

DEPARTMENT OF EDUCATION

General capabilities: A perspective from cognitive science

Centre for Education Statistics and Evaluation



Introduction

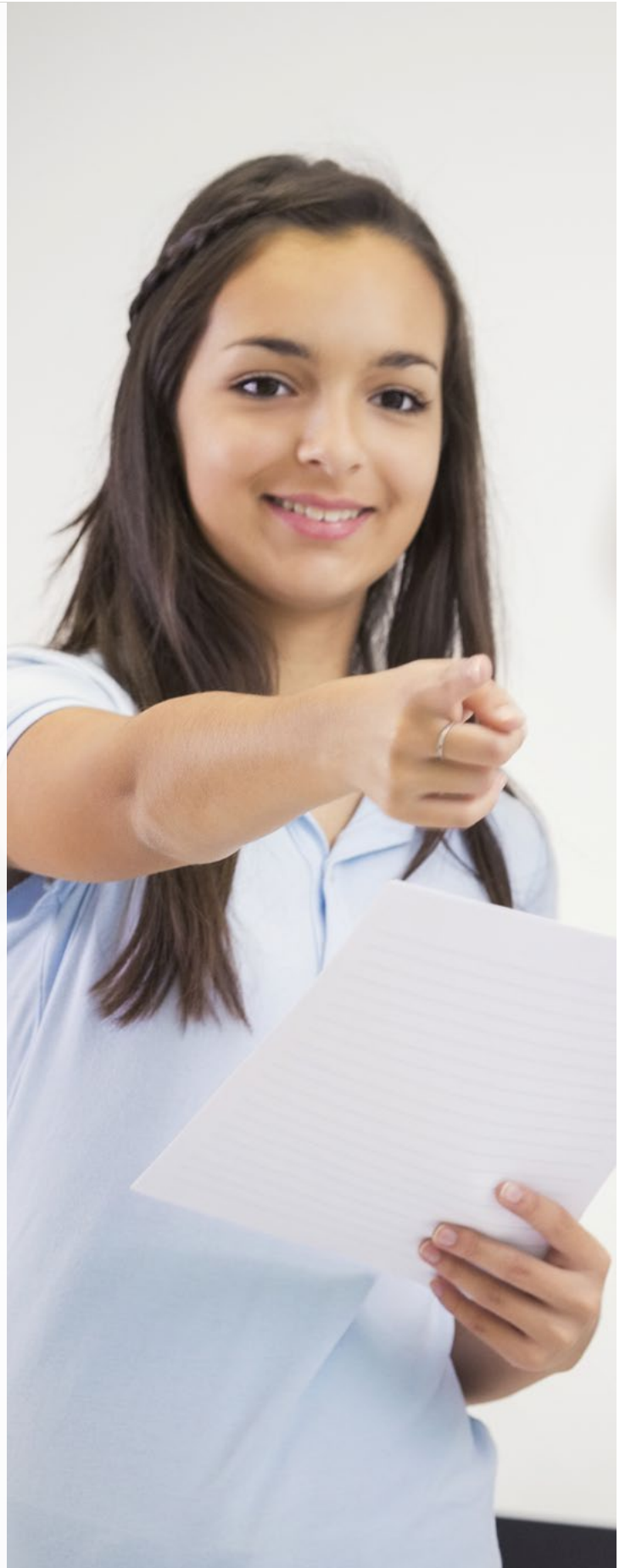
How can school systems best support their students to develop the capabilities they will need to thrive in the future? Educators and policy makers have been asking this question for decades. At various moments over the last fifty years at least, commentators have been arguing that the world is changing rapidly, and that as educators we must radically change our practice if we are to keep up. Amid this sense of urgency, some commentators argue that certain qualities – such as the ability to communicate, think critically and creatively and solve problems – have become increasingly important.

Certainly, the capabilities in question already exist in the curriculum and classrooms around the country. It would be impossible for a Year 12 student in NSW, for example, to achieve a Band 5 or Band 6 result in a HSC course without demonstrating high order thinking skills. Our challenge is to ensure that such skills and capabilities are developed in all students, and not just the top performers or those undertaking the most demanding courses of study. This paper offers a perspective from cognitive science on the most effective ways in which curriculum and the work of teachers may seek to develop students' capabilities in these areas.

Conversations about how to develop these capabilities have been hampered by a lack of clarity about key terms and concepts. This paper aims to contribute to the conversation by clarifying these terms and concepts, and by offering a perspective on the general capabilities from the viewpoint of cognitive science. It seeks to complement the perspectives offered through the NSW Department of Education's Education for a Changing World project, which aims to broaden discussion on the challenges and opportunities presented by today's artificial intelligence-enabled world, and build the evidence base on how education systems should respond to provide students with the knowledge, skills and experience they need to thrive in tomorrow's world (NSW Department of Education 2018).

Why cognitive science?

Cognitive science is an interdisciplinary field concerned with the study of the mind and intelligence (Thagard 2018). Concerned with how human brains use and store knowledge, it offers important insights for education. Cognitive science counters the assumption that general capabilities such as critical thinking are separate from, and should be taught **instead** of or in **addition** to content knowledge. In contrast, cognitive science research indicates that these capabilities can only be learnt **through** a deep and rich knowledge of content in each of the curriculum learning areas.



Background: Why the focus on 21st century skills?

The prospect of rapidly advancing technologies and an uncertain future can make it appear that educators need to change their practice radically in order to keep pace, but very similar concerns and arguments have been circulating for at least the last fifty years. As early as 1973, the Karmel report called for general competencies to be considered in Australian curricula in response to a concern that

'curricula and teaching methods tend ... to address themselves to the development of a range of attributes which is narrow in relation to the possibilities of life in a complex technological society.' (Interim Committee for the Australian Schools Commission 1973, cited in Lamb, Maire & Doecke 2017, p.8)

In 1991, the Finn Report into young people's participation in post-compulsory education and training found that changing technologies and economic circumstances meant that education systems needed to provide students with 'a strong grounding in generic, transferable skills' (Australian Education Council Review Committee 1991, p.55).

Following the 2008 Melbourne Declaration of Educational Goals for Young Australians, the Australian Curriculum was revised to include a number of general capabilities, in an effort both to support the broad development of young Australians and to ensure 'the nation's ongoing economic prosperity and social cohesion' (Ministerial Council on Education, Employment, Training and Youth Affairs 2008, p.4). These include critical and creative thinking, personal and social capability, ethical understanding, intercultural understanding, information and communication technology capability, as well as literacy and numeracy (Australian Curriculum n.d.). In May 2018, the 'Gonski 2.0' report on Australian schooling included the recommendation that school systems 'strengthen the development of the general capabilities, and raise their status within curriculum delivery, by using learning progressions to support clear and structured approaches to their teaching, assessment, reporting and integration with learning areas' (Gonski et al. 2018, p.41).

Does the 21st century need a different set of capabilities from previous decades?

The increasing focus on the need to equip students with capabilities to adapt to a radically different 21st century world appears compelling. This idea of 21st century skills has been particularly promoted by key international organisations including the World Economic Forum and the Organisation for Economic Co-Operation and Development (for example, World Economic Forum with The Boston Consulting Group 2015; OECD 2018). One of the challenges faced by educators and policy makers, however, is the difficulty of foreseeing what the future might look like, and which skills future citizens will actually require. As educationalist Dylan Wiliam argues,

'We aren't very good at predicting what jobs will be needed in the future. A hundred years ago, rising wealth would have led people to conclude that we needed more blacksmiths because as people got richer, more of them would be able to afford to own their own horses ... [But] our inability to predict the future goes both ways. Not only are we not very good at predicting which things will disappear, we are also not very good at predicting what will survive.' (Wiliam 2018, p.22)

An often-cited argument in favour of teaching general capabilities is that artificial intelligence (AI) will lead to the automation of many existing occupations, and that technological advancement will lead to the development of jobs that do not yet exist. For example, a CSIRO report suggested that 44% of Australian jobs are at high risk of automation, while 'many new jobs will also be created by technology' (Hajkovicz et al. 2016, p.8). There is disagreement, however, over the impact of AI on the labour market. Some argue that, while certain tasks may become automated, this is more likely to result in changes to the nature of the work being performed, than in the outright replacement of jobs (Arntz, Gregory & Zierahn 2016). Moreover, the impact of technological developments on jobs need not be inevitable. In a recent report, commissioned by the NSW Department of Education's Education for a Changing World project, Buchanan and colleagues observe: 'Whether new technology results in net job losses is ... just as much a matter of politics and policy as it is of technological developments' (2018, p.13).

Another claim often made in favour of privileging 'general' skills in the curriculum is that there is a causal relationship between these capabilities and student outcomes, both in schooling and in later life. In fact, there is currently insufficient evidence to confirm that these capabilities positively influence academic achievement. In their analysis of nine commonly cited 21st century skills, for example, Lamb, Maire and Doecke found that 'the scientific literature is unclear about the extent to which many of these skills (or dispositions) directly impact on student performance' (2017, p.29). The evidence on the relationships between general capabilities and later success in career and community life is also limited. In a review of the literature, Pellegrino and Hilton found, 'The available evidence is limited and primarily correlational in nature; to date, only a few studies have demonstrated a causal relationship between one or more 21st century competencies and adult outcomes' (2012, p.65; see also Gutman & Schoon 2016, p.2).

On the other hand, evidence strongly demonstrates that certain skills and knowledge, especially literacy and numeracy, continue to be essential for students to thrive. As the National Foundation Skills Strategy for Adults states, ‘people with higher language, literacy and numeracy skills are more likely to be employed, participate in their community, experience better health and engage in further training’ (Department of Industry 2013, p.2). Graham and Perin similarly say that literacy is a ‘basic requirement for participation in civil life and in the global economy’ (2007, p.3). Literacy and numeracy skills underpin workforce participation (Department of Industry 2013; OECD 2015), productivity and the broader economy (Productivity Commission 2014; Skills Australia 2010), and can also impact on social outcomes (Adams 2009; OECD 2013) and health outcomes (Department for Business, Innovation and Skills 2012; analysis of PIAAC data, in Centre for Education Statistics and Evaluation 2016, p.10).

Literacy and numeracy are foundational capabilities, providing the base on which to learn other, more complex capabilities (Centre for Education Statistics and Evaluation 2016). Indeed, research from cognitive science indicates that the automation of these skills – for example, achieving fluency in reading and number facts – is critical in freeing up students' working memory so they can progress to developing other capabilities (for example, Sweller, Ayres & Kalyuga 2011). Importantly though, literacy, numeracy and higher order thinking skills are not just about preparing students for jobs – education’s remit is much larger than that.

What is happening now?

In May 2018, the NSW government launched a comprehensive review to ‘examine, declutter, and improve the NSW curriculum’ (NSW Government 2018). If the revised NSW curriculum is to prepare students for the 21st century, then there is a particularly urgent need for its content to be informed by the best available evidence.

Definitions: How should we conceptualise these capabilities?

One of the key challenges associated with research and policy discussions about these capabilities is a lack of clarity – both in the terminology used to refer to the capabilities, and which capabilities are included in the discussion. This confusion significantly hampers educators and policy makers, because the terminology used to describe these capabilities matters – it has implications for how they will be incorporated into the schooling system.

Exactly which capabilities are most important (and therefore should be prioritised in the curriculum) is a subjective judgement, so different commentators emphasise an expansive range of different capabilities. For example, the OECD identifies as many as twenty-eight capabilities that it believes are valuable outcomes of education, including adaptability, hope, mindfulness and trust (OECD 2018). Most commentators tend to include four basic elements: communication, collaboration, creativity and critical thinking (Wiliam 2018, p.124).

As well as disagreement about the capabilities in question, there is confusion about how this broad array of diverse capabilities should be described: ‘Different writers use different labels for the same things, the same labels for different things, and organize the skills in different ways’ (Wiliam 2018, p.124). A range of terms is used by different commentators to refer to similar sets of capabilities – including 21st century skills (World Economic Forum 2015; OECD 2018), soft skills (Lambert 2017, p.3), non-cognitive skills (Gutman & Schoon 2013, p.2), and success skills (Larmer & Mergendoller 2015, p.2). Jurisdictions around the world use terms including 21st century competencies in Ontario, Canada (Council of Ontario Directors of Education 2017), capabilities for living and lifelong learning in New Zealand (New Zealand Ministry of Education 2017) and transversal competencies in Finland (Finnish National Agency for Education 2017).



Capabilities or skills?

Capabilities or competences can be considered more accurate descriptions than skills, and are the preferred term in this paper. The European Centre for the Development of Vocational Training defined skill as 'the ability to perform tasks and solve problems' (2011, p.136). A competence is much more complex – it is defined as the 'ability to apply learning outcomes adequately in a defined context (education, work, personal or professional development' (p.36). In the Australian Curriculum, capabilities are defined as a blend of 'knowledge, skills, behaviours and dispositions. Students develop capability when they apply knowledge and skills confidently, effectively and appropriately in complex and changing circumstances, in their learning at school and in their lives outside school' (Australian Curriculum n.d.). Touch typing, for example, might be considered a skill – while a broader understanding of information and communication technology (ICT) is better thought of as a competence or capability.

Biologically primary and secondary knowledge

According to an area of cognitive science called 'evolutionary educational psychology', there are two types of knowledge – biologically primary knowledge, and biologically secondary knowledge (Geary 2008, 2012; Tricot & Sweller 2014). Biologically primary knowledge includes all that information that humans have evolved to acquire in order to survive – such as the ability to listen and speak, to recognise faces and engage in social relations, and to solve problems using strategies such as 'means-ends analysis' (Newell & Simon, cited in Tricot & Sweller 2014, p.266). Some cognitive scientists argue that such knowledge is not able to be taught, because this kind of information is so important to human survival that it is acquired automatically and unconsciously (Tricot & Sweller 2014). Biologically secondary knowledge, on the other hand, refers to information that humans have not evolved to acquire, but which has become important within particular cultures relatively recently – such as reading, writing, mathematics and other disciplines taught in contemporary education systems. Biologically secondary knowledge is unlikely to be learnt without tuition – it is only acquired consciously, with active mental effort, and through explicit instruction (Geary 2008, 2012). Proponents of evolutionary educational psychology would argue that skills such as communication, collaboration, creativity and critical thinking have strong biologically primary components to them and as such there are aspects of these capabilities that cannot be explicitly taught. For example, Sweller suggests that we cannot teach creativity in a way that is divorced from content knowledge – however, we can support students to master the extensive knowledge base upon which creativity depends. 'It is notable that few if any people demonstrate creativity without first spending long periods of time developing an appropriate knowledge base' (Sweller 2009, p.17).

How general are they?

Perhaps the most confusing term used to describe these capabilities is general. The Australian Curriculum, for example, uses the term 'general capabilities' to refer to the 'knowledge, skills, behaviours and dispositions that will assist students to live and work successfully in the 21st century' (Australian Curriculum n.d.). As will be discussed below, however, evidence from cognitive science suggests that these capabilities cannot be considered general or transferable across knowledge domains (Tricot & Sweller 2014; Willingham 2007). Rather, evidence indicates that such capabilities are actually highly specific to particular areas of knowledge.

The question of whether these skills are general or specific is one of the major tensions in the debate on 21st century skills. As Lamb, Maire and Doecke have observed, 'the question of the transferability is the most contentious area of research' (2017, p.26). Advocates of elevating general capabilities in the curriculum tend to hold the view that capabilities such as critical thinking, once learnt in one area, can be unproblematically transferred to other learning areas – while critics state that there is little evidence to support this assumption. There are a large number of programs that claim to teach or assess students' critical thinking skills independently of content knowledge, for example, but the evidence suggests that these programs only provide modest benefits in students' ability to apply critical thinking skills. This is despite the large investments of time required to participate in these programs (Willingham 2007). Willingham notes, 'the evidence shows that such programs primarily improve students' thinking with the sort of problems they practised in the program – not with other types of problems' (2007, p.12). As Dylan Wiliam has argued,

'While there is some evidence that getting students to work cooperatively in one setting improves their ability to work cooperatively elsewhere, for communication, creativity, critical thinking, and problem solving, the idea that students can learn these skills in one context and apply them in another is attractive but essentially wrong.' (Wiliam 2018, p.125)

Curriculum expert Barry McGaw suggests a more flexible approach, proposing that each of the seven general capabilities in the Australian Curriculum are domain-specific to differing degrees. He suggests, for example, that capabilities such as the capacity to work with others, and meta skills such as metacognition, or learning how to learn, may be thought of as domain-independent competencies that can be developed in any learning area of the curriculum and applied to any other learning area. He suggests that competencies such as interpersonal skills may be thought of as partially domain-dependent, in that they may be developed and transferred across some learning areas of the curriculum, but not all. Finally, he suggests that competencies such as problem-solving may be thought of as domain-dependent because they can only be developed through increasingly deep study in relevant disciplines (McGaw 2018).

Evidence: Insights from cognitive science

Cognitive science has yielded important insights into how human brains use and store knowledge. These insights are derived from decades of research into how human brains learn, using randomised controlled trials – the ‘gold standard’ of scientific research. This research has led cognitive scientists to conclude that, rather than being general skills that can be applied in any area, skills such as problem-solving and critical analysis cannot be developed independently of content knowledge. ‘All educationally relevant knowledge acquired during instruction is, and only is, domain-specific’ (Tricot & Sweller 2014, p.265).

The relationship between capabilities and content knowledge

The development of general capabilities through schooling is often proposed as an alternative to a more traditional focus on the mastery of content organised through subject disciplines. The internet is often cited as a reason why we do not need to commit knowledge to memory, as we can simply look up information whenever we may need it. We know from cognitive science, however, that human brains are only capable of processing small amounts of new information at one time, though they can process very large amounts of stored information. This means that the more information students have stored in their long-term memories, the more effective they are at thinking (Clark, Kirschner & Sweller 2012).

Most people have the innate ability to apply general problem-solving strategies without being taught – such as the process of trying many different approaches until they find a solution (see text box). However, this is not an efficient way of solving problems. For students to become excellent problem-solvers, research from cognitive science indicates that they need to develop a rich and deep base of content knowledge from which they can draw in order to solve the problem at hand. One of the most famous examples of this comes from a series of studies about chess players. Researchers set out to understand why expert chess players consistently out-perform novice players. They found that there was no difference in the players’ general problem-solving abilities, nor in their general memory capacity (de Groot 1965; Chase & Simon 1973). The only difference between the expert players and the novice players was their knowledge of chess. Through years of practice, the expert chess players had acquired an enormous knowledge of the tens of thousands of different chess board configurations that they might be faced with in any game, and they automatically knew the best move for each configuration (Simon & Gilmarin 1973).

This finding from cognitive science – that skilled performance is dependent upon subject expertise – has important implications for curriculum design. This is not to dismiss the fact that there is likely to be a degree of transferability between learning areas that draw on similar knowledge domains. Literacy, for example, is a capability with initially broad applicability across learning areas. However, even component skills of literacy – such as reading comprehension – are inseparable from content knowledge (see Johns Hopkins Institute for Education Policy and Learning First 2019), and as students progress through

schooling, they will need increasingly specialised, discipline-specific knowledge in order to apply literacy capabilities successfully. For example, a student with good essay-writing skills in English may theoretically be well placed to write an essay in history, but without knowledge of the unique conventions and fields of knowledge in the discipline of history, they are unlikely to produce an excellent result. For learning areas that are further apart, the capabilities are likely to be less transferable. A student with good essay-writing skills in English and history is unlikely to be able to successfully transfer those skills to writing a scientific report in chemistry, without being explicitly taught the structure of a scientific report. These differences will be more marked in certain capabilities. While literacy capabilities may not look radically different in English compared to creative arts, critical and creative thinking would look completely different in science and the humanities.

In addition to having differing degrees of transferability, the capabilities will also be relevant to differing degrees between subject areas. Barry McGaw has ‘heat mapped’ the relevance of the general capabilities to each learning area’s content descriptions in the Australian Curriculum, illustrating that different capabilities are more thoroughly covered through the content of some learning areas than others. For example, he shows that the general capability critical and creative thinking is relevant to 93% of the content descriptions for visual arts, while it is only relevant to 43% of the content descriptions for mathematics and 37% of the content descriptions for science (McGaw 2018).

Barriers: How can the capabilities be assessed?

One of the major challenges presented by the capabilities is the problem of how to reliably assess them. The issue of assessment is significant, because if teachers and school systems are unable to measure student learning growth in capabilities such as critical thinking or communication, it is difficult to know whether interventions to teach these capabilities have been successful. While there is no doubt that a Year 12 student in NSW in an HSC course would need to demonstrate high order thinking skills in order to achieve a Band 5 or Band 6 result, it is less clear how critical thinking or other capabilities might be assessed for younger students or less high-performing students who are yet to accumulate a substantial level of knowledge. As Whitehurst notes, the theory and measurement of the 21st century skills is ‘in its infancy’, and offers ‘nothing remotely close’ to the specificity outlined in literacy and numeracy standards (2016, pp.1, 6).

There are three broad types of approaches to assessing these capabilities: student self-rating, teacher judgements, and direct assessments. Each of these approaches has strengths and weaknesses. Student self-rating is relatively easy and inexpensive to administer, reasonably reliable at an individual level, and can also be used at the school and system level (Lamb, Maire & Doecke 2017, pp.47-48). However, student self-rating may not effectively measure the skill it targets (Lamb, Maire & Doecke 2017, p.49), there are difficulties comparing results meaningfully across grade levels (Child

Trends 2014; Lai & Viering 2012; Transforming Education 2016), and students' responses to self-rating surveys may be influenced by factors such as their literacy capabilities, cultural backgrounds, or sense of pressure to portray themselves more favourably (Duckworth & Yeager 2015; Soland, Hamilton & Stecher 2013; West et al. 2016).

Teacher judgement is often the main source of information about students' capabilities (Meissel et al. 2017). This type of measurement allows teachers to adapt instruction according to student need (Pellegrino 2014), and has the potential to be used not only at the individual student level but also at a system level if reporting is uploaded centrally (Lamb, Maire & Doecke 2017, p.51). A limitation of teacher judgement is its potential subjectivity. As Miessel and colleagues argue, while 'the properties of teacher judgements and what informs these decisions remain relatively unexplored', 'previous research has indicated that teacher judgements might be biased on the basis of student characteristics and influenced by classroom and school contexts' (2017, pp.49, 51). Victoria has sought to formalise teacher judgement of the capabilities by developing a scope and sequence for critical and creative thinking, ethical, intercultural and personal and social capabilities, against which teachers can map student learning (Victorian Curriculum and Assessment Authority n.d.).

Direct assessment is a test or assessment task designed to demonstrate a student's mastery of a capability, and is often portrayed as a more objective measure. This approach is strongly dependent on the definition of the capability being measured (Lamb, Maire & Doecke 2017, p.51), with different definitions likely to lead to different results – although the definitions of the general capabilities developed by ACARA may reduce this barrier. The capability of 'critical thinking' has been the subject of more research than the other '21st century skills', and a number of education jurisdictions are currently experimenting with ways to directly assess this capability. The Programme for International Student Assessment (PISA) is currently developing a means of assessing students' creative thinking, and has plans to include this test in PISA 2021 (Lucas 2017). The NSW Education Standards Authority (NESA) has researched and developed an online critical thinking test, which it trialled with Year 11 students in 2016 and 2017 (NSW Education Standards Authority 2018). Victoria has developed a set of assessment tasks to assist teachers to assess student learning in critical and creative thinking (Victorian State Government Department of Education and Training and Victorian Curriculum and Assessment Authority n.d.). So far such work remains experimental.

Conclusion

While there is widespread agreement that critical and creative thinking are valuable attributes, these and other capabilities are difficult to define and there are debates over the best way to teach and assess them. This paper has looked at the most effective way of supporting students to develop these capabilities from the perspective of cognitive science. It reiterates the need for capabilities to be taught through subject or learning area, and intertwined with content knowledge. This accords with the way the human brain learns, is less likely to overload working memory, and more likely to promote long-term learning. From this perspective, capabilities are best developed in the context of a knowledge-rich curriculum, where learning is carefully sequenced. This will enable learners to develop an increasingly sophisticated capacity to understand and apply knowledge, as they journey from novice to expert.



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