile endeavour. This process of generating definitions and consequent questions provides students with a strategy to approach the thing they wish to analysis. It is not the analysis itself. I will look at three examples of how this type of approach could be used: one visual, one text-based, and the other diagrammatic. In each of these quite different examples, the effectiveness of a common approach will be evident.

Figure 13 shows an image created in the image manipulation program Photoshop.

Figure 13

Source: http://designblogsip.blogspot.com.au/2012/10/amazing-photoshop-manipulation-from.html

Let me apply the analysis questions that I outlined above to this image and answer them in turn.

1. What are the elements that make up this object/construct?

- The knife held at a diagonal to the viewer that separates the uncut elements of the image from the cut elements
- The sliced section of fingers
- The sliced vegetables
- A cutting board or bench top
- The colours of the image
- The first-person perspective
- The positioning of the elements

2. Can these elements be grouped into particular categories?

- There are human and non-human elements

- There are elements groups by shape
- Those generally thought to be food and those not considered food
- That which cuts and that which is being cut
- Colours of red, green, grey and pink

3. Are there causal, conceptual or logical relationships between these elements or categories?

- One kind of thing is cutting another; the other being cut
- Humans and their food
- We expect to see red from the wounds, and we do, but not where it should be
- The human slices are being collected with the food slices

4. What role does each of the elements or categories play in the overall purpose or function of the object/construct?

- The red indicating the expected blood is shifted and hence jarring
- The similarity of the shapes and sizes of the food and human finger slices emphasises their indented purpose as a kind of food
- The knife is in the act of cutting and hence this seems an active scene
- The parts together normalise the idea of cutting and eating our bodies, breaking down our strong sense of self and not-self

5. Which elements are the most significant or relevant? Why is this?

- The red colour for the striking effect of blood
- The dynamic nature of the image showing it is happening in real time
- The first-person perspective allowing us to better imagine this is happening to us
- The similar size and shape of the human and non-human elements

Were a student to have offered this response, we could see that they understand what analysis is and that there is a strategy they can use to being to explore the image that would enable them to do something effective by way of examining the deeper structure of the image.

Figure 14 represents the text of a question on the Queensland Core Skills Test.

UNIT SIX

In the 1920s a decision was made to eradicate the wolf population in Yellowstone National Park in the USA and by 1926 the last Yellowstone wolves had been killed. The following adapted extract discusses the consequences to the environment of the eradication of the wolves and the subsequent reintroduction of them 70 years later.

> When the new wolves in Yellowstone first came calling, the area's elk[1] stood their ground as though they were still dealing with coyotes[2]. Bad plan! Today Yellowstone holds half the elk it did 15 years ago in 1996.
>
> With a near-unlimited meat supply, Yellowstone's new wolves rapidly multiplied. But by 2008 their numbers had fallen. Doug Smith leads the Yellowstone Wolf Project. He says, 'Numbers of wolves never got as high as we expected based on the availability of prey. Wolves move in packs and are very selective hunters. What counts for them is vulnerable prey.' Pack-hunted elk turn into less vulnerable quarry. They become more vigilant and keep on the move more.
>
> During the wolfless era, herds practically camped at favourite winter dining spots, foraging on the young aspen, willow and cottonwood until the stems grew clubbed and stunted like bonsai plants. Released from such grazing pressure, saplings now shoot up to form lush young groves. More songbirds find nesting habitat within their leafy shade. Along waterways, vigorous willow and cottonwood growth helps stabilise stream banks. More insects fall from overhanging stems to feed fish and amphibians.

Notes: [1]species of large deer
[2]small wild dogs

Figure 14

Source: Queensland Curriculum and Assessment Authority 2004 Core Skills Test (Short Response)

One again, consider the questions outlined above in relation to the meaning of the text in the question.

1. What are the elements that make up this object/construct?

- The wolves
- The elk
- The park itself
- The rangers
- Various trees, fish and insects
- The ecosystem as a whole

2. Can these elements be grouped into particular categories?

- There are predators and prey

- Living and non-living elements of the system
- Human and non-human

3. Are there causal or logical relationships between these elements or categories?

- There are predator and prey relationships
- Causal relationships between populations abound and influence each through habits of predation and grazing
- Humans have the capacity to affect change in the ecosystem through management of causal factors

4. What role does each of the elements or categories play in the overall purpose or function of the object/construct?

- Many are part of the dynamic interaction that is the ecosystem as a whole
- Increasing one population may decrease another, and vice versa through long causal chains
- The ultimate decision as to the fate of the ecosystem seems to rest with humans

5. Which elements are the most significant or relevant? Why is this?

- Human decision making, which ultimately influences all else
- The presence or absence of wolves
- The relationship between wolves and elk
- The effect overpopulation of elks has on the ecosystem

Again, this may be an amateurish understanding of population biology, but I have been able to make significant progress using structured questions based on my understanding of analysis.

Lastly, Figure 15 shows a force diagram on a water skier.

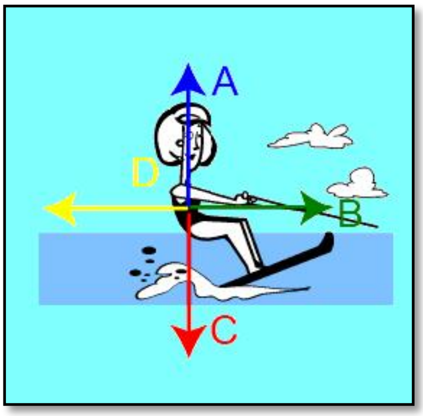

Figure 15

(http://www.wignallandwales.co.nz/NDSWB/Sample-files/waterskier.jpg)

Questions again provide a path into analysing the diagram.

1. What are the elements that make up this object/construct?

- The skier
- The water
- The rope to which the skier is attached to the boat
- Gravity
- The force of the water on the skis

2. Can these elements be grouped into particular categories?

- Objects
- Forces
- Normal (reactive) forces and other forces
- Opposing forces and non-opposing forces

3. Are there causal or logical relationships between these elements or categories?

- The tension in the rope is a function of how the skier interacts with the water
- Opposing forces can be added using vector addition
- Non-opposing forces do not affect one another
- Newton's three laws of motion are in play

4. What role does each of the elements or categories play in the overall purpose or function of the object/construct?

- The greater the net force forwards the greater the speed of the skier
- How the skis distribute weight influences the equation
- The mass of the skier also affects speed for a given force

5. Which elements are the most significant or relevant? Why is this?

- Net force forwards for determining speed
- Mass of skier to determine force/speed outcomes

This analysis may be sufficient to provide a framework for then calculating the values of the forces involved and making predictions about the outcome.

These examples demonstrate two significant points, which I will extend into a third. The first point is that it is entirely possible to teach what analysis is relatively free of a discipline context, but by using examples from a range of experiences the idea becomes clearer. Knowing what analysis is provides a strategy for interrogating the circumstances of a problem or situation through setting the questions above in context. The second point is that the ability to answer these questions will be improved as a student's understanding of the discipline increases. I might simplify this by saying that the questions are not discipline specific, but the answers are.

Similar activities can be organised to structure the understanding and use of skills such as justification. Indeed, we often use an analysis of something to justify a position to hold or action to take. My justification for why I would invest in a certain portfolio could be based on my analysis of past performance of that portfolio. A justification for choosing a particular car could be based on analysis of a range of factors such as cost, performance, fuel economy and so on. Cognitive skills thus stand in relations to one another as noted in the cognitive web model.

As a further example of these relationships, consider Figure 16 below showing a representation of the Aztecs.

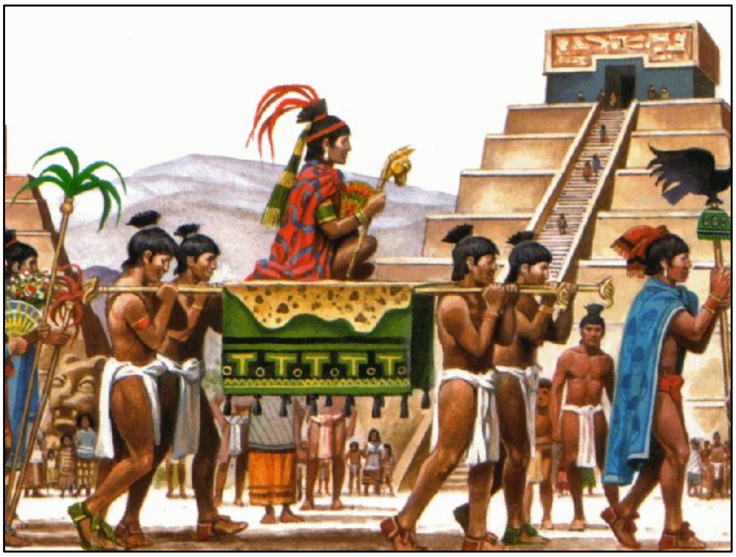

Figure 16
http://www.militaryoftheworld.yolasite.com/about-the-aztec-empire.php

Students might be asked to *infer* from this image information about climate, architecture, flora and fauna, power structures, the role of religion, etc. While doing so, they will be *analysing*, *conjecturing*, *classifying*, *identifying* and hopefully *justifying* their claims as well. An instruction relying on one type of a cognition can act as a call for other types to be deployed as necessary to complete the task. Tasks requiring cognitive work typically deploy complementary sets of skills rather than isolated skills. Appeals to focus on higher order thinking skills, such as those made by the Australian Council for Educational Research (ACER),[42] would therefore be better spent directed towards ensuring a broad range of cognitive skills is demanded of students, and that these skills are used with the kind of sophistication that allows for their effective, complementary deployment.

Cognitive skills and criteria

A consequence of this shift in focus away from a skills hierarchy is the difficulty of justifying using "higher-order" skills as discriminators for high-level cognitive performance. Criteria sheets that reserve *evaluation* or *analysis* for A or B level students, on the assumption that it is the use of those skills that indicates superior overall performance regardless of the task, are informed by the

[42] The ACER report suggests that: "Beyond the achievement of minimal competence, students also need to develop what are often called 'higher order' thinking skills including critical literacy, critical numeracy and cross-curricular competencies." (Forster, 2004)

hierarchy model and are subject to the criticisms made by Marzano—recall the error of making "a rather simple construct of difficulty as the characteristic separating one level from another." These skills can be used at a very low or passing level as well. Granted some tasks may be inherently geared to demonstrate the highest performance using these skills, but there is nothing inherent in the skills themselves that makes this logically necessary as the cognitive web model shows.

Table 2: Australian Curriculum Achievement Standards for English Years 4 and 6

Year 4 Achievement Standards	Year 6 Achievement Standards
By the end of Year 4, students ***understand that*** texts have different text structures depending on purpose and context. They ***explain*** how language features, images and vocabulary are used to engage the interest of audiences. They ***describe*** literal and implied meaning connecting ideas in different texts. They fluently read texts that include varied sentence structures, unfamiliar vocabulary including multisyllabic words. They express preferences for particular types of texts, and respond to others' viewpoints. They listen for and share key points in discussions.	By the end of Year 6, students ***understand how*** the use of text structures can achieve particular effects. They ***analyse and explain*** how language features, images and vocabulary are used by different authors to represent ideas, characters and events. Students ***compare and analyse*** information in different and complex texts, ***explaining*** literal and implied meaning. They ***select and use*** evidence from a text to ***explain*** their response to it. They listen to discussions, ***clarifying*** content and challenging others' ideas.

Source: https://www.australiancurriculum.edu.au/

That a range of "higher-order" skills can be used at a basic level also means that there is no argument for reserving analysis, say, for students above a certain year level. Table 2 shows Australian Curriculum Achievement Standards for Years 4 and 6 English. It is immediately obvious that different cognitions are required of students in these year levels to meet the standards (I have highlighted aspects to indicate this).[43] In Year 8, students go on to *interpret*, and in Year 9 they extend their cognitions to *evaluate* and *integrate* (The Australian Curriculum, n.d.). While it is true that there is evidence of a greater complexity of context from Year 4 to Year 6, and that more a complex context can lend itself to a broader range of cognitions (see §6.4, *Critical thinking in adolescence*), it is not true that in the context of Year 4 students do not analyse, compare, clarify or indeed interpret or evaluate. It may be justifiable to claim that more complex contexts mean these cognitions may be used in a more sophisticated manner, but that is a very different claim from their absence.

The danger of this approach is that if analysis is not required as a standard then the development of the skill will not be a priority. If we are going to speak about and plan for student cognitions, we should do so with care. How this can be better achieved will be dealt with after we consider the nature of teaching values.

One more point should be made about cognitive skills in the context of teaching and planning, however. It is not unusual to hear problem-solving or decision-making spoken of as part of the skill set of a critical thinker. But we can understand these things as higher-level processes which require a range of cognitive skills of the sort we have spoken about to complete. Each of these might require analysis, synthesis, identification, evaluation and so on. But the relationship between problem-solving, decision-making and the cognitive skills does not seem to be like the relationship between each of the cognitive skills. Whereas the cognitive skills make a web of interacting cognitions to be used in context, one does not draw on problem-solving to categorise in the same way one can draw on analysis. As we have seen, we can develop a strategy to analyse a situation, but a strategy to 'solve a problem' is not so generic.[44]

Values

The values of inquiry are those things that we value in the act of inquiry and in our thinking. They are also useful in communicating our thinking. In the classroom community of inquiry, however,

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[43] It is debatable whether the phrase 'understand that' is different in any meaningful way from 'know that', whereas 'understand that' is clearly different from 'understand how' (see sections 1.3 and 6.4 for supporting discussions). While understanding is not a skill, I highlight it in the table because the cognitive skills required to 'understand that' are different from those required to 'understand how' in the same context and are thus indicative of different standards based on types of cognition.

[44] For more specificity on problem solving, see (Mayer, 2012; Robertson, 2017)

what is communicated is rarely the completed product of student cognition but rather the process of student thinking as it is happening. As students and teachers move forward they share outputs and those outputs become the inputs for others and they progress collectively in a kind of thinking that is intimate and social. Students may arrive at epistemic waystations, where they pause for a short or long time and consider or evaluate their positions, but they (ideally) seldom think they have arrived at a place of certainty and pack away their tools of inquiry.[45] This fallibilistic position is the position of philosophical pragmatism outlined earlier in Chapter Three, *Pedagogy and epistemology*. The community of inquiry can offer conditions in which socially distributed cognition can flourish.

> Our daily lives are filled with instances in which we influence each other's constructive processes by providing information, pointing things out to one another, asking questions, and arguing with and elaborating on each other's ideas. (Renick, 1991, p.2)

When we are inquiring, which is to say thinking, we are in constant need of feedback on our thinking. Since values are what we need to construct criteria that can determine the quality of our thinking, the values of inquiry are at the core of the project of teaching for thinking. But it is not enough to simply give students criteria for thinking well and expect that they will be able to match their thinking, or that of others, against set criteria in the same way we can for a quality control process for items produced in a factory, for example. As I outlined in Chapter Five, *Skills, values and virtues of inquiry*, values need to be understood and applied.

Elder and Paul have chosen nine terms to cover a basic set of standards, these being: clarity, accuracy, precision, relevance, depth, breadth, logicalness, significance, and fairness. These words are not of themselves completely instructive as to their application, so some time must be spent in an educational context developing their meaning and use. In this development, their meaning may be extended or modified to suit context and purpose. To the end of greater clarity, Elder and Paul (2013) provide some expansion of the ideas through the definitions below (*ibid*, p.35).

> *Clarity*: understanding, the meaning can be grasped
> *Accuracy*: free from errors or distortions, true
> *Precision*: exact to the necessary level of detail
> *Relevance*: relating to the matter at hand
> *Depth*: containing complexities and multiple relationships

[45] Something that could be equally well described as an epistemic 'weigh-station'

Breadth: encompassing multiple viewpoints
Logic: the parts make sense together, no contradictions
Significance: focussing on the important, not trivial
Fairness: justifiable, not serving or one-sided

These definitions seem reasonably uncontroversial, but there is no imperative to keep them unmodified and it is easy to imagine how one might specify, say, the lack of ambiguity, the efficient grouping of ideas in paragraphs, and the appropriate use of technical terms as further elements of clarity. As well as making clear the general meaning of the terms, Elder and Paul also provide questions that can be used to encourage students to explore how these standards can be applied. These are given below (*ibid*, p.35).

Clarity:

- Could you elaborate?
- Could you illustrate what you mean?
- Could you give me an example?

Accuracy:

- How could we check on that?
- How could we find out if that is true?
- How could we verify or test that?

Precision:

- Could you be more specific?
- Could you give me more details?
- Could you be more exact?

Relevance:

- How does that relate to the problem?
- How does that bear on the question?
- How does that help us with the issue?

Depth:

- What factors make this difficult?
- What are some of the complexities of this question?
- What are some of the difficulties we need to deal with?

Breadth:

- Do we need to look at this from another perspective?
- Do we need to consider another point of view?

- Do we need to look at this in other ways?

Logic:

- Does all of this make sense together?
- Does your first paragraph relate to your last one?
- Does what you say follow from the evidence?

Significance:

- Is this the most important problem to consider?
- Is this the central idea to focus on?
- Which of these facts are most important?

Fairness:

- Is my thinking justifiable in context?
- Am I considering the thinking of others?
- Is my purpose fair given the situation?
- Am I using my concepts in keeping with educated usage, or am I distorting them to get what I want?

Again, these questions are a very small selection of a potentially infinite variety. I could suggest that other questions for clarity, for example, could include 'What did you mean by that word?' or 'How did you draw that conclusion?', and 'What assumptions have you made in saying that?' Let me therefore provide more detail through an expanded set of questions for each standard.

Clarity:

- Are your examples useful?
- Is your argument structure clear?
- Are your diagrams easy to understand?
- Is your paragraph structure well-developed?
- Are your words well-defined and unambiguous?

Accuracy:

- Is your argument sound?
- Are your claims justified?
- Is what you are saying true?
- Have you represented ideas faithfully?
- How could people check on your claim?

Precision:

- Is your attention to detail sufficient?

- Have you used technical terms appropriately?
- Have you quantified your information where appropriate?
- Are any bullet points categorically distinct from each other?
- Have you identified areas of vagueness or ambiguity in your topic?

Relevance:

- Have you focused on the point at issue?
- Have you selected information supporting the topic?
- Have you minimised distracting or unhelpful information?
- Have you been able to identify why information is relevant?
- Have you justified why your selection of material is relevant?

Depth:

- Are the complexities of the issue sufficiently described?
- Have you been thorough in your treatment of the issue?
- Are your analogies effective and your generalisations well-justified?
- Do your arguments consider premises that are themselves conclusions?
- Have the problematic aspects of the issue been identified and dealt with?

Breadth:

- Have you considered alternative perspectives?
- Have you represented a broad range of alternative views?
- Why have you preferred one perspective over another?
- Have you sought out others for the purpose of testing your ideas?
- Has your breadth of treatment allowed you to synthesis a new perspective?

Logic:

- Have you avoided using logical fallacies?
- Have you avoided contradicting statements?
- Are your ideas developed in a logical manner?
- Do all your premises support your conclusions?
- Have you used transition phrases to identify logical progressions?

Significance:

- Have you avoided superficial issues or arguments?
- Have you identified and developed your core ideas?
- Has your analysis identified the most significant areas?
- Have you identified the most meaningful aspects of your topic?
- Has your treatment of the topic focused on substantive aspects?

These questions can be useful as a continual point of reference for feedback on student thinking in class and, as the earlier discussions of Hattie and Timperley (2007) noted, frequent feedback is more effective than infrequent feedback in improving outcomes.

I stated in §5.2 *Values and virtues* that the application of values in inquiry is an essential part of learning why they are values and of developing virtues. The application of values is something students do, and the knowledge of how to do it is experiential (non-propositional). It is therefore important to give students experiences that help them to construct value and to see both the need for, and the path to, evaluation. The following activity is one I commonly use in teacher professional development workshops and with students. It is designed to provide a specific learning experience for students that help them appreciate the value of clarity, accuracy and precision. It can also be used to discuss significant and relevance.

Experiences in applying value

Participants are placed in groups of two, each facing the other. One of the two can see the diagram on screen (person A) and the other cannot (person B). Person B has pen and paper. When the image becomes visible, person A must instruct person B on how to move their pen so as to recreate the image on the paper. They must not name the image (if it is one that can be named), nor can they use hang gestures. They must limit themselves to simple verbal instructions such as ‘draw a horizontal line’, ‘draw a curve moving up from left to right’, or ‘draw a circle of radius 5 cm’. It is worthwhile asking person A to sit on their hands, thus focussing their attention acutely on the use of language. Some sample images are given below in Figure 17.

(i)  (ii) 

Figure 17
Two sample images for an exercise in applying value

It is ubiquitous that person A will feel a sense of frustration with themselves in terms of fashioning and delivering the correct instructions, and with person B as B interprets their comments in a way that does not reproduce the shape as A intended. Statements such as "I know that's what I said, but it's not what I meant!" are common. Person B will also experience a frustration at not being given enough specificity to draw the shape accurately, as A is often ambiguous or unclear about what they are asking B to do. B will often interpret an instruction against the intent of A and be frustrated by A's response. Two diagrams are useful here, since each of the participants has a slightly different experience. It is useful for participants to swap places and do the activity again with a new image so that each can have the full range of experiences.[46]

This activity focuses on the values of clarity, accuracy and precision in language. The feelings participants have as they complete this activity make powerful reference points for general classroom activities. For example, reproducing a diagram on the paper of another person through verbalising instructions is analogous to recreating an idea that exists in the mind of person A in the mind of person B through the respective writing and reading of an essay. A teacher or peer can refer back to the feelings of frustration they experienced in the original activity and use these as a common experience that informs meaningful feedback. They can raise issues of clarity, accuracy and precision that they feel have impeded the transmission of the idea. The experiences inherent in this activity—and future ones that call on it—allow students to bring these values to bear, and to recognise the need to do so (i.e. to develop *sensitivity* to them, the need for which was introduced in §5.2 *Values and virtues*) in acts of social cognition. As students think with others, the values are invoked as required to ensure that the inquiry is normalised and collective understanding develops in a coherent way.

Other values can also be highlighted in the activity. For example, some people taking the role of person A will ask B to draw a vertical line of a certain thickness, rather than simply a line of the natural width of the pen. Other aspects of the diagram might be idealised or overlooked for the sake of simplicity, sacrificing some level of accuracy. The reasons for such modifications are linked to the values of significance and relevance. Some might not think the thickness a significant factor in getting across the overall shape of the object. Others might think the gradual thinning of a line is relevant to the purpose or perceived aesthetic of the shape. This is related to how we can talk about ideas with each other, perhaps favouring simplicity for the sake of understanding, believing that

[46] A useful variation on this activity was demonstrated by a teacher who organised each group to assemble a small Lego package. Person A would provide a pile of Lego blocks and person B would assemble it according to A's spoken instructions with knowledge of the final build. Dramatically, person B was blindfolded.

what we simplify does not significantly alter the idea in terms of its overall value. Judgements around whether or not any of this should progress in any particular way are all matters of applying the values of inquiry and are learned through the act of applying them and examining the results of that application in terms of collective and individual understanding.

An interesting outcome of this activity is examining how participants interpret success. If person B does create a reasonably accurate reproduction, they often feel they have done well. They are sometimes surprised if I suggest that perhaps their success might have more to do with person A than it does with them. This is an important point because it speaks to the shared credit that must be a factor of true social cognition. Even though one person might come up with the finished product, so to speak, it may well be the product of each person's essential contributions.

6.3 Planning and designing thinking in context

The schema connects elements of teaching for thinking and describes the relationships between them. This is representative of a dynamic system, for the relationships among cognitive verbs and the values and virtues of inquiry, are themselves are themselves dynamic. Simply put, cognitive skills are those things we do with knowledge, values feedback on thinking, and virtues are developed through thinking with feedback in collaborative inquiry. While the schema does not explicitly mention the pedagogical conditions and principals that would allow it to operate, it does strongly imply what these are. These pedagogical imperatives are outlined below. Following this, I will demonstrate how these imperatives can be used in unit planning and in designing learning experiences.

Pedagogical imperatives

Three pedagogical imperatives emerge naturally from the schema based on an understanding of the elements and their interactions. The first imperative is to speak and plan in the language of cognition; the second, is to shift the focus of learning and assessment from the transmission of extant knowledge to inquiry; the third, an enabling imperative, is to work collaboratively whenever thinking can be shared. They are not intended to be sequential since, like Newton's three laws of motion, all three are in play all the time. The choice of which comes first below is more a function of what things are best explained first.

I present these imperatives below with some elaborations, showing how they relate to the teaching for thinking schema, and I include some steps that teachers can take to facilitate their implementation. In a later section I will give examples of how these principles can be applied in a variety of learning experiences and assessment instruments. Note that there could be many ways in which such guiding principles as follow can be constructed from the imperatives, and this is simply one such possible set. It is intended that what follows is a scaffold for educators to begin meaningful discussion with themselves and each other as to how to integrate their understanding of the teaching for thinking pedagogy into their practice—how to engage in *praxis*—and how to construct their own expression of these principles.

1. Speak and plan in the language of cognition.

Pre-service teachers often present me with plans that outline in great detail what they will be doing during the course of a lesson. But what the teacher is doing is only of interest insofar as it reveals what the students will be doing, in particular the details of student cognition. In this schematic approach, the creation of critical thinkers should begin by considering student cognitive activity and its development, with the addition that students themselves become aware of this focus. One can consciously attend to one's own cognitions by having them pointed out and one way of pointing them out is to name them and use these names as a matter of course in the classroom.

Establishing some common language around cognitive skills, with students and teachers both having a clear understanding of their meaning and use, allows the teacher to speak to what is happening cognitively in the classroom. Talking with students about their cognition helps to makes this cognition an object of focus and study, and therefore provides a path to metacognition. Speaking of the values as ways in which we can guide and give feedback on cognitive development moves beyond mere metacognition—the awareness of one's thinking—and into an *evaluation* of thinking. Some specific steps that assist to meet this end, and an explanation of how they are derived from the schema, are presented in the following subsections. These steps are intended to work in concert and may mention different aspects of the same action, for this reason there is some degree of cross-referencing in the text below.

1.1 Develop a sound understanding of the nature and purpose of cognitive skills.

Before cognitive skills can be taught to students, teachers must be aware of what these skills are and how they can be used. This may be complex, but it need not be hard. A sound knowledge of cognitive skills can be readily achieved through papers like the APA expert consensus mentioned earlier (Facione, 1990). Some cognitive skills are listed and elaborated upon in this report, and examples are given as to how they may be used. Many educational jurisdictions provide glossaries of cognitive verbs and a range of definitions across contexts for them[47]. While there is no definitive list of cognitive skills, and no universally agreed upon definition of each, this is not critical as 1.2 and 1.3 will show. §6.2 *Teaching skills and values* provides a deeper understanding of the nature of the skills, an idea of how they can be used in practice and their connection to each other.

1.2 Articulate what cognitive skills are intended as outcomes.

The cognitive skills, as understood through 1.1, that are relevant to the course can now be determined. The broader the range of cognitive skills involved, the broader the cognitive experience for students (a principle that replaces the need to focus on "higher-order" skills). Some of these skills, and the contexts in which their nuances are appreciated and their application developed, may reside better in learning experiences and others in assessment, some in laboratories and some in tutorials. To the extent that better critical thinkers can use a wider range of cognitive skills, it is desirable to explore as many options for including cognitive skills as possible—always understanding that they should be employed with scope for sophistication and depth of treatment. [48]

1.3 Determine what the cognitive skills will look like in your course.

It is overly ambitious to imagine that the full scope of a cognitive skill, such as, say, justifying, could be attained in any one assessment piece, learning experience, or even course. It is therefore important to specify what justification will look like in your course; in all the possible ways to consider justification, what best sits in the subject context? Some circumstances could demand that justification means reduction to a sound deductive argument of some sort. Others might require only an appropriate sourcing of material or a legitimate appeal to an authority. Others may demand a demonstration of how an approved method has been applied in a given situation. To use the example given in the previous section, a justification may depend on a prior analysis. In effect, this limits the skills the students will be using to a level that can be more easily articulated and assessed

[47] See, for example, the Queensland Curriculum and Assessment Authority Glossary of cognitive verbs within each senior syllabus and the International Baccalaureate Organisation's list of Command Terms within each subject guide.

[48] An overuse of cognition in a learning experience may have the same effect as adding too much content into a unit of work. In both cases, only superficial treatment is possible. To reflect this, I would add another informal principle to the collection of imperatives: there is no surer way to "dumb-down" a curriculum than to cram it full of content or spread the cognitions too thin.

in context. These are all forms of justification and it is as important to determine the exact context of the use of the skill as it is to determine what skills will be used.

1.4 Place content in the context of cognitive skills.

There is nothing about the schema that excludes content. It rather asks of the teacher what will be done with the content. If the only skill is recall, then at least that can be made clear. But content can be analysed, synthesised, categorised, inferred, evaluated, justified, explained, elucidated, represented, interpreted and identified. Any course not claiming skills beyond recall would be a poor one. So, questions can be asked about essential content in terms of the cognitive skills. For example, is the content of a particular lesson to be analysed? If so, how? What aspects could be inspected and to what level might the analysis penetrate? The greater the degree of precision in the understanding of the analysis in context required, the clearer the representation of the student of the skill and the more precisely and effectively it can be deployed and developed. This is a central skill and one that has been, in my experience, a difficult one for teachers to master. As I will shortly show in the context of unit design, getting this right allows a strong pedagogical and curriculum direction to be established.

1.5 Use criteria that address cognitive skills.

If there is a natural home for the language of what students are expected to do cognitively, it is in the course objectives and in task criteria. This claim follows from the purpose of criteria: to provide categories and standards of student performance. This is not to say that criteria must be written only in the language of cognition. Criteria terminology may speak to physical skills, discrete aspects of the task in terms of or degrees of completion, to name a few. While some of these may arguably reduce to cognitive skills, they may function perfectly well as they are. Feedback to students regarding their performance on a task is useful if it relates to the standards against which they are judged, and since we are interested in creating critical thinkers, it follows that a focus on cognitive skills in this area would be useful. One might, as an example, assign to an assessment task the three criteria of recall and identification, analysis, and evaluation, and then set standards as to how well these can be achieved that are specific to the task (see 1.3). While cognitive skills can provide criteria for assessing thinking (for that is what happens when cognitions are in criteria sheets), the standards to which they are attained can be provided by the values of inquiry. For example, the discriminator between a B and C standard in a criterion that involves *analysing* can include terms qualifying values such as *depth* and *breadth*. A criterion involving interpretation can include terms qualifying values such as *relevance* and *significance*. A criterion involving *justification* can include terms qualifying values such as *coherence* and *fairness*. The criteria for the task then become a useful tool to help students understand what is expected of them in terms of their cognition.

1.6 Give frequent feedback using the values of inquiry.

Hattie and Timperley (2007) have identified feedback as “one of the most powerful influences on learning and achievement”. They have also defined feedback as “information about the content and/or understanding of the constructions that students have made from the learning experience” (p.81). As mentioned earlier, to improve student thinking we must provide students with feedback on their cognitive performance in the language of their cognition. In this context, the “constructions that students have made from the learning experiences” include representations of their own cognition and its development. The values of inquiry, being things that we value in the act of inquiry, provide the evaluative devices we need for constructing criteria for determining the quality of our thinking. This feedback can be done through the use of criteria but, more critically, values can be invoked as needed in the real-time, collaborative learning environments. While the nature of feedback can be very influential in student progress, with some kinds of feedback (e.g. praise, computer generated, peer, etc.) having more positive effects that others (see, for example, Hattie and Timperley, 2007; Voerman et al., 2012), infrequent feedback is less effective than frequent feedback. Giving a student feedback on an essay that was the work of four weeks’ effort in class is less effective than working with the student during the course of inquiry, provided the quality of the feedback is appropriate. An analogy might once more help. The feedback to a surfer or a piano player is continual and immediate. Through a sense of balance and of hearing the progress of the activity is continually monitored and kept on track for optimal performance. The idea of playing an instrument with no sound and then listening to a recording of it at the end would seem a poor teaching method. Collaborative thinking provides a platform for immediate and frequent feedback.

1.7 Note how and where the methodology of your discipline embeds cognitive skills.

It is commonly asserted that studying a particular discipline develops critical thinking skills. Faculty websites promoting critical thinking as a graduate attribute from a range of disciplines are legion. In so far as critical thinking is commonly understood as, to some extent, the application of cognitive skills, the claims have some truth to them. Discipline methodologies have norms for cognition embedded in them, and these can easily be made explicit. For example, scientists generally seek to falsify hypotheses rather than confirm them. Not only does this falsification prevent putting effort into producing an infinite string of confirmations, each of which serves only to support the hypothesis (not prove it), it also works against the confirmation bias (that tendency to look only for confirming instances that support an existing bias). While the idea of falsification is a standard one, the cognitive aspects of it are not generally made explicit. Falsification requires deductive conclusions to be drawn, whereas generalising is an inductive process, for example. It would be difficult to assign certain cognitive skills to certain disciplines on the assumption that they typify the type of thinking in them, since most disciplines require as standard practice efficacy in a broad range of skills. Even granted that mathematics involves a disproportionate amount of deductive thinking, the skills of evaluation, justification, analysis and interpretation are still well-represented. Identifying and teaching cognitive skills in discipline methodology means teaching critical thinking can be a fundamental part of discipline instruction. [49]

2. Shift the classroom focus from knowledge to inquiry

Thinkers need to be given opportunities to experience being metacognitively evaluative and to receive feedback during the process of inquiry. This directly relates to the Hattie reference in 1.6, indicating feedback is effective when given explicitly and directed towards an end, in this case a cognitive end. It also reflects the findings of the Delphi report, which states that:

> Teaching cognitive skills also involves exposing learners to situations where there are good reasons to exercise the desired procedures, judging their performance, and providing the learners with constructive feedback regarding both their proficiency and ways to improve it. (Facione, 1990, p.15)

Shifting the focus from knowledge to inquiry in learning experiences and assessment provides opportunities to move into this metacognitively evaluative mode. I am not suggesting that inquiry should displace knowledge, simply that opportunities be sought where the focus can be shifted. Moving from knowledge to inquiry means moving from a focus on content to a focus on cognition, and therefore from simply knowing things to making use of that knowledge.

2.1 Focus on questions that open up lines of inquiry.

[49] It is important to note that while one might make a case (though I do not) for focussing on a particular skill more than other while solving problems *within* a discipline, coming to learn about the concepts in that discipline requires a broad range of skills. For example, one cannot learn *about* logarithmic relationships using only deductive thinking, whereas much of their use may be deductive.

While asking questions is a critical pedagogical practice, it is not generally well-supported through teacher reflection (Farrell and Mom, 2015). There are exceptions to this—including P4C programs, which have a well-theorised conception of questions and their pedagogical value (Cam, 2006)—but outside of these programs questioning remains something of a dark art. There is a well-defined place for questioning techniques within the schema, however, which integrates questioning strategies with developing student thinking (and is coherent with the theory and practice of P4C).

Within the schema, good questions are those which open up lines of inquiry. Since inquiry is inseparable from thinking, this can be understood as opening up opportunities to think, and, more specifically, opening up opportunities to use a broad range of cognitive skills with some sophistication. It is a significant indicator of expertise that teachers can recognise which questions are those that could be productively pursued to develop student thinking skills. Such recognition requires both good pedagogical content knowledge of the subject area and good pedagogical content knowledge of inquiry (see §2.3 *Pedagogical content knowledge*). Thus, the teacher who has a mastery of questioning is an exemplar of the fact that teaching expertise involves a deep understanding of both content and inquiry. Good questions can come from both teachers and students, however, and teaching students to think well involves teaching them to generate worthy questions, opening up their own lines of inquiry. Whatever else may be required, this would seem to be an essential skill of life-long learning. A useful device for this is the Q-Matrix (see Figure 18), which helps encourage and structure the development of question-generating skills (Wiederhold and Kagan, 2007). The matrix suggests a range of potential questions on any given subject, from the declarative to the speculative, and helps prevent a narrowing of focus, valuing both breadth as well as depth. The Q-matrix can be useful in many contexts, including at the beginning of units of work. As an introduction to coastal management, for example, the Q-matrix could be used to generate questions that will help shape the direction of inquiry throughout the unit (or at least make what is delivered a response to inquiry rather than a rolling out of information). Such questions could include “What is coastline?”—raising issues of whether rivers and lakes have them or about the variety of possible marine coastal habitats. “What does it mean to manage a coastline?”; “Why might a coastline need managing?”; and “For how long should a coastline be managed?” stimulate different but related lines of inquiry. In classroom work as reported by teachers, it is striking that activities around the Q-matrix are very inclusive. If students are asked to contribute to class discussion or to answer questions drawing on their subject knowledge, those without that knowledge are at risk of exclusion. But before a unit of work begins, all students are capable of framing issues and asking questions that do not rely on knowledge form the unit, since it has not yet been covered. Students who struggle to give content-based answers in class have more access to contributing through questions. The logical possibility therefore exits that students who do not receive positive feedback through content knowledge can receive positive feedback through having their questions acknowledged as useful.

The Q-matrix has the unique quality of not requiring students to answer the questions that are generated, at least in the initial phase of generating questions. The realisation that the question is the point, not the answer, and that not knowing the answer need not be a brake to the creative process of generating the question, is a key lesson for students.

THE Q MATRIX

	Event ***what***	Situation ***where/when***	Alternatives ***which***	People ***who***	Reasons ***why***	Means ***how***
Present ***is***						
Past ***did/was***						
Possibility ***can***						
Probability ***would***						
Prediction ***will***						
Imagination ***might***						
Decision/Choice ***should***						

Figure 18: The Q Matrix

Another use of the Q-matrix is worth mentioning. A teacher, let me call her Sally, involved in a professional development session was working in her school with a boy, let me call him Samuel, with special needs. Samuel did not engage with the work that teachers provided for him, despite the teachers making the work more and more basic to reduce any problems with understanding. Sally gave Samuel a Q-matrix to help generate questions about a particular topic. Samuel immediately showed interest in those questions generated in the lower right section of the matrix, which were of a more speculative and even ethical nature. Far from needing simpler tasks, it emerged that Samuel was interested only in more interesting aspects of his work. While this is only anecdotal evidence, it does allow for consideration that where students gravitate towards in the matrix can tell us what kinds of thinking they are interested in or disposed towards — and perhaps where in terms of cognitive development they are — which might help inform the teacher of their thinking and where to concentrate their efforts going forward. This would be an interesting area of further research.

2.2 Target a wide a range of cognitive skills over a variety of learning experiences.

As mentioned in 1.2, the broader the range of cognitive skills the greater the opportunity for students to exercise them, and to become familiar with their norms of operation. Consider a task in which two ways of thinking or operating are being examined, say two schools of sculpture in an art class. Rather than simply researching the particulars of the two schools, which requires a narrow range of cognitive skills, the students could be asked to observe two sculptures, one from each school. In doing so they could be *analysing* aspects of the sculptures, *inferring* which tools and techniques were used, *comparing* and *contrasting* shape and style, *evaluating* the outcomes in terms of aesthetics or simplicity, *classifying* the two into broader categories, and so on. They could then *synthesise* all this to present their findings. These cognitive skills could then be included in the rubric for the tasks, as per 1.5, and they could also be mentioned explicitly in student instructions within the task sheet.

2.3 Integrate the cognitive skills.

The range of skills utilised as outlined in 2.2 is important but, as discussed in §6.1, *The developmental nature of teaching critical thinking*, working with sophisticated representations and concepts, i.e. dealing with complexity, also helps to create better critical thinkers. To continue the previous example of comparing sculptures, students could also be asked to examine cultural conditions at the time of sculpting, and suggest how these might have influenced the artists' work. Greater complexity demands greater attention to cognitive detail, and this adds to the richness of the metacognitive experience since the interplay between the skills becomes more complex itself. The design of inquiry that focuses on student thinking, is much improved through a deliberate and considered integration of cognitions within a task.

2.4 Use cognitive skills as instructions in place of questions.[50]

It might seem that a task heavy with questions to be answered would be a candidate for a good inquiry task, but this is not necessarily the case. Consider a task sheet that asked the following

[50] While it is perfectly sensible on some occasions to simply ask a question, focussing on cognition allows for a far more precisely targeted response.

questions (1) What government agencies exist to assist people in emergency conditions? (2) What are the key strategies than people can use to protect themselves from floods? (3) Where are the key centers of community care in the case of flood? (4) Who is qualified to provide emergency assistance during a fire? These questions have been modelled on an existing task sheet in a school for which the answers to the question were provided in the text and accompanying material. In working with teachers on identifying the cognitions required for the task, it became quickly evident that each of these was a task that required students to *identify* the points in question. Another example from a science paper is the question "Where does the energy in the light bulb come from?" Working with the teacher, we noticed that students interpreted the problem in at least three separate ways. The first was as the instruction "identify the location of the energy", the second as the instruction "describe where the energy comes from" and the third as "explain where the energy comes from". Each of these interpretations is quite different from the others in terms of the nature of the task and in the complexity required in the answer. Phrasing questions as instructions helps us as educators to focus more intently on the kind of cognition we wish the students to undertake. Precision of language on our part provides clarity of purpose on the part of the student.[51]

2.5 Audit student tasks for their cognitive content.

The analysis of questions in 2.4 is an audit of the cognitions involved in responding to the question. Such an audit helps to examine current practice to ensure a focus on inquiry through a broad and deep use of cognitive skills. Without such an explicit focus, student thinking can end up being an *ad hoc* affair. Auditing for cognition can be more useful than the concept of "backward mapping", in which cognitions explicit in senior syllabuses are sought for in junior ones. Such a project can turn into nothing more than an exercise in word matching. Figure 19 shows the results of a scan of documents relating to the Australian Curriculum Years 9-10 and the Senior Syllabus objectives for the QCAA in the category of "Knowledge Utilisation" (a Marzano category of information processing). The presence or absence of the terms in syllabus documents was sufficient to generate this table, which has been produced by the QCAA as an aid to schools. While it is a useful task to see how and where the cognitive skills are spoken of in these documents, it is less obvious how this is pedagogically useful. Just because a cognitive verb does or does not appear in the syllabus does not mean it does not occur in the classroom, or that it should not. For example, considering what verbs are noted as being mentioned in the table below, it seems beyond the scope of reasonable

[51] I undertook a similar task with a university colleague, working through his worksheet to identify cognitions. I took the original sheet (with his permission) into my Physics teaching class to use as an example of this principle. One of my students was a former student of his that had done the worksheet. He recalled that he was not sure how to respond to some of the questions for precisely this reason.

assertions, as the table may be interpreted, that senior science subjects do not *hypothesise* or *propose* as they seem to do in the Australian Curriculum science classes. A more generous interpretation would be that they are not explicitly asked to hypothesis, but that that skill will either be called upon in the support of those skills which *are* explicitly stated, or that they are themselves constituted by the explicitly stated skill. Unfortunately, no such clarity exists in the document itself.

Cognitive verb	Australian Curriculum Years 9–10		Senior syllabus objectives									
	Achievement standards	Content descriptions	Agricultural Science	Biology	Chemistry	Earth & Environmental	Marine Science	Physics	Psychology	Agricultural Practices	Aquatic Practices	Science in Practice
argue		✓										
assess		✓										
decide/determine										✓		
design	✓											
develop	✓											
devise										✓	✓	
discuss/explore	✓		✓	✓	✓	✓	✓	✓	✓			✓
evaluate	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
experiment/test		✓	✓	✓	✓	✓	✓					
generate/test											✓	✓
hypothesise/propose	✓	✓										
investigate/examine		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
justify/prove	✓									✓		
solve											✓	✓

Figure 19

3. Work collaboratively whenever thinking can be shared.

The importance of the social environment to individual learning has a long history of theoretical support. Vygotsky (1978) and Mead (1979), for example, both promoted a strong causal connection between social interaction and individual learning. Mead was particularly succinct in his phrasing of this, noting that "the child does not become social by learning. He [sic] must become social in order to learn" (*ibid*).

There are many reasons to value collaboration in inquiry, including developing an understanding of how the values and other norms of inquiry can be applied, providing opportunities for the use of particular cognitive skills, enabling the presence of the other to develop argumentative stances, and to engage in social cognition with the goal of individual improvement. §5.2, *Values and virtues* outlines the role collaborative inquiry, including social cognition, can play in the development of developing values and virtues.

Often teachers will set up ‘debates’ to contest alternative positions, but debates as such are not always effective to develop the skills of argumentation. Debates can be more about persuasion through appeals to emotion, misrepresentation of opponents’ positions, and a lack of genuine engagement with the mind of the other. In authentic argumentation students engage with honesty and charity in an effort to understand the other and empathise with their thinking. The use of “ill-structured” problems in which students need to develop a shared understanding of the nature of the problem before moving ahead to attempt to solve it provides opportunities for deep intellectual engagement. It is perhaps no coincidence that philosophical problems are generally of this sort, and this perhaps explains some of the success of collaborative philosophical inquiry, particularly in P4C programs.

Let me draw an analogy here. When exercising for muscle growth, it is necessary to do so by exerting a force against a resistance. Typically, this resistance is provided by the weights on a bar or by opposing the weight of the body. Exercising without resistance is futile. When our views are not challenged, or when our reasoning is not open to scrutiny, there is little intellectual resistance and therefore no imperative to provide much persuasive force in opposition.

The need to acknowledge and deal with divergent views is a tangible resistance that builds intellectual capacity. It may certainly involve divergent thinking, but must also, to be called critical, contain an evaluative, convergent phase in which potential inquiry pathways and solutions are preferred over others according to criteria that may well need to be collaboratively constructed. I propose emphasising opportunities for students to engage in what I call the ‘golden tetrad’ of cognitive skills: to *explain* and *justify* their position as they *analyse* and *evaluate* the position of others. This agrees with Kuhn’s (2015) conclusions about developing individual cognitive abilities through argumentation, but also draws in elements of §6.2, *Teaching skills and values* in which cognitive skills are understood as having complex relationships with each other. In order to explain, justify, analyse and evaluate a broad range of other skills must come into play—depending on the context and sophistication of their use—including identify, categorise, infer (through deduction and induction), organise, select, hypothesise, speculate and so on. Given such a broad range of skills, the opportunities for feedback on their use through application of the values of inquiry become frequent. Opportunities for collaborative inquiry and shared thinking are therefore significant pedagogical aims. The principles at play in this context are therefore as follows.

3.1 Provide opportunities for social cognition.

Thinking together is more than sharing the results of our completed cognition with each other. It is about recognising that in the context of collaborative inquiry speaking *is* thinking. It is the means by which we articulate to each other and to ourselves how are thoughts are progressing, how they have been influenced by earlier social stimuli and how they may help shape progress towards a conclusion. Our communication with each other (including non-verbal signals) is part of the machinery of social cognition. A metalanguage that allows us to speak with each other about our thinking and the quality of it is critical in this context. The schema provides such a language and the understanding in which it can function.

One implication of this is that in constructing activities involving group work, it is sub-optimal in terms of developing cognitive abilities to partition tasks into sections for which each person in the group has responsibility. This is not sharing thinking; it is sharing the results of completed cognition. Granted there may be some synthesis at the close of such an activity, but it is ultimately poor practice in encouraging social cognition.[52]

3.2 Use collaboration for feedback on student thinking.

The feedback outlined in 1.6 is best provided frequently and consistently. Students working with each other, particularly in circumstances in which they are engaged in explanation, justification, analysis and evaluation, and also in circumstances in which they are engaged in genuine social cognition, for example, in coming to a common understanding of how a problem should be framed, are well placed to give and receive feedback on the thinking of their peers. One way, therefore, to plan for feedback in the design of learning experiences is to include structured group work.

3.3 Structure group work to lower cognitive load and engender collaborative thinking.

Since cognitive load, or working memory use, is a significant consideration in student learning (see §1.4, *Dual process thinking, working memory and schematic knowledge,* §6.6, *Warm and cool thinking* and §7.2, *Neuro-education: a research consideration*), strategies for optimising its use are

[52] This is not an encouragement to permanently avoid such activities, as they will no doubt have their use and value in certain contexts. I only intended to point out that if the goal is to improve cognition as effectively as possible, then this is not the best approach.

important in planning for learning experiences and for assessment. One consideration is that students working in groups can share the cognitive load between members. While one person is working through a cognitive task, she can source necessary information by calling on the group rather than dedicating her resources to remembering or recalling it. This dynamic restructuring of information and information processing within the group lowers the cognitive load on individuals. For example, one member of a group thinking together about a water resource plan for a particular building environment can attend to necessary information about rates of flow while another focuses on necessary information about costings. Each of these can be called upon by any other member as needed without having to both process and hold the information. This does not mean that such a distribution of information must be planned for, since that kind of knowledge distribution is often a function of people only remembering parts of what they have previously learned. But that such knowledge distribution is organically distributed between people can be used in planning for, and justifying, working together in groups. This is not simply a division of labour, as all members of the group can be engaged in the same task at the same time. What *is* being shared is cognitive load.

3.4 Generate questions collectively.

The Q-matrix outlined in 2.1 is most effective when used within groups and when there is an intermediate discussion about what constitutes a *significant* question—i.e. when students are asked collectively to decide which of their individually generated questions are the most significant. Students can build on the questions of others and are often inspired to generate questions that they would not thought of asking is working in isolation. Diversity and variety are essential components of any systematic collaborative inquiry.

3.5 Create opportunities to argue to promote and develop the skills of argumentation as an analytical framework for developing and evaluating thinking.

As suggested in §6.4, *The domain of argumentation*, arguments provide a way to instantiate the abstract elements of reasoning. They allow us to more readily identify inferential steps and processes to ourselves and to others and to 'package' our thinking in a way that is accessible to others for analysis and evaluation. They are part of the protocols of reasoning that allow easier transmission of ideas that could otherwise be achieved.

Arguments are also useful in unit and lesson planning as they can act as filters for content that needs to be included in a unit of work to achieve outcomes. As an example, a teacher in a professional development workshop constructed a unit around the enthymematic argument that "Coal mining in central Queensland should go ahead since the economic benefits locally outweigh the broader environmental concerns." The argument itself acted as the organising element of the unit, suggesting which material should be investigated to establish the truth or falsity of the premises. It also allowed for sub-arguments to be constructed, prosecuted and evaluated towards the end of establishing or opposing the conclusion of the organising argument.

These three imperatives can be used to guide the development of learning experiences and assessment to help focus on student thinking. How these imperatives can be instantiated in a unit plan and a learning experience plan is outlined in following section.

Unit and lesson design

The two examples which follow serve to illustrate how the imperatives developed in the previous section can be used to guide pedagogical decision-making in planning for student thinking. Each example is presented as it might be used and followed by a commentary that explains how the principles have been used to inform its construction.

Example 1: A sample unit plan

1. Task title	
Environmental decision making (four weeks, middle school level)	
2. Guiding questions	**3. Sample Arguments for evaluation**
Why does the environment matter?	

• Does it matter if an animal or plant becomes extinct? Why? • Should we value some species over others? • Are cute animals the most important ones? What about worms? • Can animals feel pain? How do we know? • What makes an animal happy? How do we know? • Is the natural environment the best environment? Why?	• Most species that have lived are now extinct, so there is no need to worry about present extinctions. • Humans are different from other animals and are therefore the most important species.
Are humans special? • Are humans the most important species? • Should humans get to decide which organisms live and which die? • What does it mean to 'manage' the environment? • What animals should not be pets? Why? • What is the purpose of a zoo? • If we could terraform another planet, should we?	• All animals are equally entitled to exist, so humans are not special. • Humans are the only sentient animals on Earth and therefore have special privileges. • Humans should be able to manage the natural environment to our advantage since all animals modify their environment to some degree.

4. Cognitive skill development

During this unit, students will have opportunities to:

Identify arguments regarding human nature and our role in the environment.

Analyse environmental problems, proposed solutions and arguments related to the role of humans in the environment.

Explain the philosophical basis for decision making in environmental contexts.

Categorise environmental concerns according to criteria such as valuing life, economic concerns and health issues.

Evaluate arguments and potential courses of action.

Justify arguments and positions on environmental issues.

Conjecture alternative solutions to environmental problems.

5. Applying values of inquiry

During this unit, students will develop and apply the values of ***Clarity*** in understanding the term 'environment'. ***Accuracy*** and ***precision*** in representing the current state of environmental issues. ***Relevance*** and ***significance*** in identifying issues, concerns and solutions. ***Breadth*** and ***depth*** in exploring possible perspectives and solutions to environmental issues. ***Logic*** and ***coherence*** in explaining and arguing for environmental outcomes.

Unit plan commentary:

1. Task title

The inclusion of the term 'decision-making' in the task title is a considered attempt to show that the unit focusses on thinking about the environment rather than being simply about the environment. This follows Imperative One: shift the focus from knowledge to inquiry.

2. Guiding Questions

The guiding questions open up lines of inquiry and create opportunities for students to use and develop their cognitive skills. The questions themselves are meant as guides for the teacher, but these and others like them could be generated collaboratively using the Q-matrix as a guide. They help frame important issues and set up possible topics for later discussion. The major principles at play are:

2.1 *Focus on questions that open up lines of inquiry*.
3.1 *Provide opportunities for social cognition.*
3.4 *Generate questions collectively.*

3. Arguments for evaluation

Arguments are included to (1) indicate research materials required to evaluate the argument, (2) to suggest guiding questions, (3) to analyse and evaluate the positions of others, and (4) to provide opportunities for students to explain and justify their positions. Thus, they provide opportunities for social cognition. The major principles at play are:

2.1 *Focus on questions that open up lines of inquiry*.

3.1 *Provide opportunities for social cognition.*

3.2 *Use collaboration for feedback on student thinking.*

3.4 *Create opportunities to argue to promote and develop the skills of argumentation as an analytical framework for developing and evaluating thinking.*

4. Cognitive skill development

The cognitive skills written as the focus of the unit are also used to broadly outline the goals of the unit. Critically, they are not written in isolation but are placed in the context in which they are to be used. As hinted at in Principle 1.4, *Place content in the context of cognitive skills*, this allows us to gain a sense of (1) what the curriculum must look like to create contexts of cognitive skill development (2) what pedagogical decisions need to be made to make sure that those cognitions are enacted and developed in the classroom. This stage is therefore a very significant one and requires substantial thought.

The placement of cognitions in context, once developed, also provide a basis from which criteria for the unit can be drawn. For example, one criterion might be "identify and explain', another 'analyse' and a third 'evaluate and justify'. Using the conditions in context in this way allows for a high degree of alignment between the stated goals of the unit and how students are assessed and what makes up the substance of the assessment. Questions of how one can assess student thinking seem unnecessarily angst-ridden when the value of this approach is understood. The major principles at play are:

1.1 *Develop a sound understanding of the nature and purpose of cognitive skills.*

1.2 *Articulate what cognitive skills are intended as outcomes.*

1.3 *Determine what the cognitive skills will look like in your course.*

1.4 *Place content in the context of cognitive skills.*

1.5 *Use criteria that address cognitive skills.*

2.2 *Target a wide a range of cognitive skills over a variety of learning experiences.*

2.3 *Integrate the cognitive skills.*

5. Applying the values of inquiry

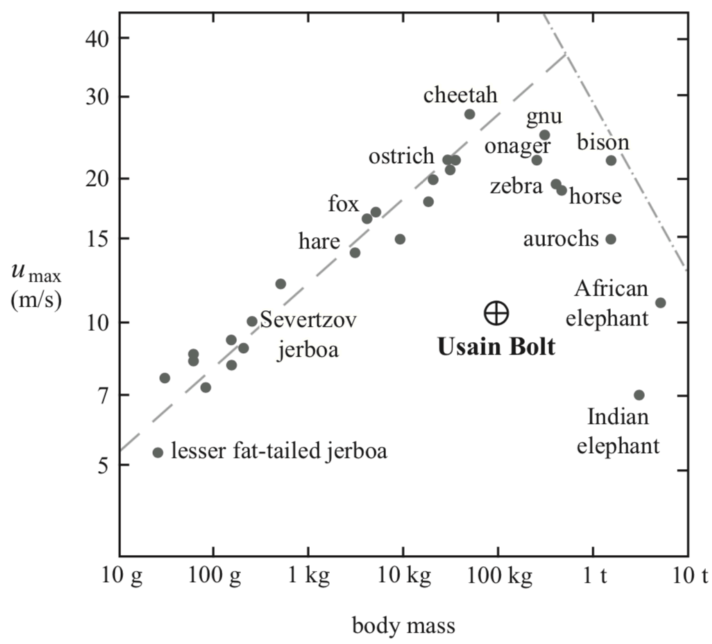
The values of inquiry are used within the schema predominantly as feedback on student cognition. It is the nature of feedback that it is invoked as required rather than being planned. For example, a piano teacher cannot decide before hearing a piece of music from a student that at bar twelve of the score she will comment that the student is playing too fast. She must wait until the student does something before providing feedback. But the teacher, being experienced with teaching this piece, might be aware that tempo will be an issue. She would therefore be aware that at some stage she will need to provide feedback concerning this and will then be on the lookout for it becoming an issue. In the same way, a teacher with some pedagogical content knowledge regarding environmental issues would be aware that clarity is needed in understanding the term 'environment', that precision will be lacking when students describe current environmental aspects, and so on as outlined in this section of the plan. In so describing the nature of feedback through values in the unit, the teacher is also providing a means of discriminating between achievement in the use of cognitions that can be used as discriminators in the criteria for assessment. Analysis can be broad but not deep, or deep in an area of lesser significance. Explanations can suffer from a lack of clarity or coherence. Justifications can have inaccurate assumptions. In all of these cases, students engaged in discussion, argumentation and social cognition can learn through feedback how to better apply the values of inquiry. The major principles at play are:

1.5 *Use criteria that address cognitive skills.*
1.6 *Give frequent feedback using the values of inquiry.*
3.1 *Provide opportunities for social cognition.*
3.2 *Use collaboration for feedback on student thinking.*
3.4 *Create opportunities to argue to promote and develop the skills of argumentation as an analytical framework for developing and evaluating thinking.*

Example 2: A sample learning experience design

1. Subject matter
• ***Analyse*** and ***interpret*** graphical data relating maximum velocity and body mass for a range of mammals. • ***Identify*** trends and relationships between maximum velocity and body mass • ***Evaluate*** given statements relating to data on the graph • ***Justify*** conclusions about whether statements are supported by data from the graph • ***Speculate*** about why the data seems to show two different linear sections.

• ***Conjecture*** about the effects of bipedalism and speed.
2. Learning experience



The diagram (left) shows maximum velocity vs mass for a number of animals, with Olympic runner Usain Bolt shown representing human achievement.

1. Label the 4 statements below as supported by the data in the diagram (S) or unsupported by the data in the graphs (U).
2. In small groups, develop arguments that support your decisions.
3. Speculate on the effects of bipedalism on speed.

a. The heavier you are, the faster you can run.
b. A body mass of between approximately 20 to 120 kg is optimal for speed.
c. A cheetah has a larger maximum velocity to body mass ratio than a gnu.
d. Humans are an exception to the trends relating body mass and maximum velocity.

3. Opportunities for feedback

- Initial discussions with students and teacher will focus on the purpose of the graph. Students can ask clarifying questions regarding the nature of the animals represented.
- Students will work in small groups to address the task, sharing their thinking with each other. These groups will then share their thinking to work towards a class consensus.
- As a group, the class will then speculate on (i) why humans seem to be an exception to identified trends (considering bipedalism but also why bipedalism has this effect) and (ii) why things seem to change over the optimal weight for speed.

4. Reflection (sample thinking)

What was the quality of student analysis? How did the groups communicate and share their thinking regarding the task? What criteria (based on the graph) did students use to evaluate the statements? What was the quality of their justifications? Was there variety within the groups? If so, why? Was it a function of their collaboration? Was their speculation based on some principles of *scalability or relevant physics? Which students found the task problematic and why? What skills can I say have been developed? What surprised me about the outcomes? What was I hoping for that didn't happen—why didn't it happen? What values were highlighted and developed?*

The commentary for this learning experience design is sequenced in consideration for presentation for students. The practice of constructing this, however, began with the learning experience itself (step 2 in the table above). The above graph prompts students to consider if the statements below the graph were supported or unsupported by the information in the graph. This helps students to better analyse and interpret information and to understand the nature of graphical displays of data. But viewed through a lens of teaching for thinking, it was developed to articulate the cognitive skills intended to be used and to make these clear to the students. It was also developed to create opportunities to deliver feedback for students on the quality of their thinking, as I outline below.

1. Subject matter

Subject matter is 'cognition in context'. In other words, the pairing of content and cognitive skills. It refers to both thinking and the context in which students will think. This use is consistent with the QCAA suite of syllabuses that have a common section explaining this use of the term. The point for this thesis, and for the QCAA, is that thinking should not be removed from subject matter. The first task in this learning experience design was to identify what cognitive skills I wished the students to use and develop and place them in the contexts in which they occurred. The major principles at play are:

> 1.1 *Develop a sound understanding of the nature and purpose of cognitive skills.*
> 1.2 *Articulate what cognitive skills are intended as outcomes.*
> 1.4 *Place content in the context of cognitive skills.*
> 2.4 *Use cognitive skills as instructions in place of questions.*
> 2.5 *Audit student tasks for their cognitive content.*

2. Learning experience

Teachers already have a broad and deep repertoire of learning experiences that they use to develop student thinking and understanding. In the project of teaching for thinking following the schematic understanding developed in this thesis, it is not necessary to rebuild curricula from scratch. It is sufficient to consider existing learning experiences and to audit them for their cognitions, perhaps using this lens to modify the learning experience to more precisely target these skills. An example of such modification was the realisation that I wished to include a need for students to justify their positions and to receive immediate feedback on their thinking as they analysed and evaluated the statements with regard to the information in the graph. I therefore extended to task to include steps 2 and 3, something that may not have happened were I not paying attention to the cognitive requirements of the task. The major principles at play are:

1.1 *Develop a sound understanding of the nature and purpose of cognitive skills.*
1.2 *Articulate what cognitive skills are intended as outcomes.*
1.4 *Place content in the context of cognitive skills.*
2.5 *Audit student tasks for their cognitive content.*
3.2 *Use collaboration for feedback on student thinking.*
3.4 *Create opportunities to argue to promote and develop the skills of argumentation as an analytical framework for developing and evaluating thinking.*

3. Opportunities for feedback

As for part 5, *Applying the values of inquiry*, in the unit outline above, even at the level of the learning experience, it is not possible to specify exactly what feedback needs to be provided in the absence of any actual student activity, whereas, at the unit level, it was possible to use pedagogical content knowledge to predict areas in which feedback would be required. At the learning experience level, we can also engineer *opportunities* for feedback, recognising that the exact type of feedback may still be beyond our predictive capabilities. Since so many of these opportunities arise from working collaboratively, in the learning experience much of the creation of opportunities is centered on working in small and large groups. The major principles at play are:

1.6 *Give frequent feedback using the values of inquiry.*
3.1 *Provide opportunities for social cognition.*
3.2 *Use collaboration for feedback on student thinking.*
3.4 *Create opportunities to argue to promote and develop the skills of argumentation as an analytical framework for developing and evaluating thinking.*

4. Reflection

The learning experience is a useful unit of treatment in that, while obviously divisible into discrete tasks, it is the smallest coherent experience for students in context. Some learning experiences, such as this one, might only take 20 minutes of class time; others might extend over several lessons. The value of this coherency is that it allows for a reflection on the part of the teacher that can be neatly expressed in terms of the cognitions and values it was intended to engender and the context in which it was done. In this section, the teacher can set up targets for examination and evaluation that are based on a schematic understanding of teaching for thinking. Some sample questions that the teacher might ask are included for reference.

This type of targeted reflection is exactly the kind of deliberate practice that is necessary for the development of expertise as outlined in §1.3 *The nature of expertise*. Including this section in the learning experience planning also allows a place to capture the deliberations that can become a part of professional pedagogical conversations with colleagues. It also allows colleagues who observe each other's teaching to understand the goal of the lesson as articulated in the planning so that feedback can be directed, on point and meaningful. Having such specificity in observation helps to avoid rather shallow commentary such as 'the students were really engaged' (a worthwhile end but not the result of a deep or significant analysis of the lesson— engaged in what way, how and importantly, *why*?). It is a point worth making that teachers in professional development programs who undergo such reflections in the knowledge that (1) it will be read by or talked about with other teachers and that (2) other teachers are going through the same process generally make more meaningful reflections. The major principles at play already articulated are seen as points of study themselves within the teacher's practice.

6.4 The domain of argumentation

The references to argumentation in the sections above signify its importance as a pedagogical tool. The educational value of argumentation should not be underestimated.

The fashioning and evaluation of arguments is fundamental to our idea of reasoning and critical thought, in as much as critical thought is analytical, informed and evaluative. Argumentation is a large part of the methodology of philosophy, but also of rational inquiry in general. Not only does it have a formal beginning in the logic of Aristotle, but Dan Sperber and Hugo Mercier even suggest that our capacity to reason has evolved 'to produce arguments in order to convince others and to evaluate arguments others use in order to convince us' (2012, p.2). It would therefore be remiss in the context of this thesis to discuss critical thinking without considering how it is related to argumentation, or how argumentation can be used to develop students' critical thinking capabilities. In considering argumentation, it is necessary to define what an argument is. To argue is to engage in an intellectual process. While there are many ways to talk about it, there seems no great need to move beyond the definition offered by Monty Python (2014) as 'a connected series of statements intended to establish a proposition'. More formally, an argument is made up of premises, those things we take to be true for the purposes of the argument, and a conclusion, the point at which we arrive after duly considering the premises and inferring to our final conclusion. There are a number of reasons why teaching the art of argumentation provides a useful focus for the development of critical thinking in adolescence.

The first reason that argumentation is useful in developing critical thinking is that arguments contextualise our reasoning skills, positioning them in the light of lived experience and relating them to specific circumstances and outcomes having meaning to the individual. This is distinct from, and preferable to, teaching argument in a decontextualised way (Bailin and Battersby, 2015). The ability to teach abstract reasoning skills is enhanced when these skills can be instantiated in a way that is relevant to an individual's concerns using concrete examples. The analysis and evaluation of arguments is also a useful method for providing a range of contexts from which broad principles of reasoning can be extracted and hence argumentation can assist in the development of metastrategic skills as outlined above. An example of this is the tendency of philosophers to seek counterexamples when definitive claims are made, a general strategy that is widely applied after having seen its utility initially across a range of contexts (Perkins and Salomon, 1989).

The second reason is that arguments provide a clear structure for presenting thinking, which in turn allows for a high-resolution analysis of the justification of a claim. The need to set out premises, or those things we take to be true for the purpose of the argument, and to show how these together form a cohesive set that justifies moving towards a particular conclusion allows assumptions to be identified and challenged and for the inference from premises to conclusion to be evaluated for validity or strength. Arguments can be evaluated by testing them for two key attributes: validity and soundness. A valid argument is one in which the conclusion is logically and necessarily entailed by the premises. A sound argument is a valid argument with true premises. We understand someone's argument can be assessed on the likelihood of the premises being true and on the strength of the logical pathway from the premises to the conclusion.

The third reason is that arguments allow a case to be presented in a manner that is independent of the arguer, that is, to be analysed and evaluated on its merits as a rationally persuasive case. Even while the context remains relevant and meaningful, the emotional turbulence associated with adolescence can be to some degree bracketed out to allow some objective standards of effective inquiry to be applied in a collaborative manner.

Constructing arguments, therefore, provides a mechanism for discussion, analysis and evaluation of claims that allows for high inferential resolution and hence increased potential for rational rejection or acceptance of claims. Moreover, it is in the acts of arguing, or explicitly evaluating arguments or justifying positions through constructing arguments, that cognitive and other social interactions between students can occur that deliver opportunities for testing ideas and establishing norms. In other words, through argumentation, students can learn how to think philosophically and be self-reflective about their own thinking and assumptions. In empirical work on the cognitive benefits of arguing in classrooms, Kuhn (2015, p.47) notes that "instruction to argue produced more lasting conceptual change than instruction simply to collaborate" .

Argumentation is also an effective means of adding rigorous analysis and evaluation to discipline areas. Even in an area as topical, heated and complex as climate science, argumentation has value in bringing clarity and coherence.

6.5 Warm and cool thinking: a model of teaching for thinking

How might we extend the dual-system thinking model into the dynamics of teaching the skills of critical thinking and of developing expert knowledge? Dual system thinking is intended to be useful only as a model, providing a means of talking about transitioning between types of cognition that might prove useful. Recall that I earlier made the connection between teaching in general and teaching for expertise, or at least that what works well for the one seems to work well for the other. This equivalence allows me to use the ideas of dual-process thinking to construct a model of cognitive change that represents both an improvement in student understanding and mastery and the teacher's mastery and development of pedagogical expertise.

Models and schemata are not the same things. A model captures some of the assumptions that are not explicit in (though they strongly underpin) the schema of teaching for thinking, such as System 1 and System 2 thinking, the concept of mastery and of the distinction between critical thinking and critical thinkers, but the model also provides an operational guide for thinking and learning as informed by the schema. Whereas a schema leaves aspect of the thing for which it is a schema undetermined, a model does not, filling in the gaps left by the schema to create a concrete object.

(Compare a schematic diagram of an airplane with a model airplane.) While the schema contains dynamic elements in that the relationship between values and cognitive skills, for example, is a dynamic one, it is not of itself a concrete representation of dynamically changing states. The model I present here is intended to represent such concrete changes.

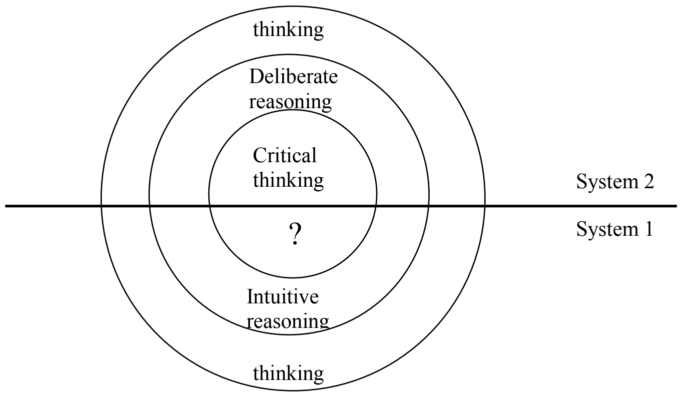
A deeper understanding of critical thinking through metacognition was the work of Chapter Four, *Metacognition* but let me revisit it here as I place it in the context of what we know about dual-process thinking, and, more importantly, place it in the broader context of education. A reasonably inclusive definition of what it means to think critically is given by Paul and Elder:

> That mode of thinking—about any subject, content, or problem—in which the thinker improves the quality of his or her thinking by skilfully taking charge of the structures inherent in thinking and imposing intellectual standards upon them. (Paul and Elder, n.d.)

In a similar vein, I explain in Chapter Four that critical thinking, as it applies to our own cognition, requires that we be aware of that cognition (or some of it at least) and to be able to evaluate it against some criteria of effective thinking in whichever domain we are working in. In other words, that to be thinking critically is to be metacognitively evaluative (the ME model). Let me briefly discuss an implication of this.

The term critical thinking is often used as if to do it is to do it well, but this does not follow. Critical thinking may be categorically different from simply reasoning or thinking, but it can be done well or poorly in this space. Consider the difference between driving a car and flying a plane. While one may be more desirable for covering long distances faster, it does not mean that any flying is better than any driving. Flying can be done poorly or well, dangerously or safely; to say that one is flying is to leave open many concerns. This is just as true for critical thinking which, while metacognitive and evaluative, can be error prone and ineffective. Critical thinking is therefore developmental and characterised by flux. The model is an attempt to provide a broad picture of thinking that draws upon some of the key ideas of the previous chapters, particularly that our thinking is an organic and dynamic process characterised by a duality of function. It is an attempt to articulate the dynamics of thinking as it develops from naïve to sophisticated, from intuitive to reflective and from that characteristic of the novice to that characteristic of the expert.

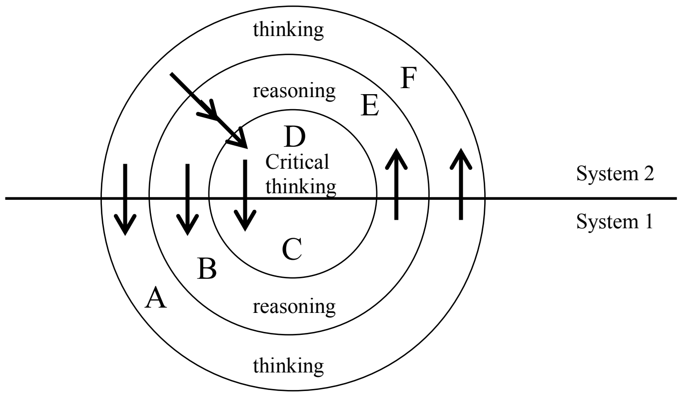
Recall that one of the characteristics of System 2 is that it is directed, and to be thinking critically through metacognition and evaluation one must also be directed. It follows, then, that critical thinking is a System 2 process (though it does not follow that all System 2 thinking is critical—the model addresses this point). But to be thinking critically, as I have outlined it, is to be cognisant of reasoning and to be able to evaluate those reasons, in thinking critically we must think using reasons and we must be able to evaluate those reasons. Reasoning is also something that requires thinking, but reasoning does not exhaust thinking. One might be wondering, questioning, desiring, or thinking in any number of ways that does not involve the search for, or creation of, reasons. One way to model the relationship between these cognitive modes, as I have suggested it, is shown diagrammatically below.



The question mark is intentional and instructive. While I maintain that critical thinking is a creature of System 2, it is possible for one to enter into a System 1 mode of thinking when the learning acquired slowly and deliberately in the System 2 space can be internalised and available through System 1 as various mental habits, heuristics and the kind of organised knowledge that is typical of experts within a domain. This is very much a Vygotskian understanding (Gonzalez Rey, 2011; Lipman, 2010; Smagorinsky, 2007; Williams, 1989). Critical thinking must pass through a System 2 stage before it can be internalised to System 1; both modes are possible when considering critical thinking and critical thinkers—since critical thinkers may have internalised many useful and effective habits and heuristics—however it still is sensible to consider critical thinking an essentially System 2 type of thinking.

To create the model of the space is also to suggest movement through it. Moving from System 1 to System 2 may simply be in response to a stimulus such as a problem to solve in which some hard cognition is required that involves the use of working memory. In other words, whenever the free flow of thought needs to be directed and focused and a cognitive gradient is experienced as a result of this need. This the world can do for us. When asked to fill out a lease arrangement form, or to multiply two large numbers together mentally, we rise to the challenge through System 2 management. Much of education practice seems to rely on theory that rests here. The concept of mastery in education can be understood as working through a process in System 2 space until it becomes habitual. Through rote learning and repetition of actions and mental pathways procedural and declarative knowledge of many sorts can be attained and mastered in this way.

A richer notion of learning is developed through considerations of what it means to search for and evaluate reasons, and to do so in a metacognitive manner. More information is mapped on to the diagram below.



The zones A to E represent the categories of thinking, reasoning and critical thinking in System1 or System 2 space. The arrows indicate movement between these zones. According to the model, moving from B to E and back to B, or from A to F and back to A is educational progress of a sort. In each of these cases the intuitive thinking inherent in System 1 is made visible (at least as much as it can be) through a System 2 analysis with a view to improving that thinking through reflection and practice and so eventually create better System 1 responses. The goal of education towards reasonableness also involves moving from zones A and B, through E and F and spending significant time moving into and occupying Zone D. Movement into zone C is possible and workable afterwards, as suggested above, but the hard intellectual lift for educators is getting to the high level operating space of zone D. The way educators can move people through the model is suggested by the nature of the thinking in each zone, and the obvious pedagogical implications of this are the work of the classroom (and much of this thesis).

Let me call the zones above the horizontal line in System 2 space the WARM zone. I coin this term using an acronym to represent some aspects of System 2 thinking: W for working, A for access, R for random and M for memory. The use of working memory as a discriminator between System 1 and System 2 thinking was discussed earlier and I have borrowed the idea of Random Access Memory (RAM) from computer use as I think it a useful analogy to describe how humans use working memory. Combining these in a memorable fashion leads to 'WARM'. Cool thinking, therefore, is that below the line and involves System 1 thinking as a point of obvious conceptual and linguistic contrast[53]. The movement between warm and cool thinking is therefore a useful way to understand developing thinking skills and some of the habits and abilities of experts. A representation of the model in a simple form is shown below in Figure 12.

Using warm thinking may also be instructive through another analogy. When a car engine overheats, the temperature gauge shows the engine as too warm. We must, as educators, be aware of how often we are asking students to operate in System 2 space lest they overheat themselves toward cognitive meltdown. While I will not explore this idea here for the moment, there could be a space in which the 'temperature' of the lesson could be averaged to sit comfortably between warm and cool zones to prevent an excess of either extreme. A lesson that is too cool may not develop skills, and a lesson that is too warm may disengage students, as the cognitive load is too high for sustained focus or concentration (Hattie and Yates, 2014).

When we think critically about what we do, and when our standards of evaluation and criteria for success are clear and accurate, we are engaged in the deliberate practice that is an essential part of the development of expertise. The model therefore also represents the development of our own expertise in teaching for thinking. It is a model of teaching for thinking and a model of developing expertise in teaching for thinking. Figure 20 (i) and (ii) below show this diagrammatically, with the wording slightly changed to represent the two projects.

[53] Suggestions for a more specific acronym include Cursory (brief/fast), Obvious (intuitively), Obscure (hidden thinking) and Low cognitive load.

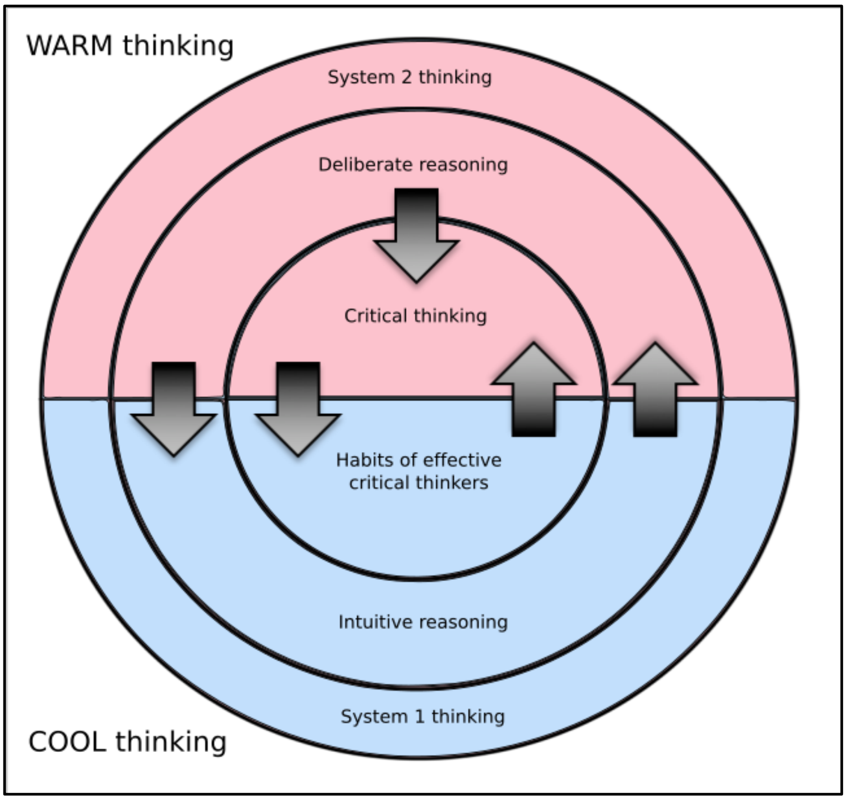


Figure 20 (i): a model for using and developing critical thinking

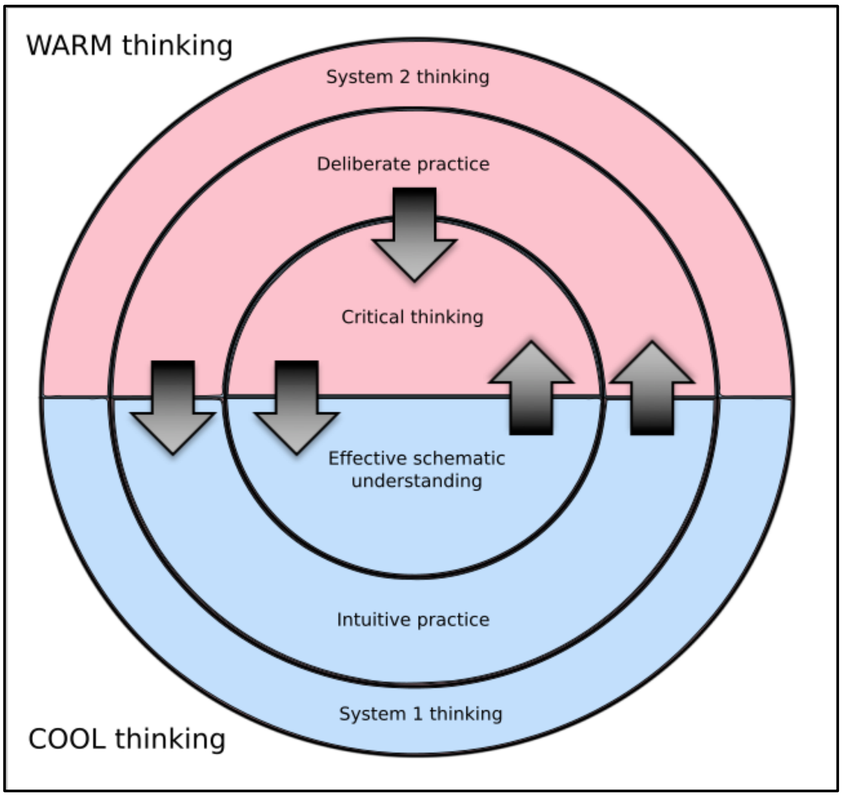


Figure 20 (ii): a model for using and developing expertise

6.6 Putting it all together

I mentioned in §2.1, *The challenge of developing schemata for thinking*, that some schemata may be simple but contain within them a great deal of complexity. The schema developed in this thesis contains such complexity. There is not only detail in unpacking the understanding of the elements and the relationships between them (the critical thinking matric in Appendix 2 is an example of this detail), but there is also detail in putting the understanding within the schema into practice. Like all schema that represent expertise, the problems of practice are an essential component. Experts, recall, are experts in what they do. It is not enough for expertise to have structured knowledge of something without also having structured how that knowledge is to be used. The activities and concepts within this chapter were designed to develop teacher understanding about how to move from theory into practice, a transition that is a necessary part of praxis—using understanding to inform practice and the results of that practice to improve understanding.

Education is characterised by change and, following Dewey, we would hope that change was growth. Not only do students themselves change as they mature, moving through epistemic stances, social capabilities and cognitive abilities, but even within these periods the process of learning to think is dynamic and sensitive to the nuances of engagement with other minds. The more pedagogical structure that we as teachers can introduce that helps us to understand this change and guide it towards improving student thinking, the more effective we become and the more explicit is the nature of our expertise. This structure has been enhanced through the work of this chapter to include developing epistemic positions and a deeper understanding of the cognitions and values in terms of how they may be internalised in pedagogical knowledge and classroom practice. For this it has been necessary to articulate guiding principles that can help in our planning for thinking and a model for movement between System 1 and System 2 thinking that can help to explain not only the development of mastery and critical thinking in students but also expertise in teaching for thinking.

But not all considerations of the schema are pedagogical. The implications of what it means for practice to teach for thinking include important changes in other areas, including institutional change, policy development, teacher training and research foci. In the next chapter, I consider some of these implications, noting that a full analysis of them all must be left for later projects.

Chapter Seven: Institutional change and research considerations

The many possible non-pedagogical implications of teaching for thinking involve areas such as:

- Teacher training
- Educational management and leadership
- Public policy
- Teacher promotions and career pathways
- University selection criteria and course preferences
- National employment strategies
- Educational research
- Innovation and creativity in industry

In this chapter I focus on two implications of the teaching for thinking pedagogy I have described. The first concerns institutional change and the second, the neuroscience of learning.

Institutional change is a critical aspect of teaching for thinking and one faced immediately by teachers undergoing professional development in teaching for thinking. It is common for teachers to speak of the institutional barriers to changes in their pedagogical practice. Aside from economic barriers to funding widespread pedagogical shifts and even when a school is sympathetic to change and willing to undertake it, not knowing exactly what to change or how to change it can frustrate attempts at progress. It is, therefore, imperative to consider what might be done to ease this transition.

In regard to the second implication, neuroscientific-educational research, I admit what has for me as an educator been the source of considerable frustration: the educational implications of findings in neuroscience and their (often highly commodified) misapplication in an area hungry for evidence-based practice. While this is acknowledged and addressed to some extent (see Busso and Pollack, 2015 who highlight a range of problems and prospective solutions), there seems still to be a need for educators to work with researchers to 'get a better handle' on the credibility and usability of research in neuroscience. It is perhaps in talking to educators about neuroscience that more progress can be made than in talking to neuroscientists about education. Neuroscientists will study what they will, but educators are the final arbiters of utility for teaching and their questions and needs might be best framed by them rather than by neuroscientists. The second focus of this chapter is, therefore, to suggest an approach to the neuroscience of learning, perhaps by way of understanding neuro-education as a potential discipline in which educators can operate as co-creators of knowledge. While it makes more sense for educators to engage with students' minds rather than their brains (the latter seems more of a surgical task than an educational one), there is something to be said for thinking about their brains as well.

7.1 Disruptive pedagogies: an institutional change consideration

Teaching for thinking is not a value neutral project. While thinking outcomes have been valued (or at least expressed as valuable), it is not always clear how an educational institution goes about delivering such outcomes. There is demonstrably less substance to the process of creating effective thinkers in modern educational institutions and more focus on consistency of outcomes. Consistency of outcomes is a function of quality control, but the use of 'control' here is problematic. In teaching for thinking at least, high levels of consistency and high-quality outcomes are difficult co-targets, particularly if we recognise that the institution itself is the source of both quality and of control. For how does one 'control' an expert teacher? If expertise is not valued, then mandated processes and procedures must of themselves be able to guarantee consistent outcomes. Some tensions in educational institutions, therefore, are a function of balancing processes and procedures against the autonomy of expert teacher judgement.

In this section, I consider an analogy between disruptive and sustaining technologies and disruptive and sustaining pedagogies. In particular, the educational community of inquiry of the sort developed through Lipman and Sharp, and potentially educating for thinking in general, can be seen through this analogy as a disruptive pedagogy. To make the analogy clear, I first give a brief overview of the concept of sustaining and disruptive technologies, and of the conditions under which an organisation can successfully adapt, or fail to adapt, to such disruption. I then develop the analogy through a contrast with sustaining and disruptive pedagogies regarding organisational resources, processes and values. I follow by drawing from the analogy ways of dealing with potential organisational concerns in dealing with disruptive pedagogies. I offer this analogy as the beginning of a discussion, and as a potential means of framing and problematising teaching for thinking, rather than as a definitive methodology.

The idea of disruptive technology—technology with the potential for creative destruction of existing business models—was developed by Clayton Christensen (1997). Christensen contrasted disruptive technologies with sustaining technologies. Sustaining technologies are those in which current technologies are improved "along the dimensions of performance that mainstream customers in major markets have historically valued" (*ibid*, p.xviii). Examples of sustaining technology in the mobile phone industry, for example, could include things such as longer battery life, faster CPUs, larger screens, higher resolution displays and a greater range of potential software applications. These are things demonstrably connected to improving performance along the lines that customers have grown to expect.[54] Disruptive technologies, on the other hand, are those technologies that do not fit with existing customer expectations (as opposed to currently articulated needs or desires) or with established industry foci. They "bring to a market a very different value proposition than had been available previously" (*ibid,* p.xviii). A useful example of disruption caused by a new technology is the ride sharing application, Uber. Uber's technology allows drivers and passengers to form a peer network to connect with each other and exchange money for rides through an online platform. Traditional taxi companies do not work on this model, having a centralised booking system to deliver industry-licensed drivers working standard hours to customers in need of transport. These models are mutually exclusive, and the growth of Uber at the expense of traditional taxi companies is the source of disruption to the existing industry, which is incapable of modifying towards, or otherwise accepting, the increasingly popular newer model.

Christensen notes that it is not so much that the technology itself is disruptive in this context, but that old business models based on sustaining technologies that attempt to contain or work with the new technology are the source of tension. While it may seem that technologies not aligned with customer or industry expectations are not candidates for success, as the market grows and the technology matures, what was a technology of minor concern disrupts the mainstream and begins to dominate.

Certain educational practices can also be seen as disruptive or sustaining. Sustaining educational practices, like sustaining technologies, attempt to refine existing processes with a view to moving further along a path that delivers well-established outcomes in a way that is commensurate with expectations and existing practice. Traditional, sustaining, pedagogical methods might look to improve student performance on standardised testing, or otherwise meet existing metrics of success through allocating more resources, extending teacher training or working instrumentally towards meeting specific ends. This type of sustaining pedagogy would, by definition, make up the bulk of

[54] There is a persistent story, most likely untrue, that Henry Ford said, "If I had asked people what they wanted, they would have said faster horses."

teacher professional development programs. Disruptive pedagogies, however, like disruptive technologies, will not fit current models and attempts to accommodate them within such models create unsustainable tension. Christensen himself has written on the concept of disruption in education (Christensen et al., 2011), but this treatment has focused on innovations other than the pedagogy of the community of inquiry, many of which including the role of technology to facilitate practices that might be disruptive. My treatment in this section is specifically pedagogical, and specifically the pedagogy of teaching for thinking.

Educational disruption may be born of the need for alternative methods of teacher training and re-training, for timetabling of non-traditional class structures, for resource allocation requirements that do not work with established administrative processes, for learning outcomes that do not match those set for standardised testing, and for difficulties in reporting on student performance in other than age-group levels, for example. The educational community of inquiry has the hallmarks of such potential disruption.

Christensen's analysis of disruptive technologies provides a framework for discussing potential organisational success or failure, and it is interesting to see if this framework is applicable for disruptive pedagogies such as that underlying the community of inquiry, and, if so, to see what implications may exist for educational institutions. Rather than move between the terms *technology* and *pedagogy*, I use the term *practice* to explore the analogy, using disruptive and sustaining practice as an inclusive term, reverting to the former terms when necessary. Similarly, rather than talk of *companies* and *schools*, I will speak of *organisations*. I do not assume equivalence, only similarity.

Resources, processes and values

According to Christensen, understanding organisational success or failure is a function of three broad categories—resources, processes and values—and how these contribute to building capability. I consider how these factors could be used to understand why the community of inquiry pedagogy might be disruptive to schools, and to ultimately seek a solution in these terms. I suggest some factors as they might apply and then discuss their nature and problematic aspects in developing the necessary capacity to implement a community of inquiry pedagogy.

Resources are, for the most part, the materials and people that an organisation has on hand to apply to the completion of a task. They "are usually *things,* or *assets*—they can be hired and fired, bought and sold, depreciated or enhanced." (Christensen, 1997, p.186). While this is a very broad category across all businesses, in the case of schools, and in the specific task of building an educational community of inquiry, the key resource would seem to be the people who are employed as teachers and administrators (there may be an argument that students and parents are also resources, but I will leave that unexamined for the moment). Teachers have the pedagogical knowledge needed to develop thinking skills in students, and administrators have the capacity to organise processes and prioritise factors that allow teachers to do so.

Processes are those things that allow tasks to be accomplished using the available resources. They are "patterns of interaction, coordination, communication, and decision-making" that translate goals into results (*ibid*, p.187). Christensen notes that while processes define what an organisation can do, they also define quite clearly what it cannot do. Processes that have developed over time in an organisation are often efficient because of their specificity and the organic nature of their development, having evolved over time to deliver specific outcomes and having undergone extensive review and refinement. But while they may be well suited to one particular context, they may fail when applied to another. Schools, being concerned with children and their holistic development, are particularly complex organisations and their processes are legion. I have mentioned some of the processes that might tightly bind a school, including the nature of the timetable and resource allocation; others could include mechanisms of assessment, pedagogical frameworks, teacher professional development and induction, reporting protocols, behaviour management strategies, unit and lesson planning templates, metrics for rewarding teacher performance, grouping of students according to age or ability, programs for gifted and talented or special needs students, and how success is celebrated, to name only a few.

Organisational values "are the criteria by which decisions about priorities are made" (*ibid,* p.188). As for processes, values should be widely understood and uniformly implemented to develop consistency of performance. Values, or at least lists of them, are ubiquitous in schools. But these are usually associated with ethical and moral principles or characteristics; and so, values such as respect, tolerance, fairness, responsibility and striving for excellence are commonplace—and rightly so. In the resources, processes and values framework, however, values take on a more mundane meaning. They are tools of prioritisation and of decision-making. Some companies may value selling fewer items at high profit and others many items at low profit, for example. What a company values informs, presumably, the principles of operation by which they work. A school's organisational values are those things that inform and shape its processes, including those I mentioned earlier. For example, a teacher may be rewarded based on results of standardised testing, or on increased student attendance or engagement, or all of the above. Academic success may be celebrated in preference or equally with sporting performance. Learning spaces may be designed and operated to enhance collaborative learning rather than learning in isolation, and so on. Each of these outcomes is realised through processes informed by values.

New resources can be attained and old ones removed with relative ease, but processes and values are not so easily modified in the face of disruption. In particular

> …by their very nature, processes are established so that employees perform recurrent tasks in a consistent way, time after time. To ensure consistency, they are meant *not* to change—or if they must change, to change through tightly controlled procedures. *This means that the very mechanisms through which organizations create value are intrinsically inimical to change* (*ibid*, p.188, italics in original).

Disruption occurs when processes and values are misaligned with the potential adoption of new goals or practices. As organisations differ markedly in their values and processes, what is disruptive for one organisation may be sustaining for another.

There are several sources of potential disruption within the community of inquiry pedagogy, characterised by their points of difference with more traditional pedagogical principles. These include that knowledge and meaning are to be collectively and collaboratively established rather than distributed through the teacher, that students work collaboratively rather than competitively, that teachers can be more a source of questions than of answers, that outcomes are measured, as Dewey advocates, by the potential for further education rather than for instrumental ends, and, perhaps most definitively, that the community of inquiry is an education in thinking rather than simply an education in knowledge acquisition. A significant consequence of this latter point, and a source of further disruption, is that assessing thinking is far more problematic on large-scale tests than is testing for recall of declarative or procedural knowledge. School values that optimise success for disruptive pedagogies, at least for the community of inquiry, are those that minimise the importance of standardised testing, prefer education for thinking and favour collaborative learning, for example.

An analytic framework

Christensen provides some useful graphical illustrations to better understand the dynamics of disruptive and sustaining technologies. I have synthesised some of the information to produce a graphical display to inform the adoption of potentially disruptive pedagogies within a school (Figure 21). On the graph, I have used the terms ‘traditional’ and ‘community of inquiry’ for the terms ‘sustaining’ and ‘disruptive’ respectively. This is modeled on a school that has traditional values and processes and that might wish to consider the community of inquiry pedagogy as a means of developing better thinking in its students.

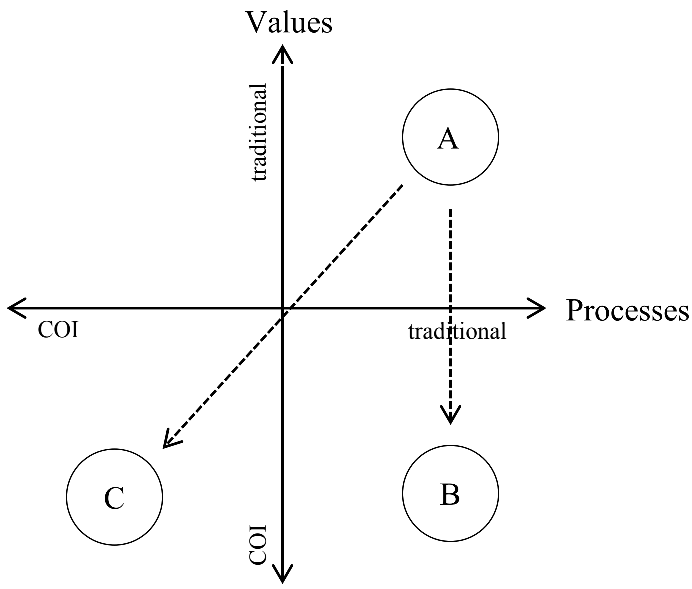


Figure 21

The vertical axis presents the range of values that are aligned with community of inquiry (disruptive) pedagogy and traditional (sustaining) pedagogy. The horizontal axis presents the domain of processes aligned with community of inquiry pedagogies and traditional pedagogies. The zones A, B and C represent school states. Zone A represents a school that has traditional values and processes. Zone B represents a school with traditional processes, but having values aligned with otherwise potentially disruptive community of inquiry pedagogy. Zone C is one in which schools’ values and processes are well aligned with community of inquiry pedagogy—and for this zone, the community of inquiry pedagogy is no longer disruptive.

In the transition from A to C, schools may move both processes and values towards the pedagogy of the community of inquiry, moving more directly through the plane, or they may first move from A towards B, changing values as a precursor to changing processes (a final move to C). Christensen uses Wheelwright and Clark’s concept of ‘heavyweight teams’ to describe how some staff in an organisation can lead the way to modifying values and processes (*ibid*, p.201). These teams are tasked with the redevelopment of values and processes to enable a transition to, or accommodation of, disruption. The creation of these teams is itself a change in process, a change in which new boundaries are drawn around groups of team members to create new groups with capabilities that are different from the capabilities of previous groups. In this way organisational capacity is developed. Christensen points out that organisational capacity does not automatically match individual capacity. This new demarcation is done with the goal of creating organisational capability that matches individual capability and allows it to flourish.

When managers tackle an innovation problem, they instinctively work to assign capable people to the job. But once they've found the right people, too many managers then assume that the organisation in which they'll work will also be capable of succeeding at the task. And that is dangerous—because organisations have capabilities that exist independently of the people who work within them (*ibid,* p.16).

Working with teams whose makeup is directed towards sustaining practice can lead to circumstances in which "projects are categorised by endless debates, grudging compromises, and little change" (Christensen et al., 2011, p.218).

While analogising between types of organisations delivers some potential for action, it is worthwhile to consider how the resources, processes and values (RPV) framework might be applied to the individual teacher. Resources available to an individual teacher might include their knowledge and understanding of content and pedagogy, and the range of affective dispositions they may bring to their classroom and to their interaction with students. Values could be understood as those things that inform their pedagogical decisions. Processes could include such things as habits of practice, routines of classroom administration and those processes taught to students to ensure consistency of educational outcomes. There seems nothing about individual teacher practice that would be incompatible with the RPV approach in terms of understanding barriers to and opportunities for change, with perhaps some exceptions such as creating heavyweight groups. The dynamic of individual and organisational RPV sets may inform one another, as well as speak to the potential for matching individual and organisational capacity overall. Either way, it would seem as important to break with the analogy here and to consider the individual as much as the organisation when dealing with an educational institute, and certainly so for the autonomy of decision making required for teachers involved in an education for thinking.

Seeking disruption

Sustaining technology is, by its nature, perpetually on the radar of leaders while disruptive technology fails to meet established metrics for success and tends to be therefore minimised, ignored or not visible at all (Christensen, 2001). Attempts to introduce the community of inquiry pedagogy may similarly be inhibited, for example, by performance demands expressed in the language of the existing pedagogical paradigm (which reflects what organisations currently value). This is not to say that it the community of inquiry pedagogy cannot perform to satisfy existing metrics, but that the causal pathway from practice to outcome is unknown, not made clear or perceived as risky. Students who are currently undergoing courses in drilling for performance improvement on standardised tests might be seen by decision-makers to be better served by continuing to do so, rather than shift their pedagogical focus onto unfamiliar and less quantifiable, and therefore potentially less predictable, processes inherent in the community of inquiry—processes which might frustrate decision-makers who "demand crisply quantified information when none exists…" (Christensen, 1997, p.166). Moreover, the expectations of parents and other concerned groups might only be articulated in ways more clearly related to existing paradigms.

If we can analogise from Christensen's examples of disruptive technology to the community of inquiry as a disruptive pedagogy, this means that those who promote it are working within a low profile, and we need, therefore, to structure our advocacy with this knowledge and attempt to shift the language to reflect new values and inform new processes. But this is not necessarily problematic. As Christensen pointedly claims in an educational context "...disruption does not take root through a direct attack on the existing system. Instead, it must go around and underneath the system. This is how disruption drives affordability, accessibility, capability and responsiveness" (Christensen et al., 2011, p.243). How this is best done is an area worthy of strategic development.

What Walter Powell and Kaisa Snellman (2004, p.199) called the 'knowledge economy', expressing the view that "the key component of a knowledge economy is a greater reliance on intellectual capabilities than on physical inputs", is now better described as a 'thinking economy', as it is effective thinkers who will produce new knowledge and frame new paths to growth and sustainability. Resolving the tensions between existing educational models and the disruptive pedagogy of teaching for thinking is an educational imperative this analysis acknowledges and supports.

7.2 Neuro-education: a research consideration

Neuroscience seems an unusual topic to include at this stage. But throughout this thesis I have maintained a focus on thinking above learning, with learning traditionally understood in terms of the transmission of extant knowledge, and there is much in the current discussion of the educational implications of neuroscience that is suspect, not least by neuroscientists themselves, as I will discuss. This section is intended to strengthen the educational focus on thinking in education by suggesting ways in which a focus on thinking in neuro-education can be developed. I am not presenting this chapter for the consideration of neuroscientists. The literature on neuroscience is far greater than a philosophical analysis of teaching for thinking can accommodate in this thesis. I am rather attempting to develop an analytical framework for teachers through which some research in neuroscience can be assimilated, or at least through which useful questions that make sense in the context of the schema developed in the thesis can be framed.

In the complex space that is the interplay between education and neuroscience, at least three broad issues have proven to be problematic. The first issue is the plethora of invalid inferences made from findings in neuroscience to their supposed value in educational practice (Royal Society, 2011). This is a function of several things, including a limited understanding of the facts and causal implications of findings in neuroscience on the part of educators and the general public, and the ease with which the products of such a limited understanding are commercialised and propagated in an educational mood tuned towards evidence-based approaches (*ibid*). The second issue is that the overall flow of information between neuroscientists and educators is both asynchronous and asymmetric. It is asynchronous in that results from research into neuroscience are often applied to educational practice in an *ad hoc* fashion with educational responses being reactive or otherwise spasmodic rather than continually informing neuroscience research in an organised manner. It is asymmetric in that the information flow is largely from neuroscientists to educators, with the burden of determining the educational significance of that information, at least in practice, more on the latter than the former. This asymmetry is not necessarily the result of a dereliction of duty on either side—after all, neuroscientists, by and large, are concerned with how the brain works and educators are concerned with what students do with their brains (or, more appropriately in this pedagogical context, their *minds*)—but progress might result from developing a more symmetric relationship. The third issue, one which contributes to the second, is that there are typically far more calls for better understanding of the science on the part of educators than there are for better understanding of pedagogical theories on the part of neuroscientists (Busso and Pollack, 2015).

One way to understand these problems is to see them as symptomatic of the emergence of the relatively new discipline of neuro-education. Disciplines often coalesce around types of problems, rather than the other way around, and the problem of how an understanding of the brain helps us to educate people is a complex and multifaceted one. This complexity is reflected in the variety of workers representing disciplines that make up the borders forming neuro-education, including cognitive science, neurology, developmental psychology, educational psychology, philosophy and educational theory, to name a few. One of the identifying characteristics of established disciplines is that they have effectively problematised their field so as to produce effective questions and, at the same time, developed the means of inquiry to answer them. It is easy to see this historically through the development of fields such as psychology and currently in newer fields such as organic electronics, for example (see, for example, Editorial, 'Embracing the organics world', 2013). Neuroscientists and educators both have problematised their fields effectively, but this is not the same thing as problematising within neuro-education. For neuro-education, I suggest the three issues I have outlined above work against the potential to effectively problematise within the area. Rather, the area itself is problematic.

Working memory

In searching for areas of study within neuro-education that have some substantive empirical base from which we can expand, or at least ground, the discipline, and for which both educators and neuroscientists have an understanding, working memory and attention emerge as likely candidates. I will focus on working memory because of the attention I have previously given it in this thesis. The concept of working memory is important to educators for several reasons, including helping to understanding the concepts of cognitive load and of mastery at the cognitive, if not neurological, level. Working memory is postulated to be the prime distinction between thinking types in the family of cognitive theories known as dual-process theories of reasoning; a duality expressed as a division into System 1 and System 2 thinking as outlined in §1.4, *Dual process thinking, working memory and schematic knowledge*. Insofar as we use the term 'cognitive load', we usually refer to the amount of working memory we need to bring to bear on a situation to effectively process it. As an example, a student learning to play scales on the violin must use working memory in the initial stages, ensuring attention is focused and sustained and thinking hard about which notes to make, when to make them, and how best to do so, and thus she endures a high cognitive load. As proficiency is achieved, and as new neural pathways are created and consolidated, the need for working memory reduces and the process of playing scales becomes more or less automatic, reducing the cognitive load. We can think of this as the student moving from Type 2 thinking in the initial stages of learning to Type 1 thinking as she approaches mastery. There is more to mastery than just a reduced need for working memory; for example, the development of schema to store knowledge in a structured way which contributes to this reduction is also important (Harasym et al., 2008). But the use of working memory remains indicative and a constituent of this change nonetheless. Many aspects of education can be understood as a transition to some degree from System 2 to System 1 thinking, including the formation of habits of learning. This notion of mastery has been outlined in Chapter Four *Metacognition* and in §6.5 *Warm and cool thinking.*

Neurologically, we know quite a few things about using working memory (see Lazar, 2017 for a recent overview), including that the pre-frontal cortex (PFC) activity needs to be synchronised with brain activity in other regions and that signals from the PFC will affect working memory by preferentially foregrounding information that is relevant to specific tasks including information represented elsewhere in the brain (D'Esposito et al., 2015). These and other findings are rich with pedagogical implications, highlighting among other things the importance of executive function in learning and suggesting the active, rather than passive, nature of this process. As outlined in §1.3 *The nature of expertise,* we know that working memory is limited in both the amount of information it can hold and process and in the time that processing can happen before it is lost, that these limits only apply to sensory memory but not to information accessed from long term memory, that knowledge organised within schema drastically reduces cognitive load during access, and that expertise is a function of the effectiveness of schema in organising knowledge. Working memory is a solid neuro-educational concept understood through the contribution of a variety of disciplines. Workers from neuroscience and education can speak with coherence and confidence in this area, as well as frame substantive and meaningful questions that can be asked and answered in a framework that equally draws on both neurological research and educational practice. Inasmuch as it is the discriminator between Type 1 and Type 2 thinking, it has also entered into the awareness of the general public through works such as the psychologist Daniel Kahneman's book *Thinking Fast and Slow* (2011). For all the above reasons, working memory is an established area of study in the field of neuro-education.

Thinking rather than learning

It is interesting that much of the language of education is centred on learning, while less attention is given to thinking. We speak about teaching and learning, but not about teaching and thinking. We have learning objectives but less so thinking objectives. We are concerned with the science of learning but not so much about the science of thinking. Clearly students are taught to think, but terms describing how students are expected to think are usually identified as learning rather than thinking, which I suggest is suboptimal for providing pedagogical direction. One solution to this may be to explicitly link thinking, rather than (or at least as well as) learning, to neuroscience.

An education in thinking is constituted in part by an attempt to improve students' cognitive skills. The cognitive skills described in §5.1, *Cognitive skills*, such as recall, analysis, synthesis, evaluation, justification and inference, can be thought of, at a certain functional level, as things you do with discipline content knowledge. These skills are not necessarily distinct skills; they form more of a relational web than a hierarchy (as explained in §6.2, *Teaching skills and values,* the move away from the hierarchical approach has resulted in the diminishing of Bloom's taxonomy from the ubiquitous educational device it once was). In the process of justifying, for example, one might call on the skills of generalisation and inference to develop a broad persuasive case. Even so, they can be collectively understood as operating on a knowledge base, and indeed towards the creation of new knowledge. The list of cognitive skills is indefinitely long, reflecting their complex nature as a category and the many contexts in which they can be used. I do not suggest that in learning to master a subject area in the traditional way these skills are not developed, but we in education tend to ask students questions that require these skills rather than teaching them directly. We often ask them to analyse and justify in problem solving, for example, but how often have we told them exactly what this entails? It is in teaching them directly (often in a discipline context) that we focus on thinking. Many syllabi and assessment criteria sheets explicitly identify these skills, and their desirability as valuable learning outcomes is not in question. Marzano and Kendall's *New Taxon*omy (2006) has established six levels of processing[55]. Levels 5 and 6, the highest in this arrangement, they call the metacognitive system and the self-system respectively. Level 4 concerns knowledge utilisation, Level 3 analysis, Level 2 comprehension and Level 1 retrieval. While these words may not themselves be completely explanatory, I suggest it is clear from the cognitive actions and skills associated with them that Levels 1 and 2 are about learning, Level 3 is about thinking, and Level 4 is about learning and thinking (though thinking as a topic is lightly treated in this taxonomy – see the chapter entitled *The New Taxonomy as a Framework for Curriculum and Thinking Skills*).

Given the prominence of cognitive or thinking skills, it is, therefore, sensible to ask what neuroscience might have to offer in the realisation of these broad educational goals. It is striking

[55] See diagram in §6.2 *Teaching skills and values.*

that the first of the list of cognitive skills above, *recall*, would be the skill educators most closely associate with research in neuroscience. Phrases like 'the laying down of memories' or 'accessing information'—phrases related to recall—are more familiar in neuroscience than phrases related to analysis or inference[56]. Indeed, outside sensory-motor skills, the most literal interpretation of 'learning' seems to value recall above other cognitive skills. I am not including the formation of long-term memory as a cognitive skill, as it does not really appear, so expressed, in many educational contexts —but this does not mean it is irrelevant to the discussion, only that we test for recall of that which has been memorised, but not directly for the formation of memory. The ability to recall knowledge is valuable, but an academic education demands far more of students than the demonstration of this skill, or at least a more nuanced one that considers how schemata are formed as knowledge is organised in long term memory. How can we take neuroscience more definitively into understanding the nature of cognitive skills? What has, or has not, been done that can point more meaningfully to these high-level skills and guide teacher practice in such skill development? And to what extent can the categorisation of these skills at a broad functional level as 'things we do with knowledge' be justified by any underlying similarity in neurological function? In attempting to answer these questions, or, more accurately, ask them in a neuro-educational framework, I will initially focus on the skills of analysis, inference, generalisation and judgement as examples since time and space are limited.

The definition of analysis varies but let me restate my definition from §6.2, *Teaching skills and values*. Analysis involves considering an object, situation or construct and seeking to identify its purpose and its constituent elements. It could involve determining how the constituent elements, or categories into which they could fall, could each contribute to the overall purpose, and if all are equally relevant or significant. It could also include identifying any causal or logical relationships between elements or categories of elements.

So what, at a higher neuro-educational resolution, does this mean? Some significant questions that neuroscience can inform include (granted that some of these are already within current understanding and are not novel questions in either education or neuroscience—they are included here for framing purposes):

1. What role does working memory play in initially recognising and analysing an unfamiliar situation?

[56] Acknowledging that factors such as attention also make up a strong research area in neuroscience.

2. How does knowledge organised into schemata contribute to identifying purpose?
3. What is pattern recognition? Is it only one skill?
4. How is the recognition of abstract causal and logical pathways related to working memory and minimised by the use of schemata?
5. The ability to categorise presumes the ability to generalise and analogise (also significant cognitive skills); can generalisation be explained through the neuroscientific understanding of how coding in the brain allows for generalisation at the level of neuronal processing of information? Or is 'generalisation' here used for different and unrelatable functional levels (a point I will return to later)?
6. Is the ability of the PFC to target relevant and significant information for use in working memory improved with practice? How is it otherwise affected? How does it know what is significant and relevant?

I would hope that someone whose expertise lay in neuro-education would be able to frame these so that I could better understand both the concept of analysis and the neuroscientific research that would be relevant to improving how to teach it. My effort to frame analysis in a neuro-educational context is not intended as an exemplar of how it should be done, but as a call for it to be so presented.

Let me consider now the skill of inference. When we infer, we move from premises to a conclusion, which we can also express as moving from existing beliefs to new beliefs. For example, if I provide the premises:

P1: All gronks are green.
P2: Fred is a gronk.

We immediately infer to the conclusion that Fred must be green. In this particular case, it is a deductive inference. Sperber and Mercier (2011) make the claim that, at the smallest unit of inference, each inferential step must be intuitive. Larger inferential leaps are made of smaller ones, and the maximum inferential resolution shows only intuitive inferences. I cannot explain, for example, why Fred must be green if you do not accept that conclusion (with perhaps the exception of trying to show this through Venn diagrams). The acceptance of such intuitive thinking is something that we fundamentally rely on in reasoning and argumentation as we rationally construct chains of reasoning. But they also point out that these types of intuitive leaps are System 1 thinking, and therefore not, by Evans' criteria, a function of working memory—and indeed cannot be. So, unlike for mastering playing a violin, mastering inferring could not be understood as moving from System 2 thinking to System 1 thinking. How, then, can we use this understanding to improve students' skills of inference?

Including induction in the skill of inferring further complicates the situation. If I provide the premises:

> P1: Every time I've had a chocolate covered oyster I've been sick.
> P2: I've just had a chocolate covered oyster.

We might infer the conclusion that I'm going to be sick. But, since this is an inductive argument where, unlike for deductive arguments, the truth of the premises does not guarantee the truth of the conclusions, we might also do so with caution. This inference seems less intuitive, and requires a more reflective approach, understanding that the inference depends on both empirical, *a posteriori*, claims and logical ones, whereas deductive inference is purely logical, or *a priori*. Presumably this would involve referencing a knowledge base, and the consequent reliance on schemata and the contribution of representations in long-term memory to our working memory. Some key questions of inference may then be (with again the acknowledgement that some of these questions may not be novel):

1. How do intuitive inferences operate? Are they simply associative or is there a more complex explanation? Either way, how can students improve this skill?
2. Is deduction a distinct process from induction at a cognitive or neurological level of explanation?
3. Why are incorrect inferences (including errors such as affirming the antecedent) also often strongly intuitive and what happens in the processes of inferring when these errors are realised?
4. If induction is distinct from deduction as a cognitive process how can this understanding help students improve the skill of inference in general?
5. How does logical reasoning differ from causal reasoning?

Perhaps neuroscientists may think these questions are aimed at too high a functional level for treatment by current work in neuroscience, and perhaps educators might be more concerned with the behavioural indicators of these skills than what is occurring neurologically (through cognitively there may be a better case for concern). But again, this is my point. They are not, of themselves, questions of limited use, but the ability to answer them, or to frame them better, may be what is needed from workers in the discipline of neuro-education. At the very least, someone with the appropriate expertise needs to stop me thinking along these lines if these questions are in principle pointless.

On the other side, we know that the capacity to make rational decisions, follow through on and prioritise tasks depends on emotional regulation (Damasio, 2001). How should educators respond to these findings?

The extent to which the categorising of cognitive skills as things we do with or to knowledge can be mirrored with some categorical precision at the neurological level seems difficult to determine. The questions I have asked about the nature of analysis and inference have focused on what we know or suspect is important in their operation, but these questions are speculative, and hence cannot speak to any significant neurological structuring. If the functional level is simply a consequent of the sort of neurological activity currently researched and applied—with no larger structures that can be associated with or characteristic of these skills (i.e. no 'analysing' structure or 'evaluating' mode) —, then the cognitive skills as we understand them could be the result of a kind of sparse coding in itself, in which emergent task complexity is derived from a limited range of neural activity.[57] This may be good news in that findings in a small number of areas could have profound effects in education across a range of thinking strategies.

There is one interesting parallel between neurological behaviour and a specific cognitive skill, however, which is so analogous it is worth commenting on. As Anton Spanne and Henrik Jorntell explain, models of neuron behaviour suggest that the ability to generalise is affected by the input of unnecessary information, causing an "increase in the number of training contexts needed to single out the dimensions that are relevant" (Spanne and Jörntell, 2015). This is exactly descriptive of the process of generalising writ large. Consider making some inquiry into a correlation between two variables. Were these two variables the only ones, then noticing a correlation would be a speedy process (if noticed in the first place). If, however, they were two of many, it may be some time before the connection was made. One might precisely say that there was an "increase in the number of training contexts needed to single out the dimensions that are relevant". The question is therefore: does the neurological input/output process for generalising a response exactly explain the

[57] In an organic a neural network, meaning could be captured by the state of one neuron or by the state of an entire brain. A state that sits between these extremes is referred to as sparse coding with the suggestion that the ratio of active neurons within a state is less than 50%.

common experience of generalising in the world? And if so, what do we know about the process that can help us to teach this skill?

Taking the teaching of the cognitive skills further, let me also consider the issues of values of inquiry. There will be questions of *depth* and *breadth* of analysis, of *precision* in the quantification of data, of *accuracy* in representing information, and in the selection of *relevant* and *significant* criteria for categorising and preferentially attending to elements. But in valuing accuracy, precision, breadth and depth, logical cohesion, plausibility and so on, students must make judgements rather than demonstrate a skill. So then, what is happening in our brains when we make a judgement by applying these values? Moreover, the experiences of learning to apply these values seem to be of the 'knowing how' sort rather than the 'knowing that' sort. In other words, the nuanced decision to apply precision over, say, accuracy in a particular inquiry is non-propositional knowledge and, like knowing how to surf, cannot be simply expressed. While that decision could be explained and understood in retrospect though propositions, as it happens it requires a judgement call. What happens neurologically during these judgement calls seems complex. Most judgements are arrived at intuitively, even when a large amount of information is being processed. When expert diagnosticians make judgements based on accessing effective schemata, for example, their error rate is 5 times less than others who rely simply on hypothetico-deductive methodology (Harasym *et al.*, 2008). Judgements may be a type of inference, or they may be something else. Either way, they are not the same as algorithmically arriving at a solution to a problem (we don't ask students to judge when we want them to determine). Presumably, judgements are at the heart of decision-making, so understanding their nature neurologically could have significant implications for education and continuing professional development.

It may seem rather arbitrary to have chosen analysis, inference, generalisation and judgement in addressing cognitive skills while others, such as justification, evaluation, and explanation remain unexamined. But neurologically speaking the hard yards may have been made. Consider that in justifying we either create a logical argument consisting of elemental inferences or refer to an accepted procedure or standard, the analysis of which provides the normative claim for our justification. In evaluating we make judgements through the application of the things we are valuing in our inquiry. Both can be understood as a synthesis of the skills already examined. I suggested earlier that the cognitive skills formed something of a relational web, and in some cases this web has diffuse nodes within which several skills may be synthesised. My point here is that understanding how some of the key cognitive skills work at the neurological level could have a large payoff in terms of the others, and hence a thinking education across a range of skills may become more achievable.

Empathetic thinking

We know there is benefit in developing thinking skills through collaborative reasoning, particularly when the skills of argumentation are in play. Collaborative or social cognition demands interplay between participants, making reasoning something of a social competence rather than only an isolated human faculty. We also have reasons to believe that interpersonal communication might involve mirror neurons (Marshall, 2014). It is interesting to speculate that attempting to understand another's argument, or attempting to get our own argument across, we might require empathy involving mirror neurons. We might on occasion construct a formal argument in isolation from the input of others, but in the dynamic act of real-time argumentation, there is a lot happening to shape our progress. The raising of a sceptical eyebrow, the acknowledging of a point, all serve as strong emotional and intellectual cues for the success or failure of a cognitive strategy. The better we are at understanding the cognition of others—the more empathetic our thinking—the better our ability to take negative and positive feedback towards improving the force of our own reason. Even when we are simply explaining rather than arguing, we are attempting to establish an understanding in someone else's mind approximating our own. To do this it is again useful to understand how others think—the general appeal to know your audience when explaining something speaks to the utility of doing so. Understanding how an audience thinks could be an exercise in psychological application alone, but the effective communicator will also be able to respond to the audience as necessary. If an explanation is required that does not involve gauging the reaction of listeners, the effective explainer can still mirror potential problems in their own mind, and the points in an explanation when these might occur, based on previous experience. The extent to which empathetic responses beyond the purely emotional can be sourced to mirror neuron activity, and the extent to which understanding this has pedagogical implications for collaborative reasoning are deeply intriguing questions.

Neuroscience and education are willing but awkward bedfellows. This is understandable as each has its own language, research focus and suggestions about how each informs the other. These problems are symptomatic of an emerging discipline, in this case neuro-education, and are compounded by the input of a variety of other fields, such as psychology, philosophy and cognitive science, that have long hovered around education. The concept of working memory, and the factors that affect it, clearly straddles neuroscience and education, and the implications of research in one discipline should substantively inform research in the other. It is, therefore, a foundation on which neuro-education can build. To quickly review, neuro-education can tell us about how students learn, but also potentially about how they think. The cognitive skills, well represented in educational outcomes, can be understood as thinking skills, and these skills constitute, in part, an education in thinking. Focussing on student thinking and the nature of cognitive skills generates a range of pertinent questions in a neuro-educational framework, many of which relate to working memory and the structure of knowledge in long-term memory. The intuitive nature of inference and judging often seem independent of working memory but may be sensitive to how knowledge is organised into schemata. It is interesting to note, however, the direct parallel of explanations of generalisation at the neurological level with generalisation at the level understood as a cognitive skill. Some skills may involve the activation of mirror neurons as they play out in the interpersonal context of collaborative cognition.

Some of this is established science and some of it, speculation, but it is speculation in the hope of phrasing productive research questions; in which not only the questions but also consequent results are understandable or interpretable by those who need them most—those whose project is teaching for thinking.

7.3 Putting it all together

Each of the above chapters has endeavoured to establish an understanding or a perspective that contribute to a greater understanding of teacher expertise in teaching for thinking. This expertise is certainly pedagogical, but it can extend, as so much expertise does, into the grounding of that practice in relationships with people, institutions and projects that share common or overlapping goals. The two foci of this chapter were intended to stimulate discussion about implications for teaching for thinking that involve such relationships. I have not attempted to be definitive in my recommendations, only suggestive. Like so much of the thesis before it, the purpose is not so much to be prescriptive as to provide a structure through which opportunities for coherent, directed, and above all productive professional dialogue can emerge.

Afterword

I said in my introduction that this thesis was intended to produce a schematic representation of the expertise involved in teaching for thinking and that it was to be as broad and simple as possible. This was not a simple task, however, since the enormous number of concepts that bear on education in general and thinking in particular create a complex and sometimes impenetrable forest of theoretical frameworks and catchy acronyms. I was left with the problem of potentially creating another framework to add to the confusion. This was reflected in the fact that for some time I called the schema a 'model for critical thinking', imagining that I had in some way created a process, a model or described a system. It was only after reading more about the nature of expertise that I realised I was working with a schema, after which the project became far more coherent and productive. A schema is something that integrates understanding, it is not something that simply adds another element to an existing bank of concepts. I immediately began to shift my language in the professional development sessions I deliver towards teacher expertise and found a very receptive audience. I realised that while education in general has been hungry for evidence-based practice, teachers were hungry for a way to understand, develop and talk about their own expertise. For if teachers do not have a clear idea of the nature of that expertise, it is difficult for others to see it either. It has become a significant driver for me that I might provide teachers and the teaching profession with such a structure.

The response to this approach from teachers, schools and a range of individuals representing regional and national education programs has been very positive. The intuitive sense that teachers have that teaching students to thinking well has benefits across and beyond the curriculum is given voice to some degree by this professional development program. Most teachers I speak with did not join the profession to transmit vast swathes of content, they joined to engage with the minds of their students and to help them flourish. A teaching for thinking focus can revitalise that purpose and give permission for teachers to see what is happening in the minds of their students as the central focus of the class.

But the thought that crosses many minds immediately after seeing the value of such a schematic approach is how it can be justified to others. This is, of course, an entirely proper consideration, but I must acknowledge this in context. What I am suggesting is the value of a focus on teacher expertise. This is not a program to be implemented within an existing paradigm, it is rather a shift to a new pedagogical paradigm. This means that evaluation needs to be focused first on the change in teacher behaviour before it is focused on student performance. If student performance is the first focus, then any change in that performance cannot be reliably attributed to change in teacher understanding and practice. It is therefore far more rigorous to make teacher understanding—and how that understanding manifests in changes to practice—the key object of initial study.

Measuring the efficacy of this pedagogy across multiple school sites, including those with diverse student populations, cultures and communities, is now underway through independent evaluation with the initial focus being on teacher behaviour. A number of schools, however, have been collecting their own data on student performance as their pedagogical expertise of their teachers develops and the results have been impressive. These data show improvement in results of students who have been exposed to this pedagogy in the number of students in A and B grades across subjects. There is also strong evidence for improvements in the Australian NAPLAN (Numeracy Assessment Program in Literacy and Numeracy) tests from students whose teachers have been trained in this pedagogical approach. Evaluations of this performance and of the causal connections to shifts in pedagogy continue.

One interesting outcome of early evaluations is that while some teachers are enthused by a focus on student thinking, some also find the necessary shift in teacher practice to reap the benefits of that focus difficult to realise. Teachers are not used to thinking within theory about their practice. As an example, it is not uncommon to see posters of the values of inquiry in classrooms next to posters of the cognitive skills and virtues, sometimes with definitions or images designed by the teachers to represent them. These posters are often the topic of discussion with students, and students are required to use them in reflection or in reviewing written work. This is all well and good, but the point of articulating these elements and their relationships to each other is to guide and develop the pedagogical understanding of the teacher. Simply adding these things to the curriculum does not contribute to teacher expertise. The schema is not intended to be delivered to students, it is intended to provide a theoretical basis for deliberate practice, including professional pedagogical discussions. While the schema is at worst inert as an object of discussion with students, it is an encumbrance for the teacher if it does not contribute to the development of their own expertise.

The call to focus on teaching for thinking is not well-received by all parties. As this thesis was in its final throes, the Gonski 2.0 report emerged, calling for an increased focus on the skills of critical and creative thinking. Rebecca Urban, writing in *The Australian* newspaper online, noted that

> The focus on critical thinking, creativity and social skills will alarm many education experts, who have been lobbying for a return to a more robust, knowledge-based curriculum. (2018)

Kevin Donnelly, writing in the same edition, lamented

> …the Gonski 2.0 report, if adopted, will condemn students to failure as it represents a continuation of Australia's dumbed-down and substandard curriculum. (2018)

This pinning of rigour to content (or whatever might be intended by the use of the word "robust") belies a simple truth: the surest way to "dumb down" a curriculum is to cram it full of content. For the more content is contained in a curriculum, above that necessary to develop core concepts, the fewer opportunities exist to think with sophistication about that content. A thinking education cannot be characterised by a dearth of opportunities to think.

The OED gives several definitions of 'rigour', including "the quality of being extremely thorough and careful", "severity or strictness" and "harsh and demanding conditions" (rigours). Whilst one can readily appreciate the need to be demanding of our students in terms of setting appropriate challenges, I'm not sure we should move towards "harsh". And "being extremely thorough and careful" seems perfectly commensurate with a focus on thinking—one might even call it an intellectual virtue. This thesis is an argument for teaching for thinking as well as for teaching for content. It presents a way of achieving this that is coherent with what we recognise as good practice and does not acknowledge calls for "returning to basics" or appeals against "dumbing down" as legitimate, provided the focus remains on the development of teacher pedagogical expertise.

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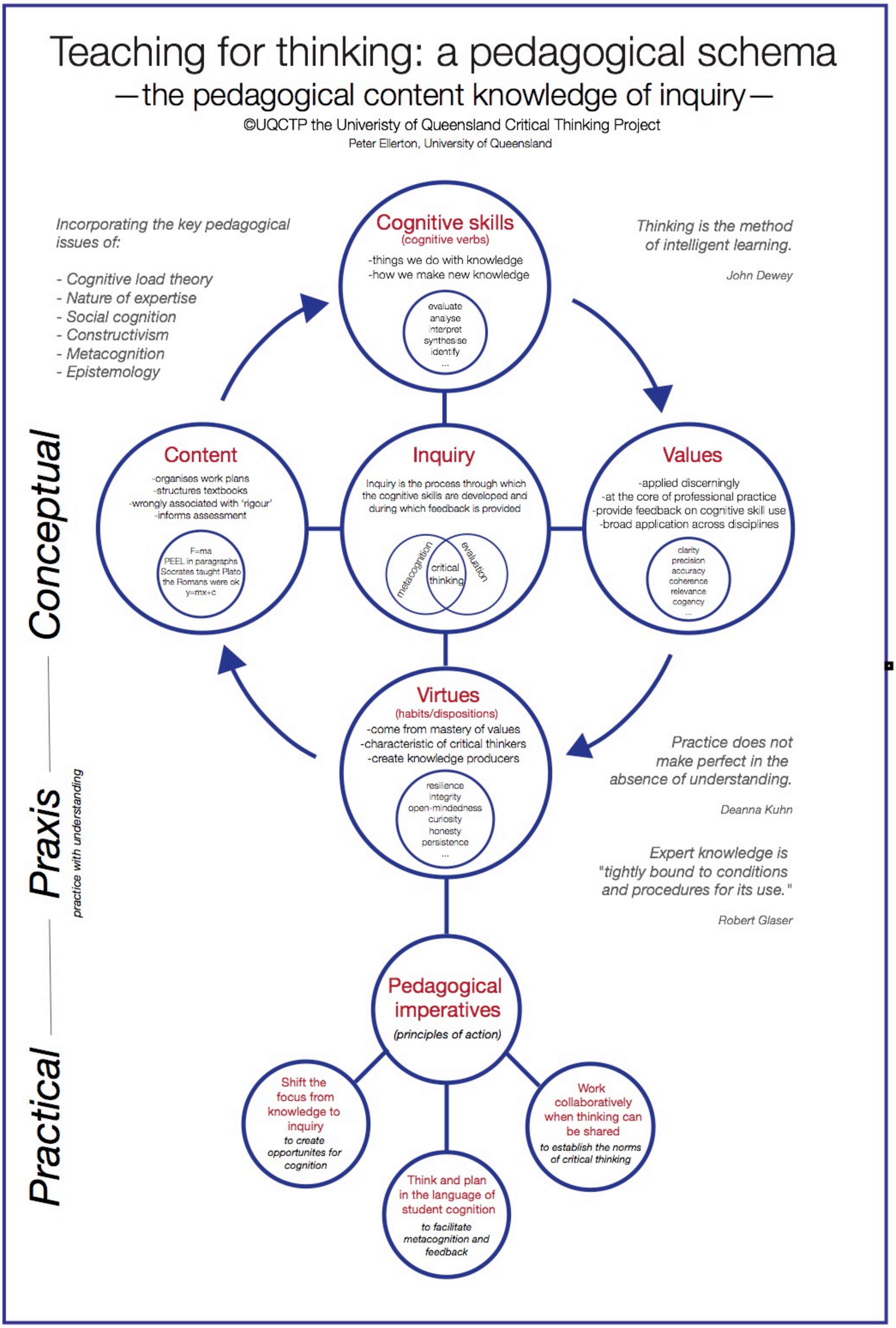
Appendixes


Teaching for thinking: a pedagogical schema
—the pedagogical content knowledge of inquiry—
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Peter Ellerton, University of Queensland
Incorporating the key pedagogical issues of:
- Cognitive load theory
- Nature of expertise
- Social cognition
- Constructivism
- Metacognition
- Epistemology
Cognitive skills
(cognitive verbs)
-things we do with knowledge
-how we make new knowledge
evaluate
analyse
interpret
synthesise
identify
...
Thinking is the method of intelligent learning.
John Dewey
Content
-organises work plans
-structures textbooks
-wrongly associated with 'rigour'
-informs assessment
F=ma
PEEL in paragraphs
Socrates taught Plato
the Romans were ok
y=mx+c
Inquiry
Inquiry is the process through which the cognitive skills are developed and during which feedback is provided
metacognition
critical thinking
evaluation
Values
-applied discerningly
-at the core of professional practice
-provide feedback on cognitive skill use
-broad application across disciplines
clarity
precision
accuracy
coherence
relevance
cogency
...
Virtues
(habits/dispositions)
-come from mastery of values
-characteristic of critical thinkers
-create knowledge producers
resilience
integrity
open-mindedness
curiosity
honesty
persistence
...
Practice does not make perfect in the absence of understanding.
Deanna Kuhn
Expert knowledge is "tightly bound to conditions and procedures for its use."
Robert Glaser
Conceptual
Praxis
practice with understanding
Practical
Pedagogical imperatives
(principles of action)
Shift the focus from knowledge to inquiry
to create opportunites for cognition
Think and plan in the language of student cognition
to facilitate metacognition and feedback
Work collaboratively when thinking can be shared
to establish the norms of critical thinking

The Critical Thinking Matrix

A high-resolution reference source for mapping critical thinking skills

Peter Ellerton, University of Queensland, Australia

I think

© UQCTP University of Queensland Critical Thinking Project. Peter Ellerton, University of Queensland		Values of Inquiry					
Cognitive Skills		**Clarity (intelligibility)**	**Accuracy**	**Precision**	**Depth (Complexity, relevance and significance)**	**Coherence**	**Breadth (Alternatives, perspectives, collaboration)**
Interpretation	**Categorising**	The criteria for categorising are unambiguous and the common characteristics of elements within the category are explicitly stated.	Categorical distinctions are drawn from accurate representations or generalisations of characteristics. Hasty generalisations are avoided.	Categorical distinctions are based on quantifiable data, specific characteristics or clear logical definitions.	Categorisations are made using relevant and significant characteristics rather than superficial resemblances. Logical and causal relationships between categories are identified.	Logical distinctions between categories are appropriate and coherent. The logical relationships within and between categories is evident.	Alternative perspectives and criteria for categorising are explored. Preferencing one framework over another is justified. Potential taxonimies are considered.
	Decoding	Terms are disambiguated and literal and intended meanings are distinguished when necessary. Implied meaning and social contexts are identified. Symbolic representations are identified and explained.	Intended or implied meaning is preserved in decoding. Literal and intended meanings are distinguished. Accurate use of symbols is evident.	Key terms are appropriately used to describe the information content. Correct procedures for working with quantitative or symbolic data are followed. Symbolic representations are used effectively.	Specific information is identified and foregrounded. Meaning is preserved by maintaining logical or causal relationships. Mastery of symbolic representation includes understanding the meaning of complex operations.	The logical content of propositions, phrases or terms is made clear and placed in context. The relationships between elements are understood.	Alternative meanings resulting from other cultural or cognitive perspectives are explored. Different interpretations of the situation are considered.
	Clarifying meaning	Key terms and technical terms are identified and explained. Literal and intended meanings are distinguished as necessary. Clarity is preserved as information moves between formats.	Statements are appropriately qualified. Limitations of understanding and representation are acknowledged. Intended or implied meaning is preserved. Paraphrasing and elucidation retain meaning.	Vagueness and ambiguity of terms and meaning identified. Key and technical terms identified and examined for appropriate use.	Nature and complexity of the problem understood and represented. Analogies or relevant similarities and illustrations used to elucidate and explain. Language examined for 'spin'.	Logical structures identified and logical coherency determined.	Language and visualisations reflect the need to cater for a diverse audience holding alternative views, approaches or perspectives.
Analysis	**Examining ideas**	Procedures of investigation are made explicit. Key concepts and structures are identified and named. Technical terms are used.	Faithful reproduction of information. Inaccuracies or contradictory information identified. Inferential relationships identified.	Detail preserved and reported. Vagueness and ambiguity eliminated or addressed. Technical terms are used appropriately and effectively.	Relevant and significant information is identified and foregrounded. Areas of focus are established. Problematic aspects are identified. Information necessary to frame and address the problem is identified. Ideas are compared and contrasted.	Causal and logical relationships are identified. Evidence is presented and evidential and inferential relationships are tested. General logical structure is identified and examined. Ideas are tested against existing knowledge.	Ideas are analysed within a transdisciplinary or collaborative approach, and through a variety of perspectives, including social, political, cultural and disciplinary.
	Identifying arguments	Premises and conclusions are made explicit. Argument structure is identified and discussed. Inferential pathways are articulated.	Argument types and structures are identified and named. Ambiguity is identified and addressed.	Nature of evidential material made clear. Procedures and algorithmic processes articulated in detail. Propositional content of premises and conclusions is identified and articulated.	The point at issue is identified. Relevant and significant information pertinent to the formation of premises is identified. Hidden premises are identified and discussed.	Logical relationships examined to determine the nature and form of argument. Claims are extracted from text and evidential relationships identified. Argument is tested for validity.	Arguments framed in various ways are recognised as potentially representing different perspectives. Recognition that the acceptance of evidence may depend on personal context, experience and perspective.
	Argument deconstruction	Correct use of terms. Identification of key components of arguments. Supporting evidence made clear. Diagrams or mapping used to make argumentation clear.	Premises, conclusions and inferential relationships are accurately presented.	Correct use of terms, including 'valid' and 'sound'. Representations are explicit and accurate.	Problematic aspects of argument structure/complexity are explored. Relevant and significant information affecting the reasoning process is identified and its role explained.	Cogency of argument is noted. Evidential and inferential links are examined for logical consistency. Hidden premises and unstated assumptions identified. Cognitive biases identified or postulated Logical fallacies identified.	Relationships between unstated assumptions or elements, such as beliefs, are identified, and the effect this may have on the reasoning process is explored. Recognising limitations of a single discipline approach or of a single methodology.
Evaluation	**Assessing claims**	Evidence is presented in context. Direct links between evidence and claims are made explicit.	Claims are faithfully reproduced. Supporting evidence is accurately represented.	Detail of claims is preserved, including quantifiable aspects.	Direct links between evidence and claims are made explicit. Claims and conclusions are connected to the nature of the problem and of the evidence. Cognitive and social biases are explored. Assess the contextual relevance of questions, information, principles, rules or procedural directions.	Claims examined/assessed for logical coherence with each other and with evidence and methodology.	Recognising various levels of credibility that might be associated with varying perspectives about the claim. Understanding the nature of claims as a function of discipline or methodological approaches.
	Assessing arguments	Premises, conclusions and evidential relationships are articulated.	Strengths and weakness inherent in argument types, including inductive and deductive arguments, are identified in context.	Key terms are used correctly and amounts quantified where appropriate or necessary. The tools and processes of evaluation of inferences are explicitly stated.	Suitability of evidential relationships examined with regard to the nature of the problem. Proposed causal and logical relationships identified and examined for weaknesses and strengths.	Causal and logical connections tested. Inductive arguments are analysed for strength and weakness, including the use of analogies and generalisations. Deductive arguments are examined for validity and soundness. Logical fallacies identified and their effect on the argument assessed.	Additional information that may be necessary to strengthen the argument identified. Argument tested using alternative standards of various disciplines or methodological approaches.
	Synthesising claims	The synthesis is clearly derived from the constituent claims, with links made explicit.	Intended and implied meaning is preserved and generalisations and categorisations accurately represent the constituent claims.	Similarities and differences of positions are made clear, and quantified where appropriate or necessary, including how these affect the synthesis.	Relevant and significant information retained and highlighted in the synthesis. Inclusion and exclusion of material in synthesis explained. Common features identified from specific cases, both explicit and implicit.	Effective inductive generalisations made. Synthesis is coherent with the logical content of the constituent claims. Purpose and meaning are developed.	Awareness of the variety of beliefs and perspectives that may be compatible with a particular claim. Synthesis considered from various framings and axioms.
Inference	**Querying evidence**	Nature of evidence is clear and evidential relationships are articulated.	Evidence is faithfully reproduced and represented with honesty and charity.	Detail is sought and presented. Information is quantified where appropriate or necessary. Exact nature and role of evidence made clear.	Premises requiring evidential support are identified and strategies for seeking significant and relevant information that might inform or test hypotheses are determined.	Logical connections between matters of fact and the point at issue or problem to be solved are made clear. Implications of evidentiary material made clear.	Inquiry encompasses or takes into account various methodologies (e.g. transdisciplinary approach).
	Conjecturing alternatives	Possible inferential pathways (paths of reasoning) articulated based upon varying use of evidence and argumentation. Alternative hypothesis and potential conclusions are clearly expressed.	Inquiry and the exploration of alternative reasoning are sensitive to maintaining the integrity of evidence and information.	Alternatives supported by calculation or other algorithmic process.	Alternative hypotheses maintain the emphasis on significant and relevant information, as well as a focus on solving the problem. Complexity is managed and problematic causal and evidential relationships are addressed across possible outcomes.	Alternatives are logically coherent with the given information and their logical implications explored.	Alternative framing of problem explored. Collaborative or multidisciplinary reasoning employed.
	Concluding	Clear articulation of pathways from premises to conclusions, including use of evidence and argumentation.	Proper and correct use of algorithms or procedures to arrive at conclusions. Correctly identify evidential and inferential relationships and show how these lead to conclusions.	Conclusions contain specific and detailed information, quantified where appropriate or necessary.	Modes of reasoning used and conclusion reached appropriate to the nature of the problem.	Logical connections between premises and conclusions evident and explained. Inferences well-supported. Cogent approach taken (i.e. appeal to reason).	Conclusions reached using a variety of reasoning modes, such as mathematical, dialectic, scientific, inductive and deductive.
Explanation	**Stating results**	Correct use of terminology, unambiguous use of language and effective and clear categorical distinctions made. Explicit representation and explanation.	Statements, descriptions, diagrams and other representations maintain the integrity of information.	Detail preserved and presented. Information quantified. Correct use of terms. Vagueness and ambiguity eliminated or addressed.	Information that is significant and relevant is highlighted. Problematic aspects are outlined.	Logical connections made explicit, showing links to evidence and conclusions. Implications made clear.	Presentation of statements, descriptions, diagrams and other representations are sensitive to interpretations other than those of the author.
	Justifying procedures	Effective use of examples and illustrations. Inferential pathways made explicit. Standards of evaluation explained and presented.	Inquiry and investigations are presented faithfully and not modified to suit the nature of the conclusions.	Process and conceptual development recorded. Calculations used to provide quantified data.	Strategies explored and evaluated. Nature of inquiry appropriate to the problem.	Methodologies, algorithms and other procedures supported by logical analysis. Reasons given for choosing areas of focus and minimising other information. Standards of evaluation explained and presented.	Evidential, conceptual, methodological, criteriological and contextual considerations are made with reference to the nature of justification as a function of alternative perspectives, beliefs and suppositions.
	Presenting arguments	Argumentative prose, diagrams, charts, graphs and graphics convey a clear meaning, adhering to convention. Points at issue clearly defined and stated.	Evidence faithfully reproduced and counter-arguments and criticisms engaged with honesty and charity.	Quantitative data included. Unnecessary information is minimised.	Identify and address counter-arguments. Causal and logical relationships that relate to the situation or problem are identified and their role made explicit. Problematic aspects identified and solutions explained.	Logical structure and coherence evident. Well-supported inferences with implications explicitly represented.	Cogent presentation but with due consideration of various reasoning modes and how alternative perspectives may influence the acceptance or definition of evidence.
Self regulation	**Metacognition**	Reflective practice is evident and cognitive development across issues is clearly reported.	Authentic representation of students' own metal processes and cognitive development.	Reflection targeted to specific processes and outcomes.	Reflections show personal engagement with significant and relevant issues. Threshold (key) ideas and concepts are identified. Deficiencies in personal knowledge that may impact rational or objective analysis acknowledged and managed.	Logical analysis of own thoughts comparable in scope and rigour to analysis of others'.	Recognition of bias, erroneous thinking or fallacious reasoning. Collaboration sought for the purpose of testing own thoughts.
	Self-correction	Recognition of bias, erroneous thinking or fallacious reasoning is recognised and reported.	Self-criticism and redirection is authentic and resembles the criticism that would be made of third persons.	Reflection leads to specific and detailed changed or specific courses of action are articulated.	Revisions geared to improve outcomes and examined for consequences to original position, findings, or opinions.	Recognition and acceptance of logical errors in preliminary thinking. Rational conclusions contrasted with personal preferences or bias.	Willingness to modify thinking through collaborative inquiry. Self-correction seen as progress.

Cognitive skills modified from Facione, P. A. (1990). Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction. Values of inquiry concept from Kuhn, T. S. (1970). The Structure of Scientific Revolutions. International Encyclopedia of Unified Science. Chicago, University of Chicago Press. 2. Values of inquiry modified from Elder, L. and R. Paul (2001). "Critical Thinking: Thinking with Concepts." Journal of Developmental Education 24(3).